LOTS 202 & 203 WANDENA ROAD
AND
LOTS 204 & 205 GREAT NORTHERN HIGHWAY
CHITTERING

ENVIRONMENTAL ASSESSMENT
AND MANAGEMENT STRATEGY

Prepared for

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and
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EXECUTIVE SUMMARY

The owners of Lots 202 & 203 Wandena Road and Lots 204 & 205 Great Northern Highway, Chittering (the project area) have applied to the Shire of Chittering for the lots to be rezoned from Agricultural Resource to General Industry. The draft Muchea Industrial Park Structure Plan 2019 (MIPSP) shows Lots 204 and 205 as part of Precinct 2 (General Industry Core) and Lots 202 and 203 as part of Precinct 4 (Light Industry following completion of quarrying).

The total area of the rezoning is approximately 82 hectares. The MIPSP concept for Precincts 2 and 4 is for industries with a minimum lot size of one hectare, with effluent disposed on site using secondary treatment systems such as aerobic treatment units.

EXISTING ENVIRONMENT

Climate, Physiography and Hydrology

The climate, physiography and hydrology of the project area are described in detail in the Local Water Management Strategy (Appendix D).

Vegetation and Flora

Vegetation Types
The project area is largely cleared of native vegetation, consisting mostly of farm paddocks and current and former quarries. All of Lot 204, most of Lot 205 and the southern part of Lot 203 are cleared paddocks with some scattered mature trees, either native or planted. Native vegetation is present in the central east of Lot 205, the northern end of Lot 202 and the north of Lot 203.

The vegetation of the low-lying western part of the site is mapped by Heddle *et al.* (1980) as Coonambidgee Complex. None of this complex remains in the project area.

The more elevated eastern part of the site is mapped by Heddle *et al.* (1980) as Reagan Complex. The vegetation on the site does not agree well with the descriptions of Reagan Complex in Heddle *et al.* (1980), notably in the presence and in some parts dominance of Wandoo and the absence of *E. todtiana* and Banksia tree species.

Beard (1981) mapped most of the project area as Pinjarra 4.30000: Medium woodland, marri and wandoo. The north-east corner (about 2.3ha) was mapped as Gingin 1020.09998: Mosaic of Medium forest, jarrah-marri and Medium woodland, marri-wandoo.

360 Environmental (2015) identified seven native vegetation associations within Lots 202 and 203:

- EaCcEm (4.15ha): Woodland of *Eucalyptus accedens, Eucalyptus wandoo, Corymbia calophylla, Eucalyptus marginata* and *Allocasuarina huegeliana* over *Xanthorrhoea preissii, Bossiaea eriocarpa, Hakea undulata, Acacia pulchella, Pultenaea reticulata, Hakea stenocarpa* and *Tetraria octandra*.

- Mps (0.1ha): Sedgeland of *Mesomelaena pseudostygia, Mesomelaena tetragona, Lepidosperma leptostachyum, Tetraria octandra, Hypocalymma robustum, Daucus glochidiatus* and *Acacia pulchella*.

- CcXp (1.17ha): Woodland of *Corymbia calophylla* over *Mesomelaena pseudostygia, Xanthorrhoea preissii, Bossiaea eriocarpa, Hibbertia hypericoides, Acacia pulchella, Banksia sessilis, Allocasuarina humilis* and *Banksia nivea*.

- EwMps (0.83ha): Low Open Woodland (young regrowth) of Eucalyptus wandoo over Mesomelaena pseudostygia, Mesomelaena tetragona, Tetraria octandra, Bossiaea eriocarpa and Daucus glochidiatus.

- Ea (0.08ha): *Eucalyptus accedens* woodland.

- Ew (2.14ha): *Eucalyptus wandoo* woodland.

- Cc (0.36ha): *Corymbia calophylla* scattered trees over pasture.

Plantecology (2020) identified two native vegetation communities within the site:

- Marri (*Corymbia calophylla*) Open Woodland over shrubland of *Xanthorrhoea preissii, Hibbertia hypericoides* subsp. *septentrionalis* and *Bossiaea eriocarpa* over herbland of *Mesomelaena pseudostygia, Caustis dioica* and *Banksia dallanneyi* var. *dallanneyi* on light brown clay loams on lower ground in the north-east of the site. Other common species include *Allocasuarina humilis, Acacia pulchella* subsp. *pulchella, Desmocladus fasciculatus, Lepidosperma asperatum* and *Conostylis aculeata* subsp. *aculeata*.

- Wandoo (*Eucalyptus wandoo*) Open Low Woodland over shrubland of *Xanthorrhoea preissii, Bossiaea eriocarpa* and *Hibbertia hypericoides* subsp. *septentrionalis* over herbland of *Tetraria octandra, Banksia dallanneyi* var. *dallanneyi* and *Lepidosperma pubisquameum* in brown gravelly clay loams on laterite on upper and middle slopes. Other common species include *Hakea stenocarpa, Gastrolobium acutum, Hakea lissocarpha* and *Desmocladus fasciculatus*.

Vegetation Condition

The native vegetation ranges in condition from Completely Degraded to Excellent. The highest quality vegetation is located in the north of Lot 203, the east of Lot 205 and the north of Lot 202, in patches of 1.3ha or less. Figure 9 shows the vegetation condition.

Flora
360 Environmental (2015) found 39 native flora taxa and seven introduced species in Lots 202 and 203. Plantecology (2020) found a total of 86 native and nine introduced taxa across Lots 202-205, most of which were found in Lots 202 and 203.

Rare and Significant Flora
No Threatened Flora pursuant to the *Biodiversity Conservation Act* 2016 or the *EPBC Act* 1999 were recorded during the vegetation surveys. One species listed as Priority Flora by the DBCA was recorded by Plantecology (2020): *Haemodorum loratum* (P3) was recorded at two sites, M01 and M05, and in adjacent areas of the Wandoo open woodland in the south eastern part of the site and in the Marri woodland.

Floristic Communities
360 Environmental (2015) tentatively assigned floristic community types (FCTs) to the vegetation associations on Lots 202 and 203 as follows:

- EaCcEm and EwMps **S8** – *Eucalyptus wandoo* woodlands
- CcXp and Mps **3c** – *Corymbia calophylla-Xanthorrhoea preissii* woodlands and shrublands / **S18** – *Eucalyptus marginata-Corymbia calophylla* woodlands on laterite

The vegetation of Lots 204 and 205, consisting mostly of isolated paddock trees, is too severely degraded to assign to any FCT except for the patch of Wandoo woodland in the east of Lot 404, which is tentatively assigned to FCT S8.

Threatened and Priority Ecological Communities
Floristic Community 3c is listed as Critically Endangered under the Western Australian *Biodiversity Conservation Act 2016* and as Endangered under the Commonwealth *EPBC Act 1999*.

No other Threatened or Priority Ecological Community was found within the project area.

Local and Regional Representation
The vegetation types present in the project area are moderately to well represented both locally and regionally, but their formal reservation status is generally poor.

Fauna

Fauna Habitats
Most of Lots 204 and 205 is cleared apart from isolated paddock trees, and offers little habitat for native fauna. The exception is an area of about 1ha in the east of Lot 205, which supports wandoo woodland in excellent condition and offers good quality habitat for fauna.

Lots 202 and 203 support areas of native vegetation ranging in condition from Completely Degraded to Excellent, as well as fully cleared areas. The vegetation in Good, Very Good and Excellent condition offers good quality habitat for fauna.

Overall, the project area contains approximately 2.4ha in Excellent condition, 2.3ha in Very Good condition and 0.5ha in Good condition.

Significant Fauna

A search of relevant databases produced an extensive list of Threatened Fauna species, Priority Fauna species and otherwise significant species from the search area. Of these, several may be present in or near the site:

- Carnaby's Black Cockatoo *Calyptorhynchus latirostris* (S1, EN)
- Forest Red-tailed Black Cockatoo *Calyptorhynchus banksii naso* (S1, VU)
- Black-striped Snake *Neelaps calonotos* (P3)
- Chuditch *Dasyurus geoffroii* (S3, VU)
- Peregrine Falcon *Falco peregrinus* (S4)
- Fork-tailed Swift *Apus pacificus* (S3, MI)
- Inornate Trapdoor Spider *Euoplos inornatus* (northern Jarrah Forest) (P3)
- Quenda *Isoodon obesulus fusciventer* (P4)

A group of Forest Red-tailed Black Cockatoo was observed in trees on the other side of Wandena Road during the site inspections. The inspections also revealed possible evidence of Carnaby's Black Cockatoo feeding beneath marri trees in the project area.

Black Cockatoo Habitat Assessment

Feeding Habitat

The project area contains nine species recorded by Valentine & Stock (2008) as food resource species for Carnaby's Cockatoo: *Corymbia calophylla, Eucalyptus marginata, Xanthorrhoea preissii, Hakea lissocarpha, Mesomelaena pseudostygia, M. tetragona, Allocasuarina fraseriana, Banksia sessilis* and *Lambertia multiflora*. In most cases (except *C. calophylla*), these species are present at low density over small areas, so the site offers limited food resources for black cockatoos. The large Marri trees in the cleared areas would be expected to provide food for black cockatoos. Limited evidence of Carnaby's Cockatoo feeding (in the form of chewed nuts) was observed in the south of Lot 203 during the site inspection.

Roosting Habitat

The EPBC Act Referral Guidelines for Black Cockatoos (DSEWPC, 2012) define black cockatoo roosting sites as tall trees or groups of tall trees, usually close to an important water source and within an area of quality feeding habitat.

The project area contains no significant water sources and limited feeding habitat. It is therefore unlikely that black cockatoos will roost in the area.

Breeding Habitat
The DSEWPC (2012) defines black cockatoo breeding habitat as follows:

- Current breeding habitat - Trees of suitable species (including Marri, Jarrah and Wandoo) with suitably-sized hollows (generally minimum 140mm opening, 200mm internal width, 450mm depth).

- Potential breeding habitat - Trees of suitable species of size at least 500mm diameter at breast height (dbh) (or 300mm for Wandoo).

360 Environmental (2015) and BES (2020) in combination found a total of 190 trees met the DEWA size criteria for potential nesting habitat, including 56 that contained hollows or potential hollows.

BES inspected all potential hollows in October 2020 with a pole-mounted camera (Cocky Cam) supplied by Birdlife Australia. The inspection found nine hollows in use by Corellas, two by Australian Kestrels and one by Kookaburras. No evidence of current or previous black cockatoo nesting was found. A large number of hollows (approximately 15 of 56 examined) contained feral bee hives.

Land Uses and Potential Contamination

Historic Landgate aerial photography shows that the project area has been largely cleared and used for farming since at least 1965. Quarrying has been underway on Lots 202 and 203 since before 1977.

The DWER Contaminated Sites Database (https://dow.maps.arcgis.com/apps/webappviewer/index.html?id=c2ecb74291ae4da2ac32c441819c6d47) shows no record of any contaminated sites in the project area.

The former clay quarry on Lots 202 and 203 is currently being backfilled with inert waste such as building rubble prior to rehabilitation. The backfilling and rehabilitation are being undertaken under the terms of a DWER Licence (L9181/2018/1), which carries conditions including control of waste acceptance and prevention of pollution.

Aboriginal and European Heritage

The Department of Planning Lands & Heritage's online database shows one registered site, (ID 3525 Ellen Brook: Upper Swan) covering the whole project area.

The DPLH has advised that the actual boundaries of the registered site do not affect the project area, and that therefore no approval under the Aboriginal Heritage Act 1972 is required for development of the project area.

Landscape

The project area is visible from Great Northern Highway and Wandena Road. The view from Great Northern Highway is partly screened but not blocked by trees planted within the property. From Wandena Road the southern end of the project area is visible through a screen of roadside trees, but for the most part is obstructed by dense vegetation and the banks of a cutting through which the road passes.

The landscape in the west consists mostly of cleared horse paddocks with scattered trees and isolated buildings set well back from the highway.

ENVIRONMENTAL IMPACTS AND MANAGEMENT

Surface Water Protection

The project area drains to Ellen Brook via culverts beneath Great Northern Highway and small drainage lines within and adjacent to the site. The contaminant of major concern in Ellen Brook and the Swan-Canning River system is phosphorus.

Industrial development has the potential to affect the volume, rate and quality of water flows in the drainage lines and Ellen Brook. Water outputs from the project area will be limited to stormwater, groundwater and minor process water (such as washdown water).

Management strategies to be implemented include:

- Industries permitted in Precinct 2 will be those that dispose of domestic-quality wastewater at a rate less than 5,400 litres per hectare per day (R10 equivalent).
- Wastewater from toilets and bathrooms will be treated by nutrient-removing systems (e.g. ATU or modified leach drains).
- The single existing drainage line crossing the project area will be retained within a roadside bioretention swale (see LWMS).
- All road runoff will be captured and infiltrated (up to 1-year ARI 1-hour storm) or detained (up to critical 100-yr storm) in bioretention swales in accordance with DWER guidelines.
- Any process wastewater generated by industries will be treated on-site to a standard suitable for discharge to the ground or disposed offsite.
- All lot drainage from storms up to 1-year ARI 1-hour will be retained and infiltrated within individual lots. Runoff from critical storms up to 100-year ARI will be detained within lots and released at a rate no greater than the pre-development rate.

- Temporary drainage controls will be implemented during the construction period.

Groundwater Protection

Groundwater is an important contributor to water flow and quality in Ellen Brook. Given the silty clay soils of the project area, groundwater throughflow and discharge is relatively low.

Groundwater protection measures will include:

- Industries in Precinct 2 (Lots 204 and 205) will be restricted to those with low water use and waste water generation of less than 5,400 litres/ha/day.

- Subsoil drains, if required, will be set at or above the pre-existing Average Annual Maximum Groundwater Level.

- Subsoil and stormwater drains will discharge to vegetated swales with PRI of at least 15.

Noise

Active management of noise within and from the Structure Plan area will not generally be required. Industries with high noise emissions may be required to undertake technical analyses to determine separation requirements. These industries may be restricted to certain parts of the Structure Plan area where suitable separations are available.

Dust

Individual lot holders within the project area will be required to manage dust to prevent dust escape beyond their boundaries. Industries that generate appreciable process dust will be required to hold a DWER licence, which will specify dust limits and monitoring requirements.

Construction Impacts

Construction of the project is expected to be carried out at various times, in accordance with the land owners' preferences. Construction of roads, drainage and other services will be undertaken by the owner(s) of each stage of subdivision.

Management of construction impacts will be the subject of conditions attached to subdivision approvals, works approvals and development approvals.

In general, control of construction impacts will be the responsibility of the construction contractor. The developer of each stage of subdivision will implement a Construction Management Plan for the development dealing with dust management, erosion and

sediment control, containment of environmentally hazardous materials (chiefly fuel and oils) and spill response.

Vegetation and Flora

The native vegetation over most of the project area consists of mature paddock trees, rows and groups of planted trees. In the eastern part of the site, the vegetation consists of Marri and Wandoo open woodland in Completely Degraded to Excellent condition.

Remnant trees within the development area will be preserved where possible. No remnant trees may be cleared without a Development Approval from the Shire of Chittering and/or a clearing permit from the DWER.

Landscaping within private lots and public areas (e.g. road reserves and drainage swales/basins) will be carried out using local native species.

Fauna

Development of the site as proposed will require the clearing of about 5.2ha of Marri and Wandoo woodland in Completely Degraded to Excellent condition.

Prior to clearing, a fauna capture and relocation exercise will be undertaken by a qualified specialist consultant to relocate any sedentary animals (e.g. snakes and lizards) from the application area. During and after clearing, monitoring of debris will be carried out to locate and salvage any fauna caught within the clearing operation.

Fauna habitat will be created in the revegetation of drainage swales and basins. Street trees planted within the project area will focus on native tree species that provide habitat for nectar-eating and seed-eating birds.

Landscape

Development in accordance with the Structure Plan will change the landscape of the project area from predominantly rural to industrial, in keeping with the industrial landscape of the overall Muchea Industrial Park.

The objective of landscaping will be not to hide the industry from view but to provide vegetation features that “soften” and break up the industrial landscape. This will include plantings within lots along the interface of Great Northern Highway, drainage swales and basins, verge trees within the developed areas and landscape buffers within lots.

In accordance with the Shire of Chittering’s *Muchea Industrial Park Design Guidelines* (2018), landscaping within lots will include:

- a minimum 2m wide landscape buffer on the primary road frontage;

- a minimum 1m wide landscape buffer on secondary road interface and side boundaries extending to the building setback line;
- one shade tree per four car parking bays; and
- one tree per 10m of road frontage.

The landscape plantings within lots will be of a mix of native trees, shrubs and ground covers. The 1-year ARI 1-hour bioretention swales within each lot will be densely planted with native sedges and low shrubs. This will form part of the 10% landscaping requirement for each lot.

Roadside bioretention swales will be densely planted with native sedges and low shrubs to stabilise the beds and banks of the swales, slow water flows and promote the uptake of sediments and nutrients from the water.

Plantings within the swales will be kept to a height that meets the definition of Shrubland in the Bushfire Hazard Assessment (Eco Logical Australia, 2020) so as not to create an unacceptable fire hazard.

MONITORING

Groundwater levels and quality will be monitored and compared against baseline levels and relevant guidelines. Surface water quality in drainage lines within, upstream and downstream of the project area will be monitored to determine what (if any) impacts the development may be having on surface water quality.

The developer of each stage of subdivision will be responsible for monitoring water quality in bores and drainage swales within that stage.

Water quality sampling will be conducted nominally once a year in late winter. Detailed water monitoring and response procedures will be developed as part of the Urban Water Management Plans to be prepared for each stage of subdivision.

IMPLEMENTATION AND FURTHER MANAGEMENT PLANS

Subdivision and development in the project area will be undertaken in accordance with the Structure Plan, this EAMS and the attached LWMS.

Development may occur in accordance with a subdivision approval or, in the absence of subdivision, a Development Approval. Subdivision approvals will include a requirement for an Urban Water Management Plan (UWMP). If development occurs without a subdivision, a Local Water Management Plan (LWMP) may be required to set out drainage design for the development.

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1.0 INTRODUCTION

1.1 Background

The owners of Lots 202 & 203 Wandena Road and Lots 204 & 205 Great Northern Highway, Chittering (the site) have applied to the Shire of Chittering for the lots to be rezoned from Agricultural Resource to General Industry. The draft Muchea Industrial Park Structure Plan 2019 (MIPSP) shows Lots 204 and 205 as part of Precinct 2 (General Industry Core) and Lots 202 and 203 as part of Precinct 4 (Light Industry following completion of quarrying). Figure 1 shows the location of the site within the draft Muchea Industrial Park Structure Plan area.

The total area of the rezoning is approximately 82 hectares. Figure 2 shows the boundaries of the site. Figure 3 shows a preliminary conceptual plan of subdivision.

The MIPSP concept for Precincts 2 and 4 is for industries with a minimum lot size of one hectare, with effluent disposed on site using secondary treatment systems such as aerobic treatment units.

1.2 Scope of the EAMS

The scope of this Environmental Assessment & Management Strategy (EAMS) is to:

- document the existing environment of the site;
- briefly describe the proposed development;
- examine the potential impacts of development;
- propose management strategies to avoid or mitigate impacts; and
- outline a proposed monitoring program.

This EAMS is accompanied by a Local Water Management Strategy (LWMS), which deals specifically with water-related matters including water supply, drainage, groundwater management and wastewater disposal.

1.3 Relevant Guidelines and Policies

1.3.1 Better Urban Water Management

Better Urban Water Management (WAPC, 2008) sets out the following objectives for water sensitive urban design:

Water Conservation

- Consumption of 100kL/pp/yr including less than 40-60 kL/p/yr scheme water.

Water Quantity

- Ecological Protection – Maintain pre-development flow rates and volumes for the 1 year ARI event. Maintain or restore desirable environmental flows and/or hydrological cycles.

- Flood Management – Maintain pre-development flow rates and volumes for the 100 year ARI event.

Water Quality

- Maintain pre-development nutrient outputs (if known) or meet relevant water quality guidelines (e.g. ANZECC & ARMCANZ, 2000).

- Treat all runoff in the drainage network prior to discharge consistent with the Stormwater Management Manual.

- As compared to a development that does not actively manage stormwater quality, achieve:

    - at least 80% reduction of Total Suspended Solids;
    - at least 60% reduction of Total Phosphorus;
    - at least 45% reduction of Total Nitrogen; and
    - at least 70% reduction of gross pollutants.

Mosquitoes and Midges

- Design detention structures so that, between the months of November and May, stormwater is fully infiltrated within 96 hours.

- Design permanent water bodies (where accepted by DWER) to maximise predation of mosquito larvae by native fauna.

1.3.2 Shire of Chittering Local Planning Scheme No. 6

"The following development requirements shall apply to the development and subdivision of land within industrial zones and to industrial land uses –

(a) the effect on the environment by means of discharge of pollutants or contaminants into the air, ground and water be avoided, or managed within acceptable limits;

(b) where an on-site wastewater disposal system is proposed –

i. land capability assessment may be required to demonstrate the capability of the site to manage wastewater and the suitability of the proposed system;
ii. the use of fill and drains to achieve the required separation from groundwater is to be limited; and
iii. a suitable and unencumbered land project area is to be set aside to distribute treated sewage, where required;

(c) within sewerage sensitive areas secondary treatment systems with nutrient removal are to be utilised;

(d) notwithstanding any other provisions of this scheme, industrial development not connected to reticulated sewerage (for treatment on-site or off-site) is to be restricted to 'dry industry' being land uses that intend to dispose of wastewater on site to the environment of a kind and volume ordinarily discharged from a habitable building at a daily volume of less than 540 litres per 1,000m^2 of the site area [R10 equivalent];

(e) where trade waste is to be managed and/or disposed of on-site or off-site the associated risks must be identified and addressed, including the vulnerability of the receiving environment where relevant;

(f) where a caretaker's dwelling is a discretionary use –

i. only one dwelling be permitted on each lot;
ii. the dwelling is to have a maximum floor area of 100m^2;
iii. the dwelling is to be incidental to the industrial land use;
iv. subdivision of the dwelling from the parent lot will not be permitted;
v. the use of notifications on title may be considered to advise prospective purchasers of potential impacts from noise, dust, odour or amenity that may arise from the location of a residential land use within the zone;
vi. the local government will not consider projects for caretakers' dwellings prior to the primary site activity being either approved or constructed;
vii. where simultaneous approval has been granted by local government for both a caretaker's dwelling and the main activity on the same lot, the main activity must be developed and operational prior to occupation of the dwelling; and
viii. caretaker's dwellings are to be carefully sited and constructed so the potential site (or estate) impacts from noise, dust, odour or amenity are minimised;

(g) in considering rezoning proposals for industrial zones, the local government may require the preparation of a structure plan, and any information relevant to the site conditions, in keeping with the matters listed in clause 67 of the deemed provisions and clause 5.7 of the scheme; and

(h) any other requirement as included in a Local Planning Policy adopted by the local government."

The Scheme shows Lot 204, most of Lot 205 and part of Lot 203 as part of a Water Prone Area (Ellen Brook Palusplain), within which the following special provisions apply:

"5.3.3 Planning Requirements

The local government will impose conditions on any Development approval relating to -

a) the construction and occupation of any dwelling or outbuilding;

b) the type of effluent disposal system used in this area shall be high performance with bacterial and nutrient stripping capabilities to the specifications of local government and the Health Department and shall be located in a position determined by local government.;

c) minimum floor levels for any building above the highest known water levels;

d) any land use that may contribute to the degradation of the surface or sub-surface water quality.

e) no development other than for conservation purposes will be permitted within 30 metres of any natural water body; AMD 21 GG 3/4/09

f) damming, draining or other developments which may alter the natural flow of surface water will not be permitted unless such works are part of an approved Catchment Management Plan."

Schedule 11 of the Scheme contains the following provisions that apply to the Muchea Industrial Park:

"2.2 Environmental Management Plans

The following Environmental Management Plans shall be prepared and used to inform the design and proposed subdivision and development within the Structure Plan area. They shall be submitted as an additional detail of a Structure Plan unless otherwise determined by the Western Australian Planning Commission.

2.2.1 Local Water Management Strategy

The developer shall submit to the Local Authority a Local Water Management Strategy (LWMS) for approval as an additional detail of a Structure Plan pursuant to clause 5.19 in order to ensure that surface and ground waters are managed with the aim of maintaining the natural water balance. The Local Authority must notify and consult with the authority responsible for water and the environment on the proposed strategy in advertising the Local Structure Plan(s) pursuant to Part 4 of the deemed provisions.

The LWMS shall be prepared in accordance with Better Urban Water Management or its successor document.

The Structure Plan design shall respond to the LWMS required by 2.2.1 and shall be implemented to the satisfaction of the Local Authority, having regard to any advice from the Department of Water.

2.2.2 Environmental Assessment and Management Strategy

The developer shall submit to the Local Authority an Environmental Assessment and Management Strategy for approval as an additional detail of a Local Structure Plan pursuant to Part 4 of the deemed provisions in order to ensure the local structure plan provides a comprehensive and coordinated response to all environmental features within the Structure Plan area and in accordance with the Muchea Industrial Park Structure Plan.

The Environmental Assessment and Management Strategy is to include the following:

- Identification of significant environmental features within the local structure plan area including flora, vegetation, fauna, wetlands and waterways.

- Identification of appropriate management strategies, consistent with industry best practice, to ensure that the local structure plan responds appropriately to these environmental features. Appropriate management strategies might include identification of buffers / setbacks, potential areas of revegetation / rehabilitation, public open space and fauna relocation.

- Consideration of Acid Sulphate Soils (if present) and identification of the likely requirement for ASS management during future planning stages.

- Identification of, and the means for retention and protection of, key cockatoo habitat trees / locations.

- Identification of measures to retain the rural character of views of the Structure Plan area from roads within, adjoining, or in the vicinity of the Structure Plan area, by providing details of vegetation screen planting, as well as the details for the siting and design of structure and major earthworks within the Structure Plan area.

The Local Authority must consult with the relevant environmental agencies regarding the proposed strategy in advertising the Local Structure Plan pursuant to clause 5.19.

The Environmental Assessment and Management Strategy shall be consistent with the EPA's current Guidance Statement No. 33 Environmental Guidance for Planning and Development, or any successor Guidance Statement.

The Environmental Assessment and Management Strategy required by 2.2.2 shall be implemented to the satisfaction of the Local Authority on the advice of the applicable environmental agencies."

This Environmental Assessment and Management Strategy (EAMS) has been prepared to satisfy the requirements of Clause 2.2.2 of Schedule 11.

1.3.3 Government Sewerage Policy

The Government Sewerage Policy (2019) requires that all new subdivision and development should be deep-sewered unless it is exempt for one of several reasons. For exempt developments, the policy establishes minimum site capability requirements and, where appropriate, density limits. In these cases, on-site effluent disposal may be approved where the responsible authority is satisfied that:

- each lot is capable of accommodating on-site sewage disposal without endangering public health or the environment; and
- the minimum site requirements for on-site sewage disposal as set out in the Policy can be met.

The Policy designates certain areas as Sewage Sensitive Areas (SSAs), including land:

- within the coastal catchment of the Swan Estuary; and
- within 1km upgradient or 250m downgradient (or overall 1km where the groundwater gradient is unknown) of a significant wetland.

Additional restrictions and requirements apply to on-site effluent disposal in SSAs, including:

- a minimum lot size of one hectare (unless exempted on a case-by-case basis);
- minimum vertical separation of 1.5m from the discharge point of effluent disposal systems to the highest groundwater table level; and
- secondary effluent treatment systems with nutrient removal.

The Policy shows all of Lots 203 and 204, most of Lot 205 and the southern part of Lot 202 within an SSA associated with the Ellen Brook catchment. Lot 203, the southern part of Lot 205 and the northern half of Lot 202 are also shown within SSAs associated with significant wetlands. Figure 3 shows the mapped SSAs.

In the case of Lot 202 and the north-east of Lot 205, the SSA mapping is considered to be erroneous. The wetland in question (a Conservation category dampland) is located upgradient of the site, is maintained by surface flow and/or locally perched groundwater (the mapped permanent groundwater table is 45-50m below the ground surface) and is separated from the site by several watercourses, drains and deep excavations, so that there is no possibility of groundwater flow from the site to the wetland. This matter is examined further in the LWMS (Appendix D).

2.0 EXISTING ENVIRONMENT

2.1 Rainfall

Muchea, like the rest of the greater Perth region, has a strongly seasonal rainfall, with most of the annual rain falling between May and September in association with winter cold fronts. Occasional heavy falls may occur from summer thunderstorms. The long-term average annual rainfall for Pearce RAAF Base (located 6.5km south of the site) is 679.7mm, of which 77% falls between the months of May and September.

Figure 4 shows a rainfall occurrence chart for Pearce RAAF.

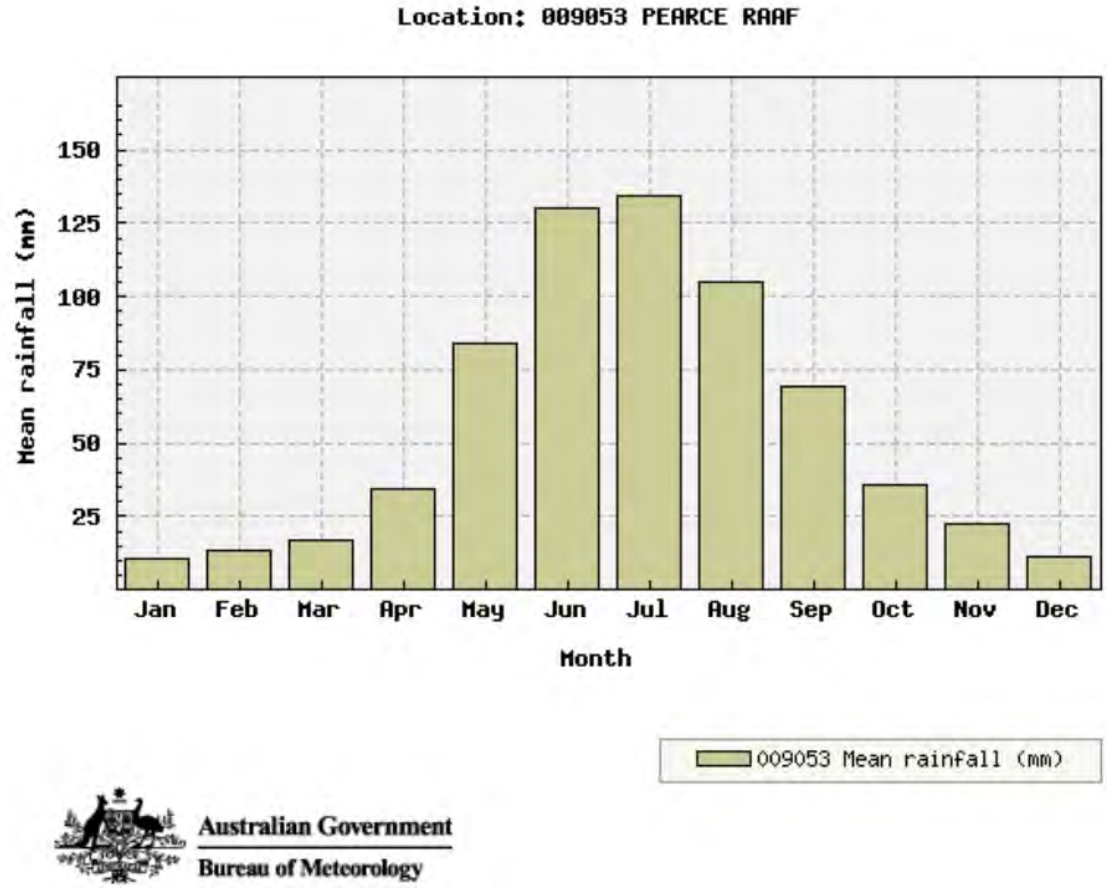

Figure 4 Pearce RAAF Mean Rainfall

2.2 Physiography

2.2.1 Topography

The site extends from a very gently sloping plain in the west to low hills in the east. The elevation ranges from 58m AHD in the south-west to 101m AHD on the eastern boundary.

The north-eastern quarter of the site, comprising Lot 202 and the northern half of Lot 203, is significantly higher and steeper than the rest of the site.

The slope is generally to the south-west, with gradients ranging from less than 1% in the north-west to over 40% in places on the eastern boundary. Excavation in the quarry on Lots 202 and 203 has produced some steeper gradients, but these are expected to be reduced in the filling and rehabilitation of the quarry. Figure 5 shows the topography of the site.

2.2.2 Geology, Landforms and Soils

The site is located on the eastern edge of the Pinjarra Plain and the western colluvial outwash zone of the Dandaragan Scarp. The soils in the west are pebbly silts belonging to the Guildford Formation, which originated as alluvial deposits washed from the Dandaragan Plateau by rivers and streams. In the eastern part the soils are colluvium, colluvial sands and Leederville Formation siltstone eroded from the scarp.

The Guildford Formation soils are described by the Geological Survey of Western Australia (Gozzard, 1982) as "Mgs_1: Strong brown silt with common fine to occasionally coarse grained, sub-rounded quartz, heavily weathered granite pebbles, some fine to medium-grained quartz sand, of alluvial origin".

The colluvial soils are described as:

- "Msg: Strong brown, firm, friable, dispersive in part, occasional pebbly horizons with little matrix, containing quartzite, quartz, granite, laterite of colluvial origin";
- "S_5: Very pale brown, medium to coarse-grained, well sorted, little fines, sub-angular to rounded quartz and feldspar, of colluvial origin"; and
- "S_6: Light grey, fine to coarse, angular to sub-rounded, quartz with some feldspar, moderately sorted, loose, of colluvial origin".

The Leederville Formation siltstone in the north-east is described as "ST_1: White, thinly bedded, well laminated, fine-grained, some large ferruginous concretions and laminae, occasionally micaceous".

Drilling by BES at four sites on Lots 204 and 205 in March 2020 showed a pebbly silty sand to pebbly silty clay profile in the top 5.5m, which corresponds to the GSWA description for the Guildford Formation. Previous drilling by Bowman & Associates Pty Ltd (2016) at four sites on Lots 202 and 203 found a silty clay profile with ironstone commonly occurring at between 5m and 18m, which corresponds generally with the GSWA descriptions for Leederville Formation and colluvium.

Figure 5 shows the site geology. Soil logs from the drilling are attached in the Local Water Management Strategy (Appendix D).

2.2.3 Soil Permeability

The permeability of the site soils will vary depending on the clay content. Test pumping during sampling of one on-site bore (WB3) indicated a hydraulic conductivity in the depth range of 2.6m to 5.1m in the order of 0.14 m/day. The permeability of the top 2m of the soil profile is expected to be higher.

Douglas Partners (2020) undertook constant-head permeability testing at six sites and at depths of 0.2 – 0.8 metres. The tests returned permeabilities ranging from 0.9 – 8.6 m/day, with a mean of 3.3m/day and a median of 4.75m/day. The geotechnical report is attached in the LWMS (Appendix D).

For preliminary drainage and effluent design purposes, a conservative permeability of 1 m/day has been assumed. Further constant-head permeability tests in accordance with the method set out in Australian Standard AS1547:2012: – *On-site Domestic Wastewater Management* will be undertaken prior to subdivision.

2.2.4 Acid Sulphate Soils

The DBCA maps the site as Low to Nil risk of Acid Sulphate Soils (ASS). The nearest mapped High ASS risk area is a palusplain about 600m to the south.

Bore sampling between July 2016 and September 2020 has found no significant indications of potential or actual ASS in the groundwater. No further investigation of ASS is considered to be necessary.

2.2.5 Phosphorus Retention Index

Previous experience has shown that the gravelly and silty clay soils of the Guildford Formation and other alluvial and colluvial soils generally have moderate to very high PRI.

PRI is a measure of the ability of a soil to adsorb and retain phosphorus from solution. A high PRI indicates that a soil is unlikely to leach phosphorus to the water table. Typical ranges for PRI values in soils are as follows:

PRI Range	*Rating*	*Typical soils*
0 – 0.5	Very Low	Bassendean Sand
2 – 4	Low – Moderate	Karrakatta Sands
5 – 12	Moderate – High	Cottesloe Sands
12 – 20	High	Crushed Limestone, Limesand
20 – 1000+	Very High	Clay

The DWER recommends a minimum PRI of 15 for soils beneath infiltration basins and swales. The site soils are expected to meet or exceed this requirement. PRI testing of soils beneath proposed infiltration basins will be undertaken before subdivision.

2.3 Hydrology

2.3.1 Groundwater

Groundwater occurs at shallow depth across the lower-lying western parts of the site (Lots 204 and 205) in winter. The depth to groundwater in most years varies from over 18 metres in the east of the site to less than two metres in winter in the west The DWER maps minimum groundwater levels at 48-53m AHD (13-48m below ground), flowing south-west towards Ellen Brook.

In wet winters, rainfall infiltration may be impeded by the low-permeability subsoils, creating temporary surface saturation in the lower and flatter parts of the site. There is no evidence in the water measurements or soil profiles of the occurrence of a seasonally perched water table.

Groundwater measurements in 14 bores in and around the site in August 2020 (Figure 6), during a drier than average winter, gave the water depths and levels shown in Table 2.1.

Simultaneous measurements of DWER bores located 680m south (Swan GWA 2-98) and 800m north (Gnangara Monitoring GD20) enabled average annual maximum groundwater levels (AAMGL) at the site to be calculated. Figure 6 shows the calculated AAMGL and depth to AAMGL contours across the site.

Table 2.1 shows that the groundwater levels measured on 21 August 2020 were about 0.4m below the AAMGL. The winter of 2020 was drier than average, and the levels measured on 21 August are considered to approximate the peak for the year.

Table 2.1 shows that the AAMGL is within one metre of the ground surface in parts of the north-west and south-west of the site. However, the pattern of groundwater levels is not uniform: Bore WB1 on the western boundary has an indicated depth to the AAMGL of over 4.5m.

Table 2.1 also suggests that the MGL may intersect the ground surface in the north-west and south-west of the site.

Table 2.1 Groundwater Depths and Levels 21 August 2020

Bore	*Depth (mbgl)*	*Level (m AHD)*	*AAMGL (m AHD)*	*MGL (m AHD)*	*Depth to AAMGL (m)*	*Depth to MGL (m)*
MW1	>17.44	<74.76	<75.19	<75.77	>17.01	>16.43
MW2	16.14	78.26	78.69	79.27	15.63	15.05
MW3	12.55	70.67	71.10	71.68	12.12	11.54
MW4	14.45	64.33	64.76	65.34	14.02	13.44
WB1	>4.68	<56.55	<56.98	<57.56	>4.25	>3.67
WB2	>4.98	65.89	<66.32	<66.90	>4.55	>3.97
WB3	1.58	67.51	67.94	68.52	1.15	0.57
WB4	2.34	59.53	59.96	60.54	1.91	1.33
TB7	1.14	57.26	57.69	58.27	0.71	0.13
TB8	1.11	64.14	64.57	65.15	0.68	0.10
TB9	0.56	74.24	74.67	75.25	0.13	-0.45
MB5	0.77	56.02	56.45	57.03	0.34	-0.24
MB7	0.65	54.86	55.29	55.87	0.22	-0.36
GD20	0.88	60.6	59.85	61.35	1.63	0.13
2-98	2.12	56.17	56.6	57.18	1.69	1.11

2.3.2 Surface Drainage

There are no natural defined drainage channels within the site, although several artificial drains have been cut in and around the quarry on Lots 202 and 203. The relatively low permeability of the soils would result in sheet flow across the ground surface during high rainfall events.

Water enters the project area from one 36ha external catchment to the east via a culvert beneath Wandena Road. This water flows via a constructed drain into a sump within Lot 202, which overflows to a farm dam on the adjoining lot and then into a drain that flows west to Great Northern Highway and ultimately into Ellen Brook. The land to the east is expected to remain as farmland for the foreseeable future, so this water inflow is not expected to change significantly in rate, volume or quality.

All drainage from the site flows eventually into Ellen Brook, the major drainage feature of the region. The Ellen Brook catchment is the largest sub-catchment of the Swan-Canning River system, contributing 6% of the total annual flow, and is the largest single contributor of nutrients to the system (WA Govt, 2011).

Ellen Brook has a surface catchment of 715km^2 (WRC, 2012). The Brook rises as Chandala Brook about 22km north-northwest of the site. The Brook is seasonal, flowing generally between May and November with an annual flow ranging from 2.1 to 48.6 GL (SRT, 2009).

2.3.3 Water Resources

The project area is within the Eclipse Hill sub-area of the Gingin Groundwater Area for the surficial and superficial aquifers, the Southern Scarp sub-area for the semi-confined (Mirrabooka) aquifer, the Cowalla sub-area for the confined Leederville-Parmelia aquifer and the Chandala sub-area for the Yarragadee aquifer. Groundwater allocations within the Gingin Groundwater Area are managed under the Gingin Groundwater Areas Allocation Plan (DoW, 2015).

Under the plan (as of 2015), the Eclipse Hill (superficial), Southern Scarp (Mirrabooka) and Cowalla (Leederville) sub-areas are over-allocated and no new allocations are available.

The DWER Water Register (https://maps.water.wa.gov.au/#/webmap/register) shows one groundwater licence for Lot 205 (GWL 152031, expiring November 2023), which is licensed to abstract up to 1,500 KL/yr from the Leederville aquifer via a bore on the adjacent Lot 206.

Water supply will be required for both potable and non-potable purposes. The Leederville aquifer is likely to be the preferred source for potable supply due to its generally higher quality and lower risk of contamination. Non-potable groundwater demand in Precinct 2 (Lots 204 and 205) is likely to be limited to landscape irrigation, as industries within this precinct will be limited to those with low water usage.

The water requirement for the fully developed project area is unknown. Calculations by Cossill & Webley (2018) based on a study carried out by GHD for the Karratha Gap Industrial Estate suggested that approximately 4 KL/ha/day will be required for both potable and non-potable uses. Over the 82ha of the site (assuming 80% developable land), this equates to a total water demand of approximately 96ML/yr.

Potable water will be supplied to the developed site by a licensed water provider. A proposed water project for the Lower Chittering Valley is currently in development by Aqua Ferre Pty Ltd, which includes construction of a water treatment facility on Lot 2 Reserve Rd, Chittering. Aqua Ferre is in the process of applying for a Water Service Provider's Licence from the Economic Regulation Authority (ERA). Aqua Ferre has confirmed that it has the capacity within its proposed licence to supply Lots 202-205 with potable water. Discussions with Aqua Ferre are ongoing.

For non-potable uses, purchase of water entitlements from existing licensed users within or outside of the site is likely to be necessary. The landowners will negotiate with existing licence holders within and outside of the project area with a view to purchasing an existing groundwater allocation., and will submit a groundwater licence application to the DWER in due course.

2.4 Water Quality

2.4.1 Groundwater

Groundwater samples have been collected from 13 bores within and around the site on various occasions since 2016. The sampling and analysis results are summarised in Tables 2.2 , 2.3 and 2.4.

Groundwater quality within the project area is moderate, which is to be expected given the soil types and the history of agriculture. Nitrogen and phosphorus concentrations are generally low to moderate

The groundwater shows mostly low acidity and sulphate contents, indicating that there is no evidence of acid sulphate soils. Dissolved metals concentrations are mostly low except for aluminium and zinc, which are slightly elevated across much of the site.

2.4.2 Surface Water

There was no flowing surface water anywhere on the subject land during any of the site inspections, so no surface water quality data are available.

Table 2.2 Groundwater Quality – Physico-Chemical Parameters

Bore (Figure 6)	*Date*	*pH*	*EC (ms/m)*	*Salinity (ppm)*	*Hardness (mg/l $CaCO_3$)*	*Acidity (mg/L $CaCO_3$)*	*Alkalinity (mg/L $CaCO_3$)*	*Acidity/Alkalinity Ratio*	*Cl (mg/L)*	*SO_4 (mg/L)*	*Cl/SO_4 Ratio*
MW1	12/7/16	**3.9**	4.72			96	< 20	>4.8	1700	58	29.3
	2/9/16	**4.6**	2.8						430	190	2.3
	28/9/16	**4.5**	2.8						430	200	2.2
	22/11/16	**4.3**	2.8						500	600	0.8
	12/1/18	**4.3**	2.7						720	210	3.4
	30/5/19	**4.40**	2.30						420	570	0.7
MW2	12/7/16	**4.6**	2.8			59	< 20	>2.95	430	190	2.3
	2/9/16	**3.9**	5.8						1700	57	29.8
	28/9/16	**3.8**	5.7						1400	57	24.6
	22/11/16	**4.3**	5.5						1600	170	9.4
	12/1/18	**3.9**	5.5						1900	59	32.2
	30/5/19	**3.9**	4.70						1700	190	8.9
MW3	12/7/16	**5.8**	7.6			57	25	2.28	2100	130	16.2
	2/9/16	**5.5**	14						5200	180	28.9
	28/9/16	**4.6**	17						5000	180	27.8
	22/11/16	**4**	2.1						4800	480	10.0
	12/1/18	**3.9**	12						4300	140	30.7
	30/5/19	**4**	9.6						3400	370	9.2
MW4	12/7/16	**4.7**	8.73			67	< 20	3.35	4100	120	34.2
	2/9/16	**5.9**	6.4						1700	130	13.1
	28/9/16	**5.4**	6.5						1800	120	15.0
	22/11/16	**5.5**	7.1						2100	390	5.4
	12/1/18	**5.6**	7.2						2400	130	18.5
	30/5/19	**5.2**	6.70						2200	440	5.0
TB7	17/8/17	6.6	0.49	294	59	19	50	0.38	100	17	5.9

TB8	17/8/17	7	0.55	330	63	7	38	0.18	110	40	2.8
TB9	17/8/17	7.4	0.63	378	48	7	67	0.10	130	23	5.7
MB5	22/8/18	6.6	0.25	150	52	15	27	0.29	44	12	3.7
MB7	22/8/18	**6.3**	3.5	2100	170	77	65	0.45	1100	130	8.5
WB3	2/10/20	6.1	0.23	138	32	20	18	1.11	40	9	4.44
WB4	2/10/20	6.1	7.9	4740	620	24	19	0.95	1800	540	3.33
Aquatic Ecosystems[a]		6.5-8.0	0.12-0.3	72-180	ng	40[c]	ng	1[c]	ng	ng	
Irrigation[b]		6-8.5	1.3	780	60-350	ng	ng		350	ng	
Notes	ng denotes "no guideline". a. ANZECC (2000) Aquatic Ecosystem trigger values (Nutrient, pH and Conductivity are for lowland rivers; Dissolved Metals are for freshwater ecosystems 90% species protection) b. ANZECC (2000) Irrigation trigger values (long-term irrigation up to 100 years) c. DEC(20__) Oxidation indicator triggers for ASS-affected groundwater.										

Table 2.3 Groundwater Quality – Nutrients

Bore (Figure 6)	*Date*	*TN*	*TKN*	*NH_3*	*NOx*	*TP*	*FRP*
MW1	12/7/16	0.6	0.3	<0.01	**0.27**	**0.15**	
	2/9/16	**5.0**	0.7	0.02	**4.3**	**0.2**	
	28/9/16	**4.88**	0.6	<0.01	**4.3**	<0.25	
	22/11/16	**4.9**	0.9	0.01	**4**	**0.29**	
	12/1/18	**4.7**	0.2	0.02	**4.5**	-	
	30/5/19	**4.7**	0.3	<0.01	**4.4**	-	
MW2	12/7/16	**3.7**	<0.2	<0.01	**3.7**	**0.35**	
	2/9/16	0.5	0.3	<0.01	**0.24**	**0.1**	
	28/9/16	0.35	<0.2	<0.01	**0.35**	**0.27**	
	22/11/16	0.6	0.3	0.03	**0.33**	**0.2**	
	12/1/18	0.9	<0.2	0.04	**0.29**	-	
	30/5/19	0.28	<0.2	<0.01	**0.28**	-	
MW3	12/7/16	**1.5**	0.9	0.12	**0.56**	<0.05	
	2/9/16	0.8	0.6	0.24	**0.19**	**0.13**	
	28/9/16	**1.8**	1.6	0.35	**0.2**	**0.33**	
	22/11/16	0.5	0.4	0.13	0.09	0.05	
	12/1/18	<0.2	<0.2	0.08	<0.05	-	
	30/5/19	<0.2	<0.2	0.04	<0.05	-	
MW4	12/7/16	**1.7**	1.1	0.03	**0.63**	**0.32**	
	2/9/16	**2.2**	0.4	0.05	**1.8**	<0.05	
	28/9/16	**2.3**	0.4	0.02	**1.9**	**0.31**	
	22/11/16	1.1	0.4	0.08	**0.71**	**1.8**	
	12/1/18	0.5	<0.2	0.18	**0.45**	-	
	30/5/19	0.43	0.4	0.13	0.06	-	
TB7	17/8/17	0.6	0.4		**0.18**	0.04	<0.01

TB8	17/8/17	1.2	1		**0.25**	**0.3**	<0.01
TB9	17/8/17	**6.2**	2.4		**3.8**	**3.5**	<0.01
MB5	22/8/18	**2**	<0.2		**2**	**0.2**	<0.01
MB7	22/8/18	1.2	1		**0.21**	**0.2**	0.02
WB3	2/10/20	1.2	0.0		1	0.03	<0.01
WB4	2/10/20	1.4	0.3		0.12	0.03	<0.01
Aquatic Ecosystems[a]		1.2	ng		0.15	0.065	0.04
Irrigation[b]		5	ng		ng	0.05	ng
Notes	ng denotes "no guideline". a. ANZECC (2000) Aquatic Ecosystem trigger values (Nutrient, pH and Conductivity are for lowland rivers; Dissolved Metals are for freshwater ecosystems 90% species protection) b. ANZECC (2000) Irrigation trigger values (long-term irrigation up to 100 years).						

Table 2.4 Groundwater Quality – Metals

Bore (Figure 6)	*Date*	*Al*	*As*	*Ca*	*Cd*	*Cr*	*Cu*	*Fe*	*K*	*Hg*	*Mg*	*Mn*	*Na*	*Ni*	*Pb*	*Zn*
MW1	12/7/16	**18**	0.014	8	<0.0002	**0.085**		48		<0.0001		0.038		-	**0.017**	**0.037**
	2/9/16	**0.29**	<0.001	3.4	<0.0002	<0.001		<0.05		<0.0001		0.006		0.003	<0.001	**0.032**
	28/9/16	**0.2**	<0.001	<5	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.002	<0.001	**0.019**
	21/11/16	**0.52**	<0.001	2.4	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.002	<0.001	**0.017**
	12/1/18	**6.5**	0.009	<5	<0.0002	**0.047**		20		<0.0001		0.01		0.005	0.005	**0.026**
	30/5/19	**0.21**	<0.001	2	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.002	<0.001	0.012
MW2	12/7/16	**93**	0.072	4	<0.0002	**0.43**		360		<0.0001		0.087		-	**0.05**	**0.11**
	2/9/16	**4.3**	<0.001	11	<0.0002	<0.001		<0.05		<0.0001		0.028		**0.019**	<0.001	**0.056**
	28/9/16	**3.8**	<0.001	7.2	<0.0002	<0.001		<0.05		<0.0001		0.023		0.013	<0.001	**0.031**
	21/11/16	**4.1**	<0.001	8.3	<0.0002	<0.001		0.06		<0.0001		0.029		**0.016**	<0.001	**0.049**
	12/1/18	**5.3**	0.002	8.8	0.0002	**0.018**		5		<0.0001		0.028		**0.016**	0.003	**0.031**
	30/5/19	**3.3**	<0.001	7.8	<0.0002	<0.001		<0.05		<0.0001		0.025		0.013	<0.001	<0.005
MW3	12/7/16	**29**	0.029	38	<0.0002	**0.26**		170		<0.0001		0.012		-	**0.023**	**0.038**
	2/9/16	**0.35**	<0.001	110	<0.0002	<0.001		<0.05		<0.0001		0.11		0.009	<0.001	**0.054**
	28/9/16	**1.1**	<0.001	66	<0.0002	<0.001		<0.05		<0.0001		0.27		**0.015**	<0.001	**0.07**
	21/11/16	**5**	<0.001	37	<0.0002	0.001		0.47		<0.0001		0.12		0.012	0.003	**0.023**
	12/1/18	**3.6**	<0.001	32	<0.0002	0.001		<0.05		<0.0001		<0.005		0.009	**0.01**	0.013
	30/5/19	**3.6**	<0.001	35	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.008	<0.05	0.012
MW4	12/7/16	**130**	0.05	76	<0.001	**0.71**		360		<0.0005		0.11		-	**0.098**	**0.16**
	2/9/16	<0.05	<0.001	28	<0.0002	<0.001		<0.05		<0.0001		0.005		0.002	<0.001	**0.033**
	28/9/16	<0.05	<0.001	20	<0.0002	<0.001		<0.05		<0.0001		0.005		0.003	<0.001	**0.02**
	21/11/16	**0.1**	<0.001	35	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.004	<0.001	**0.032**
	12/1/18	**0.72**	0.002	44	<0.0002	**0.011**		2.8		<0.0001		<0.005		0.002	<0.001	0.011
	30/5/19	**3.6**	<0.001	42	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.013	<0.05	<0.005
TB7	17/8/17	<0.1	<0.001	5.6	<0.002	<0.01	<0.01	0.04	0.9	<0.0002	11	-	54	<0.01	<0.01	0.01

TB8	17/8/17	<0.1	<0.001	9.1	<0.002	<0.01	<0.01	0.02	3.8	<0.0002	9.9		60	<0.01	<0.01	<0.01
TB9	17/8/17	0.3	<0.001	7.2	<0.002	<0.01	<0.01	0.16	6.6	<0.0002	7.2		80	<0.01	<0.01	<0.01
MB5	22/8/18	0.1	<0.002	17	<0.002	<0.002	<0.01	0.08	2.3	<0.0002	8.8		29	<0.01	<0.01	<0.01
MB7	22/8/18	0.2	<0.002	54	<0.002	0.003	<0.01	4.3	8	<0.0002	67		630	0.01	<0.01	**0.07**
WB3	2/10/20	0.03	<0.002	4.5	<0.0001	<0.001	<0.001	0.01	4.2	<0.0001	5		22	0.002	<0.001	<0.005
WB4	2/10/20	<0.01	<0.002	18	<0.0001	<0.001	<0.001	<0.01	4.5	<0.0001	140		1200	0.008	<0.001	0.013
Aquatic Ecosystems[a]		0.08	0.136	ng	0.0004	0.006	0.0018	ng	ng	0.0019	ng		ng	0.013	0.0056	0.015
Irrigation[b]		5	0.1	ng	0.01	0.1	0.2	10	ng	0.002	ng		230	0.2	2	2
Notes	ng denotes "no guideline". a. ANZECC (2000) Aquatic Ecosystem trigger values (Nutrient, pH and Conductivity are for lowland rivers; Dissolved Metals are for freshwater ecosystems 90% species protection) b. ANZECC (2000) Irrigation trigger values (long-term irrigation up to 100 years).															

2.5 Vegetation and Flora

The project area is largely cleared of native vegetation, consisting mostly of farm paddocks and current and former quarries. All of Lot 204, most of Lot 205 and the southern part of Lot 203 are cleared paddocks with some scattered mature trees, either native or planted. Native vegetation is present in the central east of Lot 205, the northern end of Lot 202 and the north of Lot 203.

Plantecology (2020) surveyed the vegetation and flora of the project area in November 2019. 360 Environmental (2015) undertook a vegetation survey of Lots 202 and 203 in March 2015. The full report of the Plantecology (2020) survey is attached in Appendix A. The descriptions below are based on the findings of both surveys.

2.5.1 Vegetation Types

The vegetation of the low-lying western part of the site is mapped by Heddle *et al.* (1980) as Coonambidgee Complex, ranging from a low open-forest and low woodland of pricklybark-banksia (*E. todtiana - B. attenuata - B. menziesii – B. ilicifolia*) with local admixtures of *B. prionotes*, to an open-woodland of marri-banksia. None of this complex remains in the project area.

The more elevated eastern part of the site is mapped by Heddle *et al.* (1980) as Reagan Complex, ranging from low open-woodland of *B. attenuata – B. menziesii – E. todtiana* to closed-heath, depending on the depth of soil. The vegetation on the site does not agree well with the descriptions of Reagan Complex in Heddle *et al.* (1980), notably in the presence and in some parts dominance of Wandoo and the absence of *E. todtiana* and Banksia tree species.

Beard (1981) mapped most of the project area as Pinjarra 4.30000: Medium woodland, marri and wandoo. The north-east corner (about 2.3ha) was mapped as Gingin 1020.09998: Mosaic of Medium forest, jarrah-marri and Medium woodland, marri-wandoo.

360 Environmental (2015) identified seven native vegetation associations within Lots 202 and 203, as shown on Figure 7:

- EaCcEm (4.15ha): Woodland of *Eucalyptus accedens, Eucalyptus wandoo, Corymbia calophylla, Eucalyptus marginata* and *Allocasuarina huegeliana* over *Xanthorrhoea preissii, Bossiaea eriocarpa, Hakea undulata, Acacia pulchella, Pultenaea reticulata, Hakea stenocarpa* and *Tetraria octandra*.

- Mps (0.1ha): Sedgeland of *Mesomelaena pseudostygia, Mesomelaena tetragona, Lepidosperma leptostachyum, Tetraria octandra, Hypocalymma robustum, Daucus glochidiatus* and *Acacia pulchella*.

- CcXp (1.17ha): Woodland of *Corymbia calophylla* over *Mesomelaena pseudostygia, Xanthorrhoea preissii, Bossiaea eriocarpa, Hibbertia hypericoides, Acacia pulchella, Banksia sessilis, Allocasuarina humilis* and *Banksia nivea*.

- EwMps (0.83ha): Low Open Woodland (young regrowth) of Eucalyptus wandoo over Mesomelaena pseudostygia, Mesomelaena tetragona, Tetraria octandra, Bossiaea eriocarpa and Daucus glochidiatus.

- Ea (0.08ha): *Eucalyptus accedens* woodland.

- Ew (2.14ha): *Eucalyptus wandoo* woodland.

- Cc (0.36ha): *Corymbia calophylla* scattered trees over pasture.

Plantecology (2020) identified two native vegetation communities within the site:

- Marri (*Corymbia calophylla*) Open Woodland over shrubland of *Xanthorrhoea preissii, Hibbertia hypericoides* subsp. *septentrionalis* and *Bossiaea eriocarpa* over herbland of *Mesomelaena pseudostygia, Caustis dioica* and *Banksia dallanneyi* var. *dallanneyi* on light brown clay loams on lower ground in the north-east of the site. Other common species include *Allocasuarina humilis, Acacia pulchella* subsp. *pulchella, Desmocladus fasciculatus, Lepidosperma asperatum* and *Conostylis aculeata* subsp. *aculeata*.

- Wandoo (*Eucalyptus wandoo*) Open Low Woodland over shrubland of *Xanthorrhoea preissii, Bossiaea eriocarpa* and *Hibbertia hypericoides* subsp. *septentrionalis* over herbland of *Tetraria octandra, Banksia dallanneyi* var. *dallanneyi* and *Lepidosperma pubisquameum* in brown gravelly clay loams on laterite on upper and middle slopes. Other common species include *Hakea stenocarpa, Gastrolobium acutum, Hakea lissocarpha* and *Desmocladus fasciculatus*.

Figure 8 shows the vegetation mapping by Plantecology (2020).

2.5.2 Vegetation Condition

The native vegetation ranges in condition from Completely Degraded to Excellent. The highest quality vegetation is located in the north of Lot 203, the east of Lot 205 and the north of Lot 202, in patches of 1.3ha or less. Figure 9 shows the vegetation condition.

2.5.3 Flora

360 Environmental (2015) found 39 native flora taxa and seven introduced species in Lots 202 and 203. Plantecology (2020) found a total of 86 native and nine introduced taxa across Lots 202-205, most of which were found in Lots 202 and 203. Appendix B

presents a consolidated flora species list for the site, totalling 103 native taxa and 12 introduced species.

2.5.4 Rare and Significant Flora

The DBCA's Naturemap and Commonwealth databases of Threatened and Priority Flora list 42 plant taxa with the potential to occur within the site (Table 2.5). Of these, 19 are listed as Threatened under the *Biodiversity Conservation Act 2016*. Two species are listed as Priority 1, six as Priority 2, 11 as Priority 3 and six as Priority 4. One Priority 4 species (*Centrolepis caespitosa*) is also listed as Threatened under the EPBC Act. Table 2.5 summarises the likelihood of occurrence of these species at the site.

No Threatened Flora pursuant to the *Biodiversity Conservation Act* 2016 or the *EPBC Act* 1999 were recorded during the vegetation surveys. One species listed as Priority Flora by the DBCA was recorded by Plantecology (2020): *Haemodorum loratum* (P3) was recorded at two sites, M01 and M05, and in adjacent areas of the Wandoo open woodland in the south eastern part of the site and in the Marri woodland. One species of *Cyathochaeta* was recorded by 360 Environmental (2015) but, due to the timing of the survey, it could not be determined whether it was the Priority 3 species *C. teretifolia.*

Table 2.5 Significant Flora Potentially Occurring Within the Site

Taxon	*DBCA Cons Code*	*EPBC Cons Code*	*Recorded Habitat(s)*	*Closest Record*	*Likelihood of Occurrence*
Acacia anomala	DRF	VU	Western slopes of the Darling Range east of Perth, on shallow grey sands over laterite.	4km	Unlikely
Acacia drummondii ssp. affinis	P3		Lateritic gravelly soils.	5km	Likely
Adenanthos cygnorum ssp. *chamaephyton*	P3		Grey sand, lateritic gravel.	2km	Likely
Andersonia gracilis	DRF	EN	Known from the Badgingarra, Dandaragan and Kenwick areas. Seasonally damp, black sandy clay flats near swamps.	111km	Unlikely
Anigozanthos viridis ssp. *terraspectans*	DRF	VU	Winter-wet depressions on grey sandy clay loam or grey sand in low heath that is regenerating after fire.	111km	Unlikely
Anthocercis gracilis		VU	Sandy or loamy soils. Granite outcrops.	31km	Unlikely
Caladenia huegelii	DRF	EN	Mixed woodland of Jarrah, Banksia, Sheoak, marri from just north of Perth to Busselton, usually within 20m of the coast. Mostly deep grey-white sand of the Bassendean dune system.	16km	Unlikely
Centrolepis caespitosa	P4	EN	Winter-wet claypans dominated by low shrubs and sedges.	8km	Unlikely
Chamaescilla gibsonii	P3		Clay to sandy clay. Winter-wet flats, shallow water-filled claypans.	4km	Unlikely
Chamelaucium sp. *Gingin* (N.G. Marchant 6)	DRF	EN	White/yellow sand in woodland with *Eucalyptus todtiana*, *Banksia attenuata* and *Hibbertia* sp.	13km	Unlikely
Conospermum densiflorum ssp. *unicephalatum*	DRF	EN	Low-lying sandy clay soils with surface gravel, over 10km between Gingin and Moora.	75km	Unlikely
Cyathochaeta teretifolia	P3		Grey sand, sandy clay in swamps and creek edges.	3km	Unlikely
Darwinia foetida	DRF	CE	Grey-white sand on swampy, seasonally wet sites.	1.6km	Unlikely
Diplolaena andrewsii	DRF	EN	Loam, clay. Granite outcrops and hillsides.	17km	Possible
Diuris micrantha	DRF	VU	Seasonally wet flats among sedges and scattered shrubs.	73km	Unlikely

Diuris purdei	DRF	EN	Under dense shrubs in seasonally-wet swamps and drainage lines.	55km	Unlikely
Drakaea elastica	DRF	EN	Bare patches of grey-white sand in low-lying areas alongside winter-wet swamps, typically in banksia woodland or spearwood thicket.	32km	Unlikely
Drosera occidentalis ssp. *occidentalis*	P4		Sandy and clayey soils. Swamps and wet depressions.	1.2km	Unlikely
Drosera sewelliae	P1		Laterite and silica sand soils.	6km	Possible
Eryngium pinnatifidum ssp. *Palustre* (G.J. Keighery 13459)	P3		Winter-wet areas, damplands and claypans.	2km	Unlikely
Eleocharis keigheryi	DRF	VU	Clay, sandy loam. Emergent in freshwater: creeks, claypans.	10km	Unlikely
Eucalyptus balanites	DRF	EN	Gently sloping heathlands on light-coloured sandy soils over laterite.	64km	Unlikely
Eucalyptus leprophloia	DRF	EN	Known over 90km range from north of Badgingarra to the Mt Adams area. Range of habitats including slopes of hills in brown loam over laterite.	154km	Unlikely
Grevillea althoferorum ssp. *fragilis*	DRF	EN	Base of the Darling Scarp on greyish-yellow colluvial sand, in banksia woodland.	2.7km	Unlikely
Grevillea christinae	DRF	EN	Clay loam, sandy clay, often moist.	76km	Possible
Grevillea corrugata	DRF	EN	Known from two locations 10km south of Bindoon, on gravelly loam in partially-cleared eucalyptus woodland on roadsides.	16km	Unlikely
Grevillea curviloba ssp. *curviloba*	DRF	EN	Winter wet, deep peaty grey sands over limestone.	4km	Unlikely
Grevillea curviloba ssp. *incurva*	DRF	EN	Open heath in winter-wet areas on sand over limestone or ironstone.	2km	Unlikely
Guichenotia tuberculata	P3		Sandy clay over laterite, sand.	69km	Possible
Haemodorum loratum	P3		Grey or yellow sand, gravel.	63km	Present
Hibbertia glomerata ssp. *ginginensis*	P1		Sand, brown clay, laterite and near roadsides.	30km	Possible
Oxymyrrhine coronata	P4		Slopes and flats with dry gravel over laterite.	4km	Possible
Persoonia rudis	P3		White, grey or yellow sand, often over laterite.	4km	Possible
Platysace ramosissima	P3		Sandy soils.	2km	Possible

Schoenus sp. Bullsbrook (J.J. Alford 915)	P2		Grey peaty sand, low-lying flats.	13km	Unlikely
Stenanthemum sublineare	P2		Littered white sand on the Swan Coastal Plain.	13km	Unlikely
Stylidium aceratum	P2		Sandy soils, swamp heathland.	3km	Unlikely
Stylidium longitubum	P3		Sandy clay, clay. Seasonal wetlands.	14km	Unlikely
Stylidium paludicola	P3		Peaty sand over clay. Winter-wet habitats. Marri and melaleuca woodlands.	14km	Unlikely
Stylidium squamellosum			Brown to red-brown clay loam. Winter-wet depressions. Open woodland, shrubland.	2km	Unlikely
Synaphea grandis	P4		Laterite.	1km	Likely
Tetraria sp. Chandala (G.J. Keighery 17055)	P2		Mound springs, wetlands and peaty sands.	14km	Unlikely
Thelymitra manginii K. Dixon & Batty ms (*Thelymitra dedmaniarum*)	DRF	EN	Open wandoo woodlands on red-brown sandy loam associated with dolerite and granite outcrops.	18km	Unlikely
Thelymitra stellata	DRF	EN	Low heath and scrub in jarrah and wandoo woodland on ridges and slopes, also on river banks and breakaways, on red, brown, yellow or grey sandy loams, clay or gravel over laterite or gravel.	5km	Possible
Trichocline sp. Treeton (B.J. Keighery & N. Gibson 564)	P2		Sand over limestone, sandy clay over ironstone. Seasonally wet flats.	8km	Unlikely
Verticordia lindleyi ssp. *lindleyi*	P4		Sand, sandy clay. Winter-wet depressions.	5km	Unlikely
Verticordia serrata var. *linearis*	P4		White sand, gravel. Open woodland.	3km	Unlikely

2.5.5 Floristic Communities

360 Environmental (2015) tentatively assigned floristic community types (FCTs) to the vegetation associations on Lots 202 and 203 as follows:

- EaCcEm and EwMps **S8** – *Eucalyptus wandoo* woodlands
- CcXp and Mps **3c** – *Corymbia calophylla-Xanthorrhoea preissii* woodlands and shrublands / **S18** – *Eucalyptus marginata-Corymbia calophylla* woodlands on laterite

The vegetation of Lots 204 and 205, consisting mostly of isolated paddock trees, is too severely degraded to assign to any FCT except for the patch of Wandoo woodland in the east of Lot 404, which is tentatively assigned to FCT S8.

2.5.6 Threatened and Priority Ecological Communities

Floristic Community 3c is listed as Critically Endangered under the Western Australian *Biodiversity Conservation Act 2016* and as Endangered under the Commonwealth *EPBC Act 1999*.

The DBCA and EPBC Threatened and Priority Ecological Community databases list several other TECs and PECs within 5km of the project area:

- Muchea Limestone – Shrublands and Woodlands on Muchea Limestone (Endangered (DBCA) Endangered (EPBC));
- SCP07 – Herb rich saline shrublands in clay pans (Vulnerable (DBCA) Critically Endangered (EPBC));
- SCP3a – *Corymbia calophylla - Kingia australis* woodlands on heavy soils, Swan Coastal Plain (Critically Endangered (DBCA));
- Mound Springs – Communities of Tumulus Springs (organic mound springs, Swan Coastal Plain) (Critically Endangered (DBCA) Endangered (EPBC));
- SCP23b – Northern *Banksia attenuata – B. menziesii* woodlands (Priority 3 (DBCA));
- SCP25 – Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands (Priority 3 (DBCA)); and
- SCP22 – *Banksia ilicifolia* woodlands (Priority 3 (DBCA)).

None of these floristic communities was found in the project area.

2.5.7 Local and Regional Representation

Table 2.6 summarises the status of the site vegetation types State-wide, in the Swan Coastal Plain Bioregion, the Shire of Chittering and within 15km of the site. The data in the table are sourced from the following:

- 2013 Native Vegetation extent by Vegetation complexes on the Swan Coastal Plain south of Moore River (Local Biodiversity Program, 2013).
- CAR Analysis Report 2009. WA Department of Environment & Conservation, Perth www2.landgate.wa.gov.au/slip/portal/services/files/carreserveanalysis2009.xls.
- Vegetation Extent-By-Type GIS database (Department of Agriculture, 2005).
- Swan Coastal Plain Vegetation Complexes GIS database (DPaW, 2016).
- CALM Estate GIS database (CALM, 2009).

Table 2.6 Remnant Vegetation Status

Vegetation Unit	*Pre-European Extent (km^2)*	*Current Extent (km^2)*	*% Remaining*	*% In Secure Reserves*
Remnant Vegetation				
Shire of Chittering	1,218	496	41	3
15km Radius	748	269	36	12
Reagan Complex (Heddle *et al.*, 1980)				
Swan Coastal Plain	91	31	34	6
Shire of Chittering	20	10	51	
15km Radius	39	18	46	4
Pinjarra 4 (Beard, 1981)				
Statewide	106	14	13	1.4
Shire of Chittering	45	7	16	0.6
15km Radius	97	29	30	0.4
Gingin 1020 (Beard, 1981)				
Statewide	56	19	34	1.8
Shire of Chittering	36	12	34	0.5
15km Radius	56	24	43	2

The table shows that the vegetation types present in the project area are moderately to well represented both locally and regionally, but that their formal reservation status is generally poor. Figure 10 shows the local and regional representation and reservation.

2.6 Fauna

2.6.1 Species and Habitats

Most of Lots 204 and 205 is cleared apart from isolated paddock trees, and offers little habitat for native fauna. The exception is an area of about 1ha in the east of Lot 205, which supports wandoo woodland in excellent condition and offers good quality habitat for fauna.

Lots 202 and 203 support areas of native vegetation ranging in condition from Completely Degraded to Excellent, as well as fully cleared areas. The vegetation in Good, Very Good and Excellent condition offers good quality habitat for fauna.

Overall, the project area contains approximately 2.4ha in Excellent condition, 2.3ha in Very Good condition and 0.5ha in Good condition.

The following fauna habitats have been identified at the site:

- Marri and Wandoo woodlands with largely undisturbed understorey;
- Eucalypt woodlands with degraded understorey; and
- Cleared paddocks with isolated mature Marri, Wandoo and Jarrah trees.

The Marri and Wandoo woodlands offer a range of feeding and nesting habitats for native fauna including mature trees with hollows, shrubs, dense understorey, groundcover and ground litter. These are expected to support a wide range of reptile, mammal and bird species.

The Eucalypt woodlands with degraded understorey have little or no ground cover or shrub layer and are expected to offer low-quality habitat for birds and some disturbance-tolerant terrestrial species.

The cleared paddocks with isolated mature trees would provide grazing habitat for kangaroos, particularly in areas close to uncleared woodland in the east of Lot 205. Stock troughs in the paddocks are focal points for ducks (particularly Maned or Wood Duck, *Chenonetta jubata* and Mountain Duck or Shelduck, *Tadorna tadornoides*), which feed in small flocks in the paddocks around the troughs. The paddocks also support a large population of the introduced Long-Billed Corella (*Cacatua tenuirostris*), which is an agricultural pest in Western Australia.

The mature trees in the paddocks are mostly larger than 0.5m diameter at breast height (dbh), and a number contain hollows of various sizes that offer potential nesting sites for black cockatoos and other bird species. Results of a survey of potential nesting hollows are given in Section 2.5.3 below.

2.6.2 Significant Fauna

A search was made of relevant databases for the area surrounding the project area. The databases searched included:

- DBCA Naturemap (15km radius including the project area);
- DBCA Threatened Fauna Database (15km radius including the project area);
- EPBC Protected Matters Search Tool (10km radius including the project area); and
- Birds Australia Birdata database (1 degree/60nm square including the project area).

The searches produced an extensive list of Threatened Fauna species, Priority Fauna species and otherwise significant species from the search area. Many of those were marine or aquatic species for which no habitat exists in the project area. Species that might occur in the project area or its surrounds are summarised, and their likelihood of occurrence in the project area assessed, below:

- Carnaby's Black Cockatoo *Calyptorhynchus latirostris* (S1, EN) – Feeds and breeds in eucalypt and Banksia woodland from the lower Murchison to the lower south-west. Numerous records of occurrence near the project area. The project area contains food resources including Marri trees and potential nesting sites. Signs of feeding on Marri nuts, possibly by Carnaby's Black Cockatoo (or possibly by Twenty-Eight Parrots) were observed beneath trees in the south of Lot 203 during the site inspection in March 2020.

- Forest Red-tailed Black Cockatoo *Calyptorhynchus banksii naso* (S1, VU) - Feeds and breeds in eucalypt and Banksia woodland from Gingin to the lower south-west. May occur in and around the project area. The project area contains food resources including Marri trees and potential nesting sites. A small group (8-10 individuals) was observed in Wandoo trees on the opposite side of Wandena Road during the site inspection March 2020.

- Black-striped Snake *Neelaps calonotos* (P3) - Inhabits dense leaf litter in Banksia and eucalypt woodlands with sandy soil from Lancelin south to Mandurah. Likely to be present in or around the project area.

- Black-flanked Rock Wallaby *Petrogale lateralis* subsp. *lateralis* (T, EN) – Restricted to parts of Cape Range, Little Sandy Desert, granite rocks in the Avon Wheatbelt, Kalbarri National Park and Barrow and Salisbury Islands. Occurs on rocky habitats with a preference for complex caves and crevices. Unlikely to be present in the project area due to the absence of suitable habitat.

- Woylie *Bettongia penicillata ogilbyi* (T, EN) - Formerly widespread species now restricted to six known sites in the south-west. Inhabits open eucalypt forest, open mallee woodlands and shrublands. Unlikely to be present in the vicinity due to predation by foxes and cats.

- Douglas' Broad-headed Bee *Hesperocolletes douglasi* (T, CR) – Recently rediscovered in Banksia woodland at Pinjar in 2019 after being presumed extinct. Only previous sighting was on Rottnest Island in 1938. Unlikely to be present in the project area.

- Chuditch *Dasyurus geoffroii* (S3, VU) - Occurs in a wide range of habitats including woodlands, dry sclerophyll forests and riparian vegetation. The project area provides foraging habitat and the species is likely to be an occasional visitor to the project area.

- Peregrine Falcon *Falco peregrinus* (S4) - A wide-ranging species that prefers nesting in cliff faces. Likely to overfly the project area but would not be resident.

- Rainbow Bee-eater *Merops ornatus* (S3, MI) - A common and widespread migratory species that utilises a wide range of habitats, with a preference for nesting in open sandy ground. The project area has few open sandy areas and is unlikely to provide habitat for the species.

- Fork-tailed Swift *Apus pacificus* (S3, MI) - A widespread and almost entirely aerial species. Likely to overfly the project area but would not be resident or dependent upon it.

- A short-tongued bee *Leioproctus douglasiellus* (CR) - Known from only three locations within the Perth metropolitan area in association with two plant species: *Goodenia filiformis* and *Anthotia junciforme*, neither of which are present at the site.

- Brush-tailed Phascogale *Phascogale tapoatafa* (P3) - Inhabits dry sclerophyll forests and open woodlands with hollow-bearing trees and sparse ground cover between Perth and Albany. A specimen was captured in open Tuart woodland in Baldivis, 23km south-west of the project area, in 2017 (Australian Ecological Services, 2017). Unlikely to be present at the site due to its scarcity and the absence of its preferred habitat.

- Graceful Sunmoth *Synemon gratiosa* (P4) - Inhabits coastal heathland on Quindalup dunes and banksia woodland on Spearwood and Bassendean dunes, in association with two species of mat-rush, *Lomandra maritima* and *L. hermaphrodita.* Neither plant species was found in the project area so the moth is unlikely to be present.

- Inornate Trapdoor Spider *Euoplos inornatus* (northern Jarrah Forest) (P3) – Known from several locations in the northern Jarrah forest, the closest 6.5km south-east of the site. May be present in uncleared areas at the site.

- A short-tongued Bee *Leioproctus contrarius* (P3) – Occurs on the Swan Coastal Plain in association with *Scaevola repens* var. *repens* and *Lechenaultia* spp, neither of which are present at the site.

- Quenda *Isoodon obesulus fusciventer* (P4) - Inhabits dense ground cover in forests, woodlands and heaths, preferring areas around wetlands and damplands. May be present in uncleared parts of the project area although no evidence of presence (e.g. diggings) were observed.

- Grey Wagtail *Motacilla cinerea* (MI) – Breeds in northern Europe and migrates to the southern hemisphere, mostly Africa and Asia. Two Western Australian records from near Pemberton and Northcliffe. Unlikely to be present at the site.

2.6.3 Black Cockatoo Habitat Assessment

Feeding Habitat
The project area contains nine species recorded by Valentine & Stock (2008) as food resource species for Carnaby's Cockatoo: *Corymbia calophylla, Eucalyptus marginata, Xanthorrhoea preissii, Hakea lissocarpha, Mesomelaena pseudostygia, M. tetragona, Allocasuarina fraseriana, Banksia sessilis* and *Lambertia multiflora*. In most cases (except *C. calophylla*), these species are present at low density over small areas, so the site offers limited food resources for black cockatoos. The large Marri trees in the cleared areas would be expected to provide food for black cockatoos. Limited evidence of Carnaby's Cockatoo feeding (in the form of chewed nuts) was observed in the south of Lot 203 during the site inspection.

Roosting Habitat
The EPBC Act Referral Guidelines for Black Cockatoos (DSEWPC, 2012) define black cockatoo roosting sites as tall trees or groups of tall trees, usually close to an important water source and within an area of quality feeding habitat.

The project area contains no significant water sources and limited feeding habitat. It is therefore unlikely that black cockatoos will roost in the area.

Breeding Habitat
The DSEWPC (2012) defines black cockatoo breeding habitat as follows:

- Current breeding habitat - Trees of suitable species (including Marri, Jarrah and Wandoo) with suitably-sized hollows (generally minimum 140mm opening, 200mm internal width, 450mm depth).

- Potential breeding habitat - Trees of suitable species of size at least 500mm diameter at breast height (dbh) (or 300mm for Wandoo).

360 Environmental (2015) found 126 Marri, Jarrah and Wandoo trees in Lots 202 and 203 that met the DSEWPC (2012) definition of future breeding habitat. None of the trees contained visible hollows potentially suitable for black cockatoo nesting. BES (2020) found 122 trees across Lots 202-205 that met the DSEWPC (2012) size criteria, including 56 that contained hollows or potential hollows, of which eight appeared to be

of a suitable size for black cockatoos. Across the two surveys, a total of 190 trees met the DEWA size criteria for potential nesting habitat.

BES inspected all potential hollows in October 2020 with a pole-mounted camera (Cocky Cam) supplied by Birdlife Australia. The inspection found nine hollows in use by Corellas, two by Australian Kestrels and one by Kookaburras. No evidence of current or previous black cockatoo nesting was found. A large number of hollows (approximately 15 of 56 examined) contained feral bee hives.

Figure 11 shows a consolidated map of all potential nesting trees identified by 360 Environmental (2015) and BES (2020).

2.7 Land Uses and Potential Contamination

Historic Landgate aerial photography shows that the project area has been largely cleared and used for farming since at least 1965. Quarrying has been underway on Lots 202 and 203 since before 1977.

The DWER Contaminated Sites Database (https://dow.maps.arcgis.com/apps/webappviewer/index.html?id=c2ecb74291ae4da2ac32c441819c6d47) shows no record of any contaminated sites in the project area. The nearest mapped contaminated site is a service station in Muchea, 3.3km north-west of the project area. There is no potential for this contamination to directly affect the project area.

The former clay quarry on Lots 202 and 203 is currently being backfilled with inert waste such as building rubble prior to rehabilitation. The backfilling and rehabilitation are being undertaken under the terms of a DWER Licence (L9181/2018/1), which carries conditions including control of waste acceptance and prevention of pollution.

There is no visual or photographic evidence of any contaminating activities now or in the past within the project area.

2.8 Aboriginal and European Heritage

The Department of Planning Lands & Heritage's online database shows one registered site, (ID 3525 Ellen Brook: Upper Swan) covering the whole project area. Appendix C shows the search report.

The DPLH mapping usually extends well beyond the actual registered site boundary in order to protect sensitive sites. The DAA has advised that the actual boundaries of the registered site do not affect the project area, and that therefore no approval under the Aboriginal Heritage Act 1972 is required for development of the project area. The DPLH advice is attached in Appendix C.

2.9 Landscape

The project area is visible from Great Northern Highway and Wandena Road. The view from Great Northern Highway is partly screened but not blocked by trees planted within the property. From Wandena Road the southern end of the project area is visible through a screen of roadside trees, but for the most part is obstructed by dense vegetation and the banks of a cutting through which the road passes.

The landscape in the west consists mostly of cleared horse paddocks with scattered trees and isolated buildings set well back from the highway.

Figure 12 shows views of the site from Great Northern Highway and Wandena Road.

3.0 ENVIRONMENTAL IMPACTS AND MANAGEMENT

3.1 Surface Water Protection

The project area drains to Ellen Brook via culverts beneath Great Northern Highway and small drainage lines within and adjacent to the site.

Ellen Brook is a major tributary of the Swan-Canning River system and the largest contributor of nutrients, mostly from agriculture on the grey sandy soils west of the Brook. Small creeks and drainage lines are important contributors to the flow and water quality of Ellen Brook.

Industrial development has the potential to affect the volume, rate and quality of water flows in the drainage lines and Ellen Brook. Water outputs from the project area will be limited to stormwater, groundwater and minor process water (such as washdown water). In addition, the limited availability of water (groundwater or scheme) will mitigate against the establishment of industry with high water requirements.

Management
The aim of surface water protection is to maintain or improve the quality of surface water leaving the project area. Given the site's current use for agriculture, this is considered achievable.

The contaminant of major concern in Ellen Brook and the Swan-Canning River system is phosphorus. Monitoring in September 2018 (BES, 2020) showed that Ellen Brook carries very heavy phosphorus loads. Phosphorus is a major contaminant in agricultural runoff but a minor component in runoff from industrial areas.

Management strategies to be implemented include:

- In accordance with the Shire of Chittering Town Planning Scheme No. 4, industries permitted in Precinct 2 will be those that dispose of domestic-quality wastewater at a rate less than 5,400 litres per hectare per day (R10 equivalent).

- Wastewater from toilets and bathrooms will be treated by nutrient-removing systems (e.g. ATU or modified leach drains) in accordance with Health Department requirements. An analysis of the capability of the site to support on-site effluent disposal is presented in the Local Water Management Strategy (Appendix D).

- The single existing drainage line crossing the project area will be retained within a roadside bioretention swale (see LWMS).

- All road runoff will be captured and infiltrated (up to 1-year ARI 1-hour storm) or detained (up to critical 100-yr storm) in bioretention swales in accordance with

DWER guidelines. Stormwater management is detailed in the LWMS. Figure 13 shows an overview of the stormwater management system.

- Any process wastewater generated by industries will be treated on-site to a standard suitable for discharge to the ground or disposed offsite.

- All lot drainage from storms up to 1-year ARI 1-hour will be retained and infiltrated within individual lots. Runoff from critical storms up to 100-year ARI will be detained within lots and released at a rate no greater than the pre-development rate.

- A monitoring program for surface water will be implemented as detailed in the LWMS.

- Temporary drainage controls will be implemented during the construction period (see Section 3.5).

3.2 Groundwater Protection

Groundwater is an important contributor to water flow and quality in Ellen Brook. Given the silty clay soils of the project area, groundwater throughflow and discharge is relatively low.

Bore samples collected in September 2020 show that the quality of groundwater is generally good, with moderate to low concentrations of phosphorus and nitrogen.

The Structure Plan aims to maintain groundwater levels, discharge volumes and quality at their pre-development levels. With the removal of horse grazing, the quality of groundwater is expected to gradually improve.

Management
Groundwater protection measures are detailed in the LWMS and will include:

- Industries in Precinct 2 (Lots 204 and 205) will be restricted to those with low water use and waste water generation of less than 5,400 litres/ha/day (see Structure Plan report).

- Subsoil drains, if required, will be set at or above the pre-existing Average Annual Maximum Groundwater Level (AAMGL).

- Subsoil and stormwater drains will discharge to vegetated swales with PRI of at least 15 (see LWMS).

3.3 Noise

Industrial land use is inherently noisy. Noise sources include traffic, machinery, power tools, ventilators and percussive impacts.

The western side of the project area experiences intermittent high levels of noise from heavy vehicles using Great Northern Highway, although the level and frequency of this noise has diminished substantially since the opening of the new Tonkin Highway further to the west.

Noise-sensitive premises (residences) are located in Muchea 1,800 metres west of the project area. Isolated residences are also located west of Great Northern Highway (70m west of the project area) and east of Wandena Road (350m east of the project area).

Other noise sources include an active clay quarry located 600m north and air traffic (including jets) from Pearce RAAF Base located 6.5km south. The project area is in line with the main runway at Pearce.

Future noise sources will include industry to the west and north as part of the Muchea Industrial Park.

Management
Active management of noise within and from the Structure Plan area will not generally be required. Industries with high noise emissions may be required to undertake technical analyses to determine separation requirements. These industries may be restricted to certain parts of the Structure Plan area where suitable separations are available.

3.4 Dust

Industrial land uses may generate significant amounts of dust, depending on the activities carried out and the condition of the ground surface. Potentially dusty activities include processing (materials handling), unsealed roads and exposed soil surfaces.

The silty soils of the project area are susceptible to dust generation when disturbed. The main dust risk will be during construction work. Management of construction impacts including dust is detailed in Section 3.5.

Sensitive dust receptors are the same as those for noise: the town of Muchea and residences located east and west of the project area.

Management
Individual lot holders within the project area will be required to manage dust to prevent dust escape beyond their boundaries. Industries that generate appreciable process dust will be required to hold a DWER licence, which will specify dust limits and monitoring requirements.

3.5 Construction Impacts

Construction of the project is expected to be carried out at various times, in accordance with the land owners' preferences. Construction of roads, drainage and other services will be undertaken by the owner(s) of each stage of subdivision.

Construction stage impacts relate mainly to the movement of machinery and the presence of areas of exposed soil, and include noise, vibration, dust, erosion and sedimentation.

Management
Management of construction impacts will be the subject of conditions attached to subdivision approvals, works approvals and development approvals.

In general, control of construction impacts will be the responsibility of the construction contractor. The general principles of construction management will be as follows:

The developer will implement a Construction Management Plan for the development dealing with dust management, erosion and sediment control, containment of environmentally hazardous materials (chiefly fuel and oils) and spill response. The key elements of the Construction Management Plan will include the following:

Dust Minimisation
- No topsoil stripping will be undertaken in dry conditions when the wind speed is greater than 25km/h unless appropriate dust control watering is undertaken prior to and during disturbance..
- No earthworks will be undertaken in dry conditions when the wind speed is greater than 40km/h unless appropriate dust control watering is undertaken prior to and during disturbance.
- Dust will be suppressed on open ground and stockpiles by regular watering, hydromulching, wind fencing and/or covering.
- An adequate supply of water for dust suppression will be kept on site at all times.
- Soil stockpiles will be limited to a height of 2.5m to minimise dust generation and to facilitate watering.
- Other dust minimisation measures will include minimising areas of disturbance, limiting volume and speed of construction traffic and instructing site workers in dust minimisation.

Erosion and Sedimentation
- Drains and bunds will be constructed at the beginning of site disturbance as necessary to capture and direct all runoff from disturbed areas into settling ponds. Drains, bunds and ponds will be appropriately designed and sized to provide adequate settling of sediments from drained water before release.
- Vehicles and machinery will be kept to designated roads, tracks and work areas.

Water Conservation

- Water consumption during construction will be minimised by:
  - limiting dust suppression watering to prevent ponding and runoff; and
  - use of non-water dust control methods such as wind fencing and hydromulching where appropriate.

Hazardous Materials

- All environmentally hazardous materials will be stored in their original labelled containers (or labelled jerrycans or drums in the case of petroleum fuels) in a ventilated enclosure equipped with appropriate signage, fire extinguishers and a spill response kit.
- Petroleum products will be held in a bunded enclosure.
- Material Safety Data Sheets (MSDS) and a chemical register for all hazardous materials on the site will be maintained by the site supervisor in the site office.

Complaints Register

- The site supervisor will maintain a written record of any public complaints and the actions taken in response.

3.6 Vegetation and Flora

The native vegetation over most of the project area consists of mature paddock trees, rows and groups of planted trees. In the eastern part of the site, the vegetation consists of Marri and Wandoo open woodland in Completely Degraded to Excellent condition.

Development of the project area as proposed will involve the clearing of approximately 2.42ha of Marri and Wandoo woodland in Excellent condition, 2.33ha in Very Good condition, 0.48ha in Good condition and 0.86ha in Degraded condition. In addition, up to approximately 110 isolated native paddock trees (Marri, Wandoo and Jarrah) may be removed where they cannot be retained.

Remnant trees within the development area will be preserved where possible. No remnant trees may be cleared without a Development Approval from the Shire of Chittering and/or a clearing permit from the DWER.

Landscaping within private lots and public areas (e.g. road reserves and drainage swales/basins) will be carried out using local native species.

3.7 Fauna

Development of the site as proposed will require the clearing of about 6.1ha of Marri and Wandoo woodland in Degraded to Excellent condition.

Prior to clearing, a fauna capture and relocation exercise will be undertaken by a qualified specialist consultant to relocate any sedentary animals (e.g. snakes and lizards) from the application area. During and after clearing, monitoring of debris will be carried out to locate and salvage any fauna caught within the clearing operation.

Fauna captured or salvaged during this operation will be relocated to parks or reserves in consultation with and by permission of the DBCA. Any injured fauna found after clearing will be taken to a refuge where possible. Any feral animals captured, as well as native animals that are too badly injured to recover, will be euthanased.

Fauna habitat will be created in the revegetation of drainage swales and basins. Street trees planted within the project area will focus on native tree species that provide habitat for nectar-eating and seed-eating birds.

3.8 Landscape

3.8.1 Overview

Development in accordance with the Structure Plan will change the landscape of the project area from predominantly rural to industrial, in keeping with the industrial landscape of the overall Muchea Industrial Park.

The objective of landscaping will be not to hide the industry from view but to provide vegetation features that “soften” and break up the industrial landscape. This will include plantings within lots along the interface of Great Northern Highway, drainage swales and basins, verge trees within the developed areas and landscape buffers within lots.

3.8.2 Landscape Plantings

The Shire of Chittering Town Planning Scheme imposes a general requirement that all non-residential lots should provide landscaping with approved species to a minimum of 10% of the total lot area, including a minimum of one shade tree per four car parking bays.

The Shire of Chittering’s *Muchea Industrial Park Design Guidelines* (2018) set out the Council’s requirements and recommendations for development layout within lots, streetscaping, landscaping, bushfire management, fencing, signage and building design. The Guidelines require:

- a minimum 2m wide landscape buffer on the primary road frontage;
- a minimum 1m wide landscape buffer on secondary road interface and side boundaries extending to the building setback line;
- one shade tree per four car parking bays; and
- one tree per 10m of road frontage.

The landscape plantings within lots will be of a mix of native trees, shrubs and ground covers. The 1-year ARI 1-hour bioretention swales within each lot will be densely planted with native sedges and low shrubs. This will form part of the 10% landscaping requirement for each lot.

3.8.3 Streamline Revegetation

Roadside bioretention swales will be densely planted with native sedges and low shrubs to stabilise the beds and banks of the swales, slow water flows and promote the uptake of sediments and nutrients from the water. The areas to be planted, species and planting densities are described in more detail in the Landscape Master Plan (BES, 2020).

Plantings within the swales will be kept to a height that meets the definition of Shrubland in the Bushfire Hazard Assessment (Eco Logical Australia, 2020) so as not to create an unacceptable fire hazard.

4.0 MONITORING

Baseline water quality results for the project area are shown in Tables 2.2, 2.3 and 2.4. Groundwater levels and quality will continue to be monitored and compared against baseline levels and relevant guidelines. Surface water quality in drainage lines within, upstream and downstream of the project area will be monitored to determine what (if any) impacts the development may be having on surface water quality.

The developer of each stage of subdivision will be responsible for monitoring water quality in bores and drainage swales within that stage.

Water quality sampling will be conducted nominally once a year in late winter. Detailed water monitoring and response procedures will be developed as part of the Urban Water Management Plans to be prepared for each stage of subdivision.

5.0 IMPLEMENTATION AND FURTHER MANAGEMENT PLANS

Subdivision and development in the project area will be undertaken in accordance with the Structure Plan, this EAMS and the attached LWMS.

Development may occur in accordance with a subdivision approval or, in the absence of subdivision, a Development Approval. Subdivision approvals will include a requirement for an Urban Water Management Plan (UWMP). If development occurs without a subdivision, a Local Water Management Plan (LWMP) may be required to set out drainage design for the development.

6.0 REFERENCES

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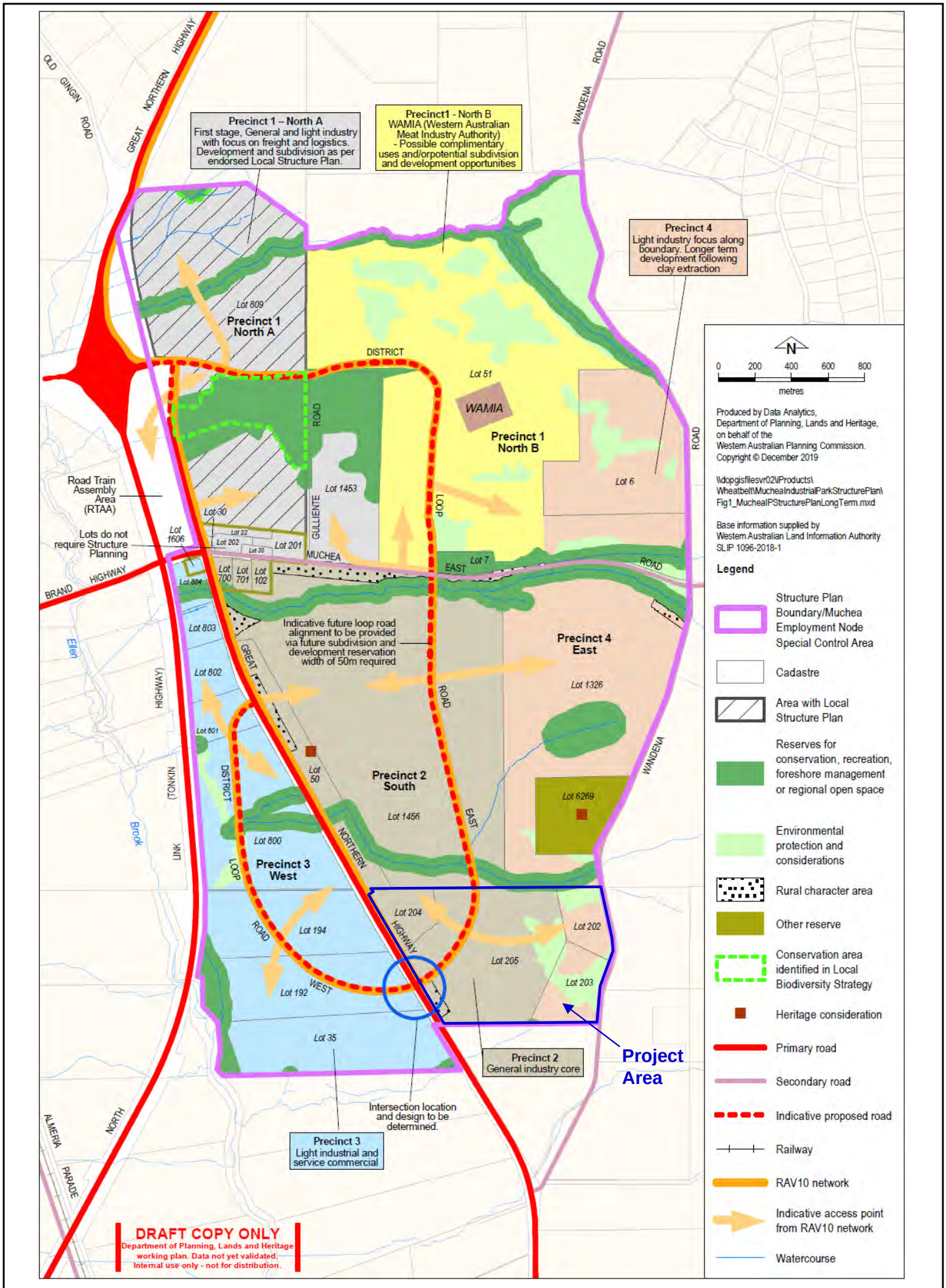
Figures



Source: WAPC, 2019

Figure 1

DRAFT MUCHEA INDUSTRIAL PARK STRUCTURE PLAN

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Figure 2

THE SITE AND SURROUNDINGS

Image source: Google

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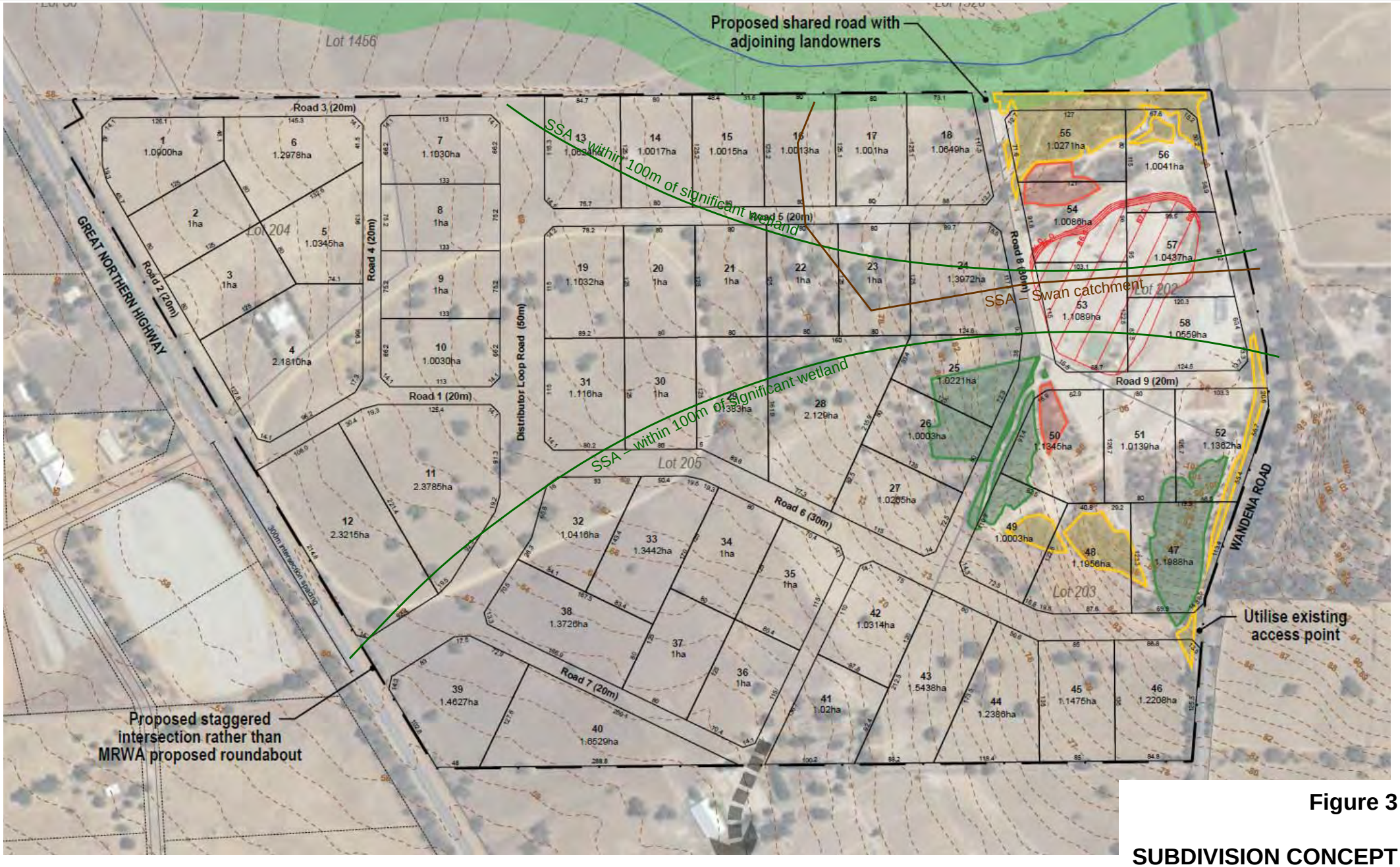

Figure 3

SUBDIVISION CONCEPT

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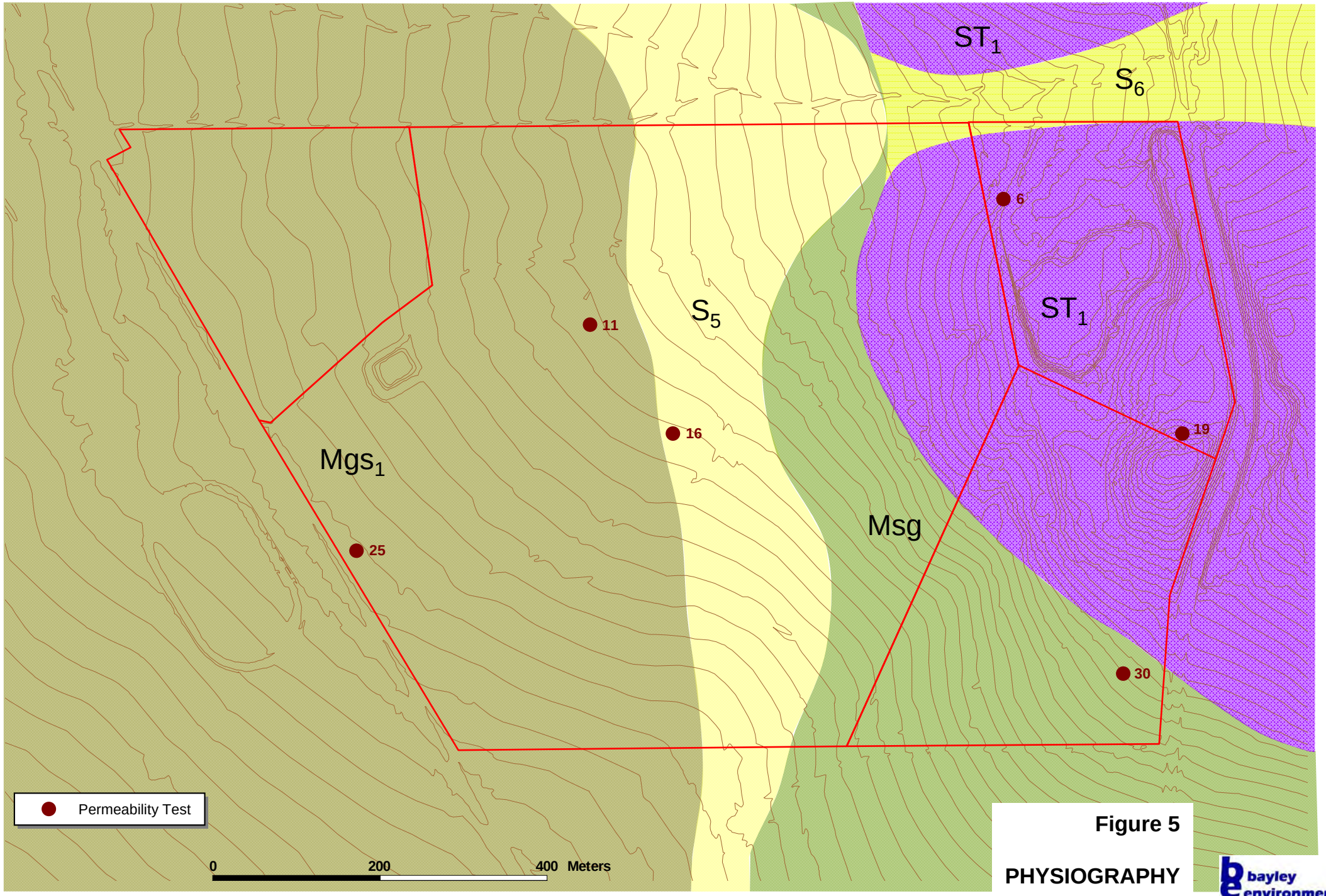

Figure 5

PHYSIOGRAPHY

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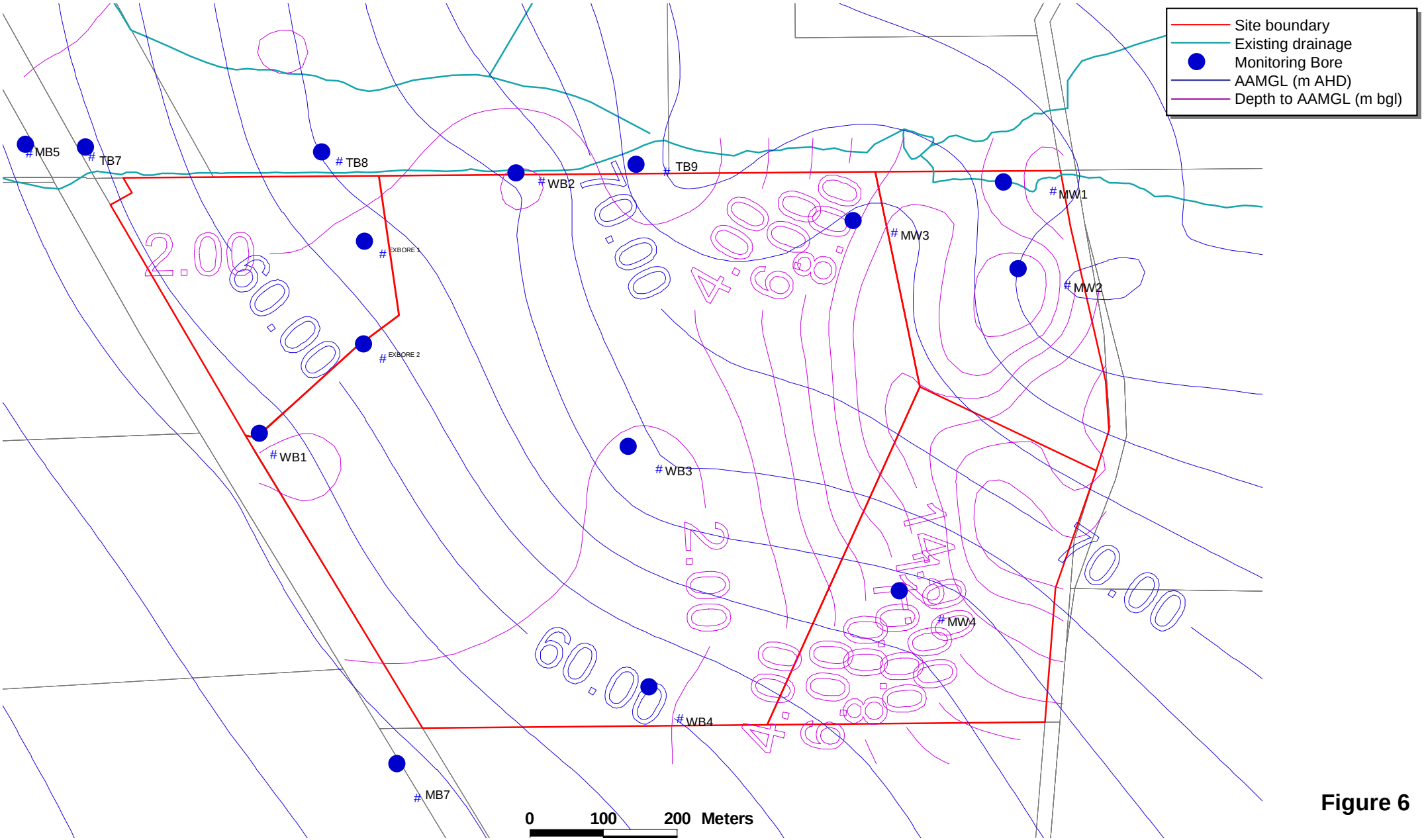

Figure 6

HYDROLOGY

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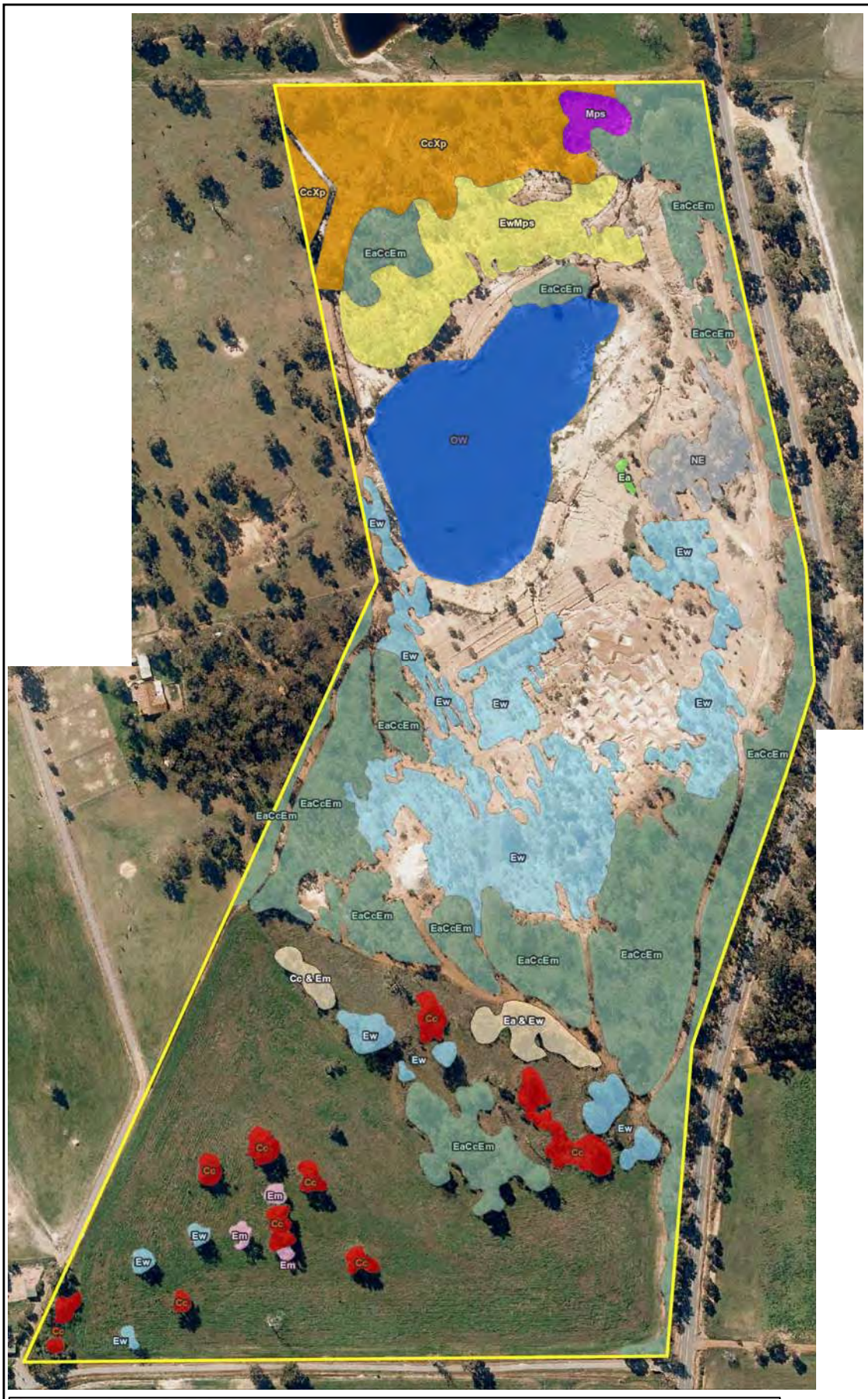

	Cc (0.36 ha)	*Corymbia calophylla*
	CcXp (1.17 ha)	Woodland of *Corymbia calophylla* over *Mesomelaena pseudostygia, Xanthorrhoea preissii, Bossiaea eriocarpa, Hibbertia hypericoides, Acacia pulchella, Banksia sessilis, Allocasuarina humilis* and *Banksia nivea*
	Ea (0.08 ha)	*Eucalyptus accedens*
	EaCcEm (4.15 ha)	Woodland of *Eucalyptus accedens, Eucalyptus wandoo, Corymbia calophylla, Eucalyptus marginata* and *Allocasuarina huegeliana* over *Xanthorrhoea preissii, Bossiaea eriocarpa, Hakea undulata, Acacia pulchella, Pultenaea reticulata, Hakea stenocarpa* and *Tetraria octandra.*
	Em (0.03 ha)	*Eucalyptus marginata*
	Ew (2.14 ha)	*Eucalyptus wandoo*
	EwMps (0.83 ha)	Low Open Woodland (young regrowth) of *Eucalyptus wandoo* over *Mesomelaena pseudostygia, Mesomelaena tetragona, Tetraria octandra, Bossiaea eriocarpa* and *Daucus glochidiatus.*
	Mps (0.10 ha)	Sedgeland of *Mesomelaena pseudostygia, Mesomelaena tetragona, Lepidosperma leptostachya, Tetraria octandra, Hypocalymma robustum, Daucus glochidiatus* and *Acacia pulchella*
	NE (0.25 ha)	Non-endemic species
	OW (1.46 ha)	Open Water

Figure 7

VEGETATION MAPPING - 360 ENVIRONMENTAL

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Figure 8

VEGETATION MAPPING - PLANTECOLOGY

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Figure 9

VEGETATION CONDITION

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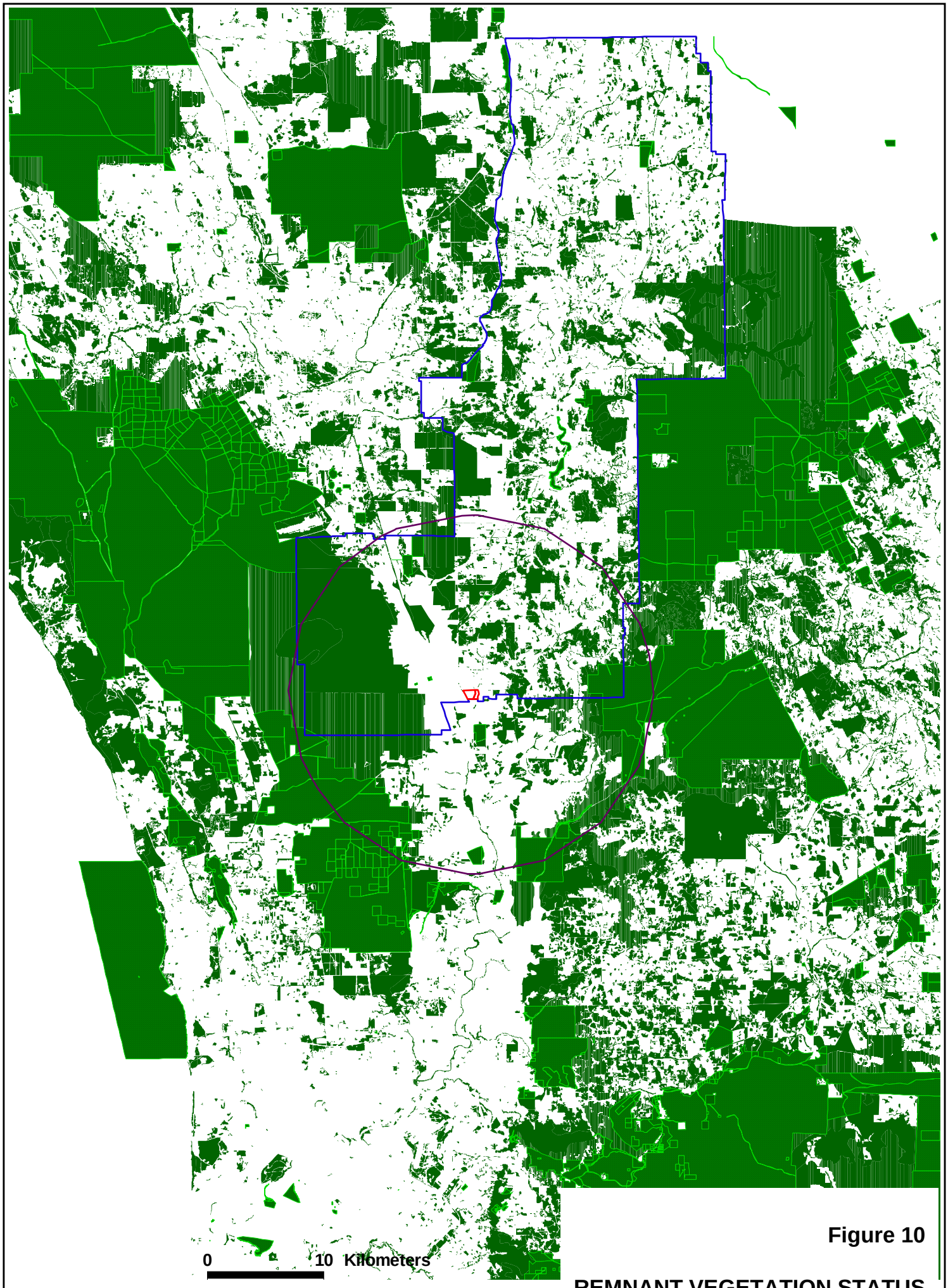

Figure 10

REMNANT VEGETATION STATUS

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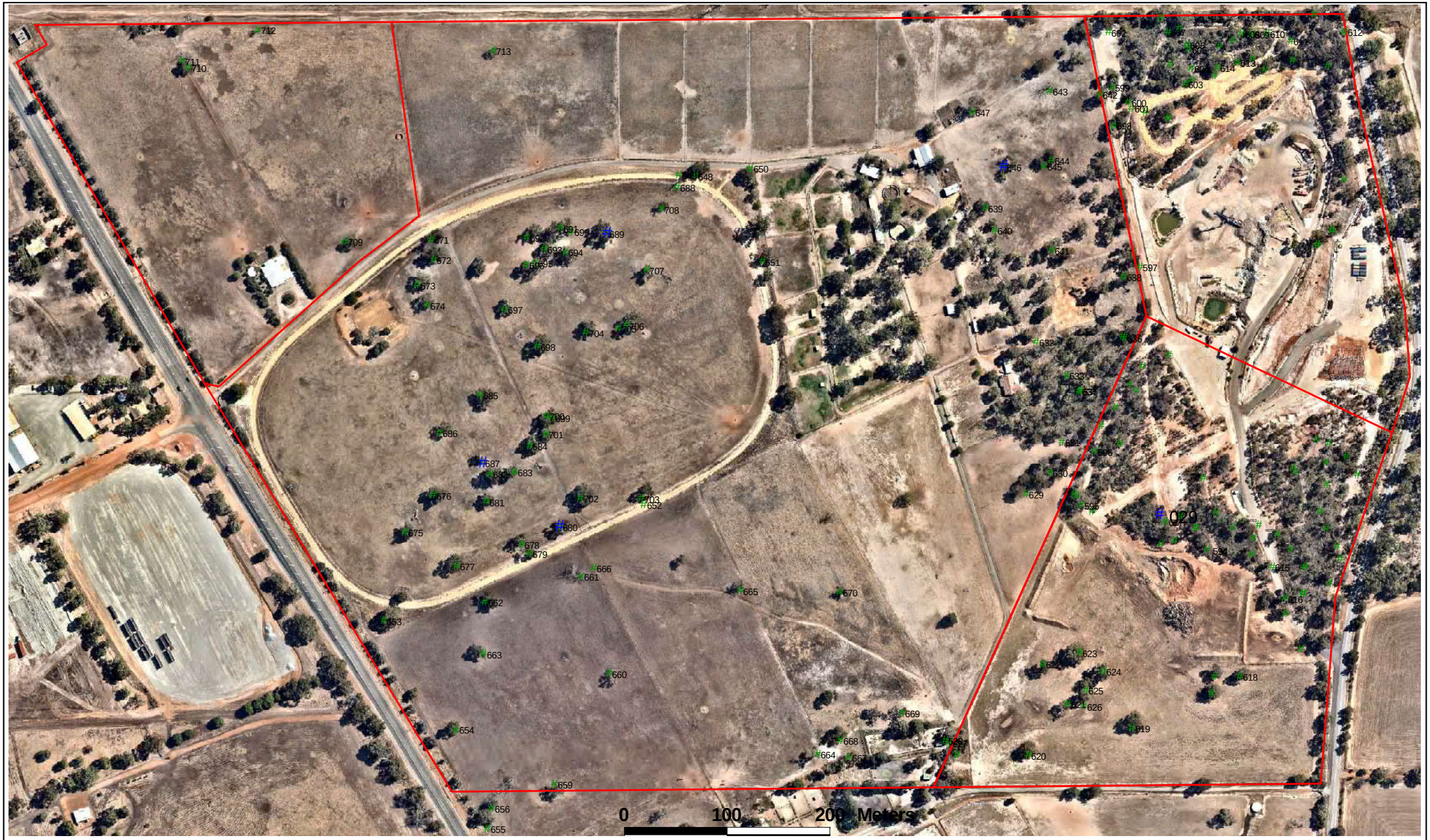

Site boundary
Tree >0.5m dbh
Tree >0.5m dbh with occupied hollow

Figure 11

POTENTIAL BLACK COCKATOO BREEDING HABITAT

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1 Wandena Rd looking north-west into Lot 203

2 Wandena Rd looking north-west into quarry entrance

3 Wandena Rd looking north-west towards Lot 202

4 Great Northern Hwy looking north-east into Lot 205

5 Great Northern Hwy looking east into Lot 205 entrance

6 Great Northern Hwy looking south-east into Lot 204

Images: Google (2017)

Figure 12

VIEWS FROM GREAT NORTHERN HIGHWAY AND WANDENA ROAD

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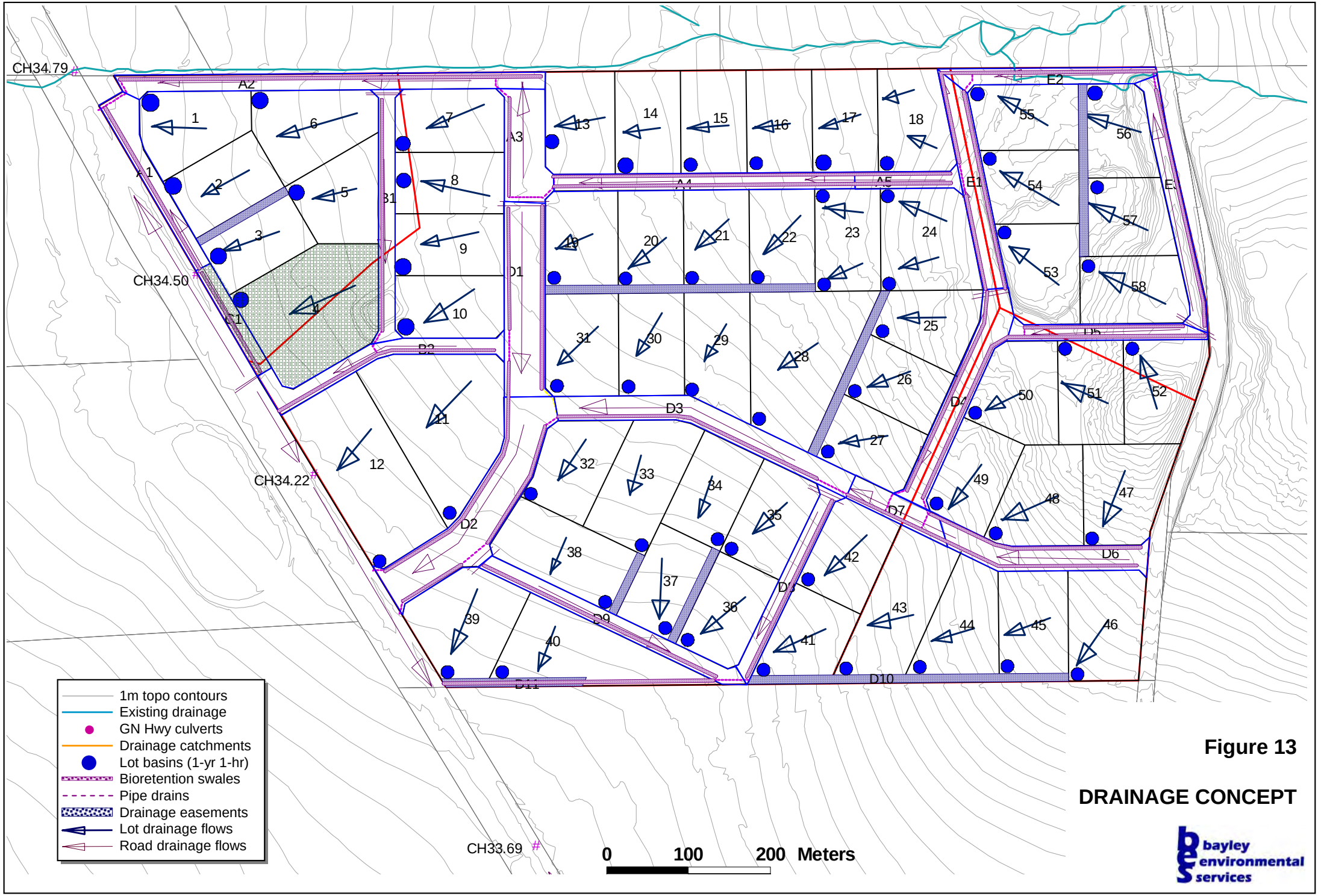

Figure 13

DRAINAGE CONCEPT

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Appendix A

Botanical Survey Report (Plantecology Ltd, 2020)

Lots 202, 203, 204 & 205 Wandena Rd Muchea Flora and Vegetation Survey

PREPARED FOR BAYLEY ENVIRONMENTAL SERVICES

Plantecology CONSULTING

FEBRUARY 2020

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Executive Summary

Plantecology Consulting was commissioned by Bayley Environmental Services to undertake a detailed flora and vegetation survey at Lots 202, 203, 204 and 205, Wandena Rd, Muchea, (the site), in the Shire of Chittering. The site covers approximately 82 ha, of which approximately 15 ha is within Lots 202 and 203. Lots 202 and 203 are currently used for extractive industry, while Lots 204 and 205 support a horse stud.

The field survey was conducted by a botanist from Plantecology Consulting on the 13th November 2019. The site was traversed on foot and search made for conservation significant flora. A detailed survey of the vegetation was undertaken at five 100 m^2 sampling plots (10m x 10m quadrats) and two recce plots, which are used to record the structure, condition and dominants in a patch. The sampling plots were selected to adequately sample the flora within a stand (Figure 2). Plots were positioned to sample a representative and homogeneous (i.e. not located in transitional areas between communities) area of each community. The location of each corner of a plot was recorded with a hand-held GPS unit and a photograph of the plot taken looking inward to the quadrat. All vascular plant species were recorded and an estimate of the Foliage Cover (FC) percentage was made for each species.

A total of 86 native and 9 non-native (exotic) taxa were recorded within the site, representing 31 families and 69 genera. The dominant families containing mostly native taxa were Fabaceae (11 native taxa, one exotic taxon), Myrtaceae (7 native taxa), Cyperaceae (7 native taxa), and Proteaceae (10 native taxa). Most exotic species were grasses (Poaceae, three exotic taxa).

No Threatened Flora pursuant to the *Biodiversity Conservation Act* (2016) nor the *EPBC Act* (1999) were recorded during the survey. One species listed as Priority Flora by the PWS was recorded during the survey. *Haemodorum loratum* (P3) was recorded at two sites, M01 and M05, and in adjacent areas of the *Eucalyptus wandoo* open woodland in the south eastern part of the site and the *Corymbia calophylla* woodland.

The survey identified two native plant communities within the site:

Corymbia calophylla open woodland

Woodland of *Corymbia calophylla* over shrubland of *Xanthorrhoea preissii, Hibbertia hypericoides* subsp. *septentrionalis* and *Bossiaea eriocarpa* over herbland of *Mesomelaena pseudostygia, Caustis dioica* and *Banksia dallanneyi* var. *dallanneyi* on light brown clay loams.

This unit occurs in the lower ground in the northern part of the site. Other common species include *Allocasuarina humilis, Acacia pulchella* subsp. *pulchella, Desmocladus fasciculatus, Lepidosperma asperatum* and *Conostylis aculeata* subsp. *aculeata.*

Eucalyptus wandoo open low woodland

Low open woodland of *Eucalyptus wandoo* subsp. *wandoo* over shrubland of *Xanthorrhoea preissii, Bossiaea eriocarpa* and *Hibbertia hypericoides* subsp. *septentrionalis* over herbland of *Tetraria octandra, Banksia dallanneyi* var. *dallanneyi* and *Lepidosperma pubisquameum* in brown gravelly clay loams on laterite.

This unit occurs on upper and mid-slopes within the site. Other common species include *Hakea stenocarpa, Gastrolobium acutum, Hakea lissocarpha* and *Desmocladus fasciculatus.*

The vegetation condition within the site reflects past and current pastoral and quarrying activity within the site with the vegetation adjacent to the quarry area in poorer condition than that within vegetation remnants. Pastured areas, infrastructure areas for the horse stud and

extractive industries, formed tracks and stands where the understorey has been replaced by exotic species have been rated as 'Completely Degraded'. The largest stand in this category is approximately 66 ha of Lots 204 and 205, which are used for pastures with paddock trees of *Corymbia calophylla* and the supporting infrastructure of the horse stud. Also rated as 'Completely Degraded' is the area at the southern extremity of Lots 202 and 203 where an open tree layer of *Eucalyptus wandoo* and *Corymbia calophylla* remains but the understorey consists almost entirely of **Ehrharta calycina* and **Avena barbata*. Stands where the vegetation structure has been significantly altered but retain more native species are rated as 'Degraded' and occur on the southern edge of the quarry area. Adjacent to an area undergoing rehabilitation in the northern part of Lots 202 and 203 is a stand of 'Good' vegetation where the vegetation is sparser from previous disturbance but still retains its basic structure.

Nine of the taxa recorded during the survey are exotics (weeds), none of which are Declared Pests under the *Biosecurity and Agriculture Management Act* 2007. The most abundant weeds were **Ehrharta calycina* and **Avena barbata,* recorded in the more degraded areas of the site.

The search of DBCA's databases for Threatened and Priority communities showed that the Commonwealth-listed Endangered community 'Banksia-dominated woodlands of the Swan Coastal Plain IBRA region' or its buffer zone is mapped as occurring within the site. To be considered a part of this community, a vegetation stand must include at least one of the diagnostic species *Banksia attenuata, Banksia menziesii, Banksia prionotes* or *Banksia ilicifolia.* None of these species were recorded within the site and neither the *Corymbia calophylla* woodland nor the *Eucalyptus wandoo* woodland can be considered part of the 'Banksia-dominated woodlands of the Swan Coastal Plain IBRA region' community. Neither the *Corymbia calophylla* woodland nor the *Eucalyptus wandoo* woodland are listed as PECs or TECs.

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1 Introduction

Plantecology Consulting was commissioned by Bayley Environmental Services to undertake a detailed flora and vegetation survey at Lots 202, 203, 204 and 205, Wandena Rd, Muchea, (the site), in the Shire of Chittering (Figure 1). The site covers approximately 82 ha, of which approximately 15 ha is within Lots 202 and 203. Lots 202 and 203 are currently used for extractive industry, while Lots 204 and 205 support a horse stud.

1.1 Purpose

The purpose of the survey was to provide a detailed assessment of botanical values within the site, which could then inform the proposed rezoning of the site from rural to industry

The objectives of the survey were to:

- Undertake a detailed flora and vegetation survey in accordance with the Environmental Protection Authority's (EPA) Technical Guidance: Flora and Vegetation Survey for Environmental Impact Assessment (2016).
- Identify the presence of any Threatened Ecological Communities (TECs) and Priority Ecological Communities (PECs);
- Undertake a systematic search for all vascular plant taxa present; and
- Record the locations and numbers present of any Threatened Flora and Priority Flora.

1.2 Existing Environment

Much of the site currently being used for extractive industry has been developed for that purpose. Some areas have been revegetated after the end of quarrying while two areas of native vegetation remain in the northern and southern parts of the site. The vegetated remnants are dissected by tracks and firebreaks, while the northern remnant is also dissected by some drainage channels. The majority of the horse stud have been cleared to create pasture and farm infrastructure with only a small patch of remnant vegetation remaining adjacent to the extractive industry lots.

1.3 Climate

The Muchea area experiences a dry Mediterranean climate of hot dry summers and cool wet winters. Long-term climatic averages indicate the site is located in an area of moderate to high rainfall, receiving 655.1 mm on average annually (data for Pearce RAAF, station number 9053, the nearest currently reporting station; Bureau of Meteorology 2019) with the majority of rainfall received between May and August. The area experiences rainfall on an average of 107 days per year. Mean maximum temperatures range from 17.9 °C in July to 33.5 °C in January. Mean minimum temperatures range from 8.2 °C in August to 17.5 °C in February.

1.4 Soils

The Atlas of Australian Soils maps the soils for the majority of the site as Map Unit Wd9 (Natural Resource Information Centre 1991). Map Unit Wd9 comprises broad valleys and undulating interfluvial areas with some discontinuous breakaways and occasional mesas. Lateritic materials mantle the area and the chief soils are sandy acidic yellow mottled soils containing

much ironstone gravel in the A horizons. The western portion of the horse stud is mapped as Sp2, which comprises gently sloping terraces of the Ridge Hill Shelf. The main soils are hard acidic yellow soils containing ironstone gravels and associated brown sands, often containing ironstone gravels at depth.

1.5 Conservation Significant Flora

Under the *Biodiversity Conservation Act 2016* ('BC Act'), the Minister for the Environment produces a gazetted list of Threatened Flora under three categories: Critically Endangered, Endangered and Vulnerable. The Parks and Wildlife Service (PWS) also produces a list of Priority Flora that have not been assigned statutory protection under the BC Act but may be under some degree of threat (PWS 2019a). The PWS recognises four Priority Flora levels. The definitions for each category of Threatened and Priority Flora are shown in Appendix E.

As well as protection under State legislation, selected flora are also afforded statutory protection at a Federal level pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act provides for the protection of Threatened species, pursuant to Schedule 1 of the Act, and are defined as "Critically Endangered", "Endangered", "Vulnerable" or "Conservation Dependent" under Section 179. Definitions of these categories are shown in Appendix E. Any action likely to have a significant impact on a species listed under the EPBC Act requires approval from the Commonwealth Minister for Agriculture, Water and the Environment.

A search of the DBCA and Commonwealth databases of Threatened and Priority Flora as well as NatureMap returned a list of 49 taxa with the potential to occur within the site (Table 1). Of these taxa, 11 are listed as Threatened under the BC Act. *Diuris drummondii* is an orchid of winter-wet depressions and swamps that flowers from November through to January. *Thelymitra stellata* is an orchid that occurs in gravel and lateritic loams and flowers from October to November. *Eleocharis keigheryi* is a freshwater emergent that flowers from August to November. The remaining Threatened Flora on the list are perennial shrubs and should be observable at all times of the year. The timing of the survey should, therefore, be appropriate to detect the Threatened Flora on the list.

Table 1: Threatened and Priority Flora potentially occurring within the survey area based on database searches. (VU = Vulnerable; EN = Endangered; CR = Critically Endangered; T = Threatened; 1 – 4 = Priority Flora Category)

Taxa	PWS Rating	EPBC Act Category	Flowering Period
Acacia anomala	T	VU	Aug-Sep
Acacia cummingiana	3		May – Jun, Aug
Acacia drummondii subsp. affinis	3		Jul - Aug
Acacia pulchella var. reflexa acuminate bracteole variant (R.J. Cumming 882)	3		Jul - Sep
Adenanthos cygnorum subsp. *chamaephyton*	3		Jul, Sep - Jan
Anigozanthos humilis subsp. *chrysanthus*	4		Jul – Oct
Caustis gigas	2		May
Chamaescilla gibsonii	3		Sep
Chamelaucium sp. Gingin (N.G. Marchant 6)	T	VU	
Cyathochaeta teretifolia	3		
Darwinia foetida	T	CR	
Diuris drummondii	T	VU	Nov - Jan
Drosera occidentalis	4		Oct - Jan
Drosera sewelliae	1		Oct
Eleocharis keigheryi	T	VU	Aug – Nov
Eryngium pinnatifidum subsp. *palustre*	3		
Gastrolobium crispatum	1		Sep - Oct
Gastrolobium nudum	2		Feb
Grevillea althoferorum subsp. *fragilis*	T	CR	
Grevillea candolleana	2		Aug - Sep
Grevillea corrugata	T	EN	?Aug - Sep
Grevillea curviloba subsp. *curviloba*	T	EN	Oct
Grevillea curviloba subsp. *incurva*	T	EN	Aug - Sep
Guichenotia tuberculata	3		Aug - Oct
Hydrocotyle lemnoides	4		Aug - Oct
Hydrocotyle striata	1		
Hibbertia glomerata subsp. *ginginensis*	2		Jul - Sep
Hypocalymma sylvestre	T		Aug
Hypolaena robusta	4		Sep - Oct
Isotropis cuneifolia subsp. *glabra*	3		Sep
Leucopogon squarrosus subsp. *trigynus*	2		
Millotia tenuifolia var. *laevis*	2		Sep - Oct
Ornduffia submersa	4		
Oxymyrrhine coronata	4		
Persoonia rudis	3		Sep -Jan
Platysace ramosissima	3		Oct - Nov
Schoenus capillifolius	3		Oct - Nov
Schoenus griffinianus	3		Sep – Oct
Stylidium aceratum	3		Oct – Nov
Stylidium paludicola	3		Oct – Dec

Taxa	PWS Rating	EPBC Act Category	Flowering Period
Stylidium squamellosum	2		Oct – Nov
Synaphea grandis	4		Oct - Nov
Tetraria sp. Chandala (G.J. Keighery 17055)	2		Aug - Oct
Tetratheca pilifera	3		Aug - Oct
Thelymitra stellata	T	EN	Oct – Nov
Thysanotus sp. Badgingarra (E.A. Griffin 2511)	2		Dec
Verticordia lindleyi subsp. *lindleyi*	4		May, Nov – Jan
Verticordia rutilastra	3		Sep - Nov
Verticordia serrata var. *linearis*	1		Sep - Oct

1.6 Conservation Significant Communities

The PWS defines an ecological community as "a naturally occurring assemblage that occurs in a particular type of habitat" (PWS 2019b). A Threatened Ecological Community (TEC) is one that has declined in area or was originally limited in distribution. Uncommon ecological communities that do not strictly meet TEC defined criteria, or are inadequately defined, are listed by the PWS as a Priority Ecological Community (PEC). Definitions of the categories of Threatened and Priority Ecological Communities are given in Appendix E.

As well as protection under State legislation, selected ecological communities are also afforded statutory protection at a Federal level pursuant to the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The EPBC Act provides for the protection of TECs, which are listed under section 181 of the Act, and are defined as "Critically Endangered", "Endangered" or "Vulnerable" under Section 182. Similar to flora listed under the EPBC Act, any action likely to have a significant impact on a TEC listed under the EPBC Act requires Commonwealth approval.

A search of the DBCA databases of Threatened and Priority Ecological Communities (TECs and PECs) identified five conservation-coded community types with the potential to occur within the site. These were:

- The Critically Endangered 'Communities of Tumulus Springs (Organic Mound Springs, Swan Coastal Plain)';
- The Vulnerable 'Herb rich saline shrublands in clay pans (SCP 7)';
- The Endangered 'Shrublands and woodlands on Muchea Limestone of the Swan Coastal Plain';
- The Priority 3 'Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands'; and
- The Priority 3 'Banksia-dominated woodlands of the Swan Coastal Plain IBRA region', listed as Endangered under Commonwealth legislation and includes the State-listed PECS:
    - Swan Coastal Plain *Banksia attenuata – Banksia menziesii* woodlands (FCT 23b); and
    - Banksia woodland of the Gingin area restricted to soils dominated by yellow to orange sands.

The 'Communities of Tumulus Springs (Organic Mound Springs, Swan Coastal Plain)' and the Shrublands and woodlands on Muchea Limestone of the Swan Coastal Plain' are both listed by the Commonwealth as Endangered communities, while the 'Herb rich saline shrublands in clay pans (SCP 7)' is listed as Critically Endangered.

1.7 Ecological Linkages

Ecological linkages are important conservation tools that allow the movement of fauna, flora and genetic material between areas of remnant habitat. The movement of fauna and the exchange of genetic material between vegetation remnants improves the viability of those remnants by allowing greater access to breeding partners, food sources, refuge from disturbances such as fire and maintains the genetic diversity of plant communities and populations. Local ecological linkages seek to improve the viability of local natural areas by providing connections to other local or regionally significant natural areas and regional ecological linkages. The vegetation stands within the site is not part of either a regional or local ecological linkage (Shire of Chittering 2010).

1.8 Vegetation Complexes

Vegetation complexes are a series of plant communities forming a regularly repeating pattern associated with a particular soil unit (Government of Western Australia 2000). Two vegetation complexes have been mapped as potentially occurring within the site: Reagan Complex, which is described as varying from a low open woodland of Banksia species and/or *Eucalyptus todtiana* (Pricklybark) to a closed heath, depending on the depth of soil; and Coonambidgee Complex, which ranges from a low open forest and low woodland of *Eucalyptus todtiana* (Pricklybark) - *Banksia attenuata - Banksia menziesii - Banksia ilicifolia* with localised occurrences of *Banksia prionotes* to an open woodland of *Corymbia calophylla* - Banksia species (Webb et al. 2016). Reagan Complex has been mapped as a Swan Coastal Plain vegetation complex and has 33.8% of its original 9 180 ha pre-European extent remaining (Webb *et al.* 2016). Only 3.7% of its original extent is protected for conservation (Webb et al. 2016). Coonambidgee Complex has 45% of it original 6272 ha remaining, with 650 ha currently protected in the reserve system (Webb et al. 2016).

2 Methods

2.1 Field Survey

The field survey was conducted by a botanist from Plantecology Consulting on the 13th November 2019. The site was traversed on foot and search made for conservation significant flora. A detailed survey of the vegetation was undertaken at five 100 m^2 sampling plots (10m x 10m quadrats) and two recce plots, which are used to record the structure, condition and dominants in a patch. The sampling plots were selected to adequately sample the flora within a stand (Figure 2). Plots were positioned to sample a representative and homogeneous (i.e. not located in transitional areas between communities) area of each community. The location of each corner of a plot was recorded with a hand-held GPS unit and a photograph of the plot taken looking inward to the quadrat. All vascular plant species were recorded and an estimate of the Foliage Cover (FC) percentage was made for each species.

Environmental data recorded included topographic position, aspect, slope, soil colour and texture class, rock outcropping, litter cover as well as the degree of disturbance and an estimate of the time since the last fire event. The condition of the vegetation of the site was assessed to assist in determining the conservation values of the site. The vegetation condition was rated according to Keighery (1994), a vegetation condition scale commonly used in the metropolitan and southwest regions. The categories are listed and defined in Table 2. Data on the vegetation structure was also recorded and included the height of the three main strata and the dominant species within each stratum. The vegetation structural description follows that of the National Vegetation Information System (Thackway *et al*. 2006).

All plant specimens collected during the field survey were dried, pressed and then sorted in accordance with requirements of the Western Australian Herbarium. Identification of specimens occurred through comparison with named material and through the use of taxonomic keys. Taxonomic determinations were made using reference material at the Western Australian State Herbarium. Taxa names utilise the current terminologies from FloraBase (2019). Family names utilise the revised phylogeny of the Angiosperm Phylogeny Group - APGIII (FloraBase 2019).

2.1 Study Limitations and Survey Effort

Various factors can limit the effectiveness of a vegetation survey. Pursuant to EPA Technical Guidance: Flora and Vegetation Survey for Environmental Impact Assessment (EPA 2016), these factors have been identified and their potential impact on the effectiveness of the survey has been assessed (Table 3).

The survey was undertaken in mid-November 2019 and would likely have intercepted the flowering period of most annuals of conservation concern with the potential to occur within the site. However, the spring of 2019 was much drier than normal, which may have affected the flowering of some species.

Table 2: Vegetation Condition Scale (Keighery 1994)

Vegetation Condition	Definition
Pristine (1)	Pristine or nearly so, no obvious signs of disturbance.
Excellent (2)	Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.
Very Good	Vegetation structure altered, obvious signs of disturbance. For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing
Good	Vegetation structure significantly altered by very obvious signs of multiple disturbances. Retains basic vegetation structure or ability to regenerate it. For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management. For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.
Completely Degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

Table 3: Potential limitations affecting the vegetation survey

Potential limitations	Constraint	Comment
Availability of contextual information	No	Sufficient regional and local information was available to place the survey site in its environmental context.
Competency and experience of the botanists undertaking the survey	No	The survey was undertaken by botanists with a comprehensive knowledge of Southwestern Western Australia vegetation, with at least 15 years' experience in vegetation surveys in Western Australia.
Seasonality	Minor	The survey was undertaken in spring 2019. The rainfall in the three months prior to the survey was well below average for the area, especially in September. Maximum and minimum temperatures were approximately 2^0 higher than the mean.
Adequate ground coverage and intensity of survey effort	No	The survey area was traversed on foot. It is considered the survey quadrats and mapping points provided adequate coverage given the degraded nature of most of the site.
Proportion of Flora identified	No	The survey recorded an estimated 77% (chao2 estimator) of the plant taxa present, although this still represents fewer species than could be expected from an undisturbed system.
Disturbance	Minor	Part of the site has and is being used for quarrying. Formed access tracks and firebreaks dissect the remnant patches and some historic tracks are still evident. Drainage channels have also been constructed in the northern part of the site. The historic disturbances may have had an impact on the species richness and structure of the vegetation and limit some of the conclusions that may be drawn from the data.
Resources	No	Adequate resources were available to conduct the survey.
Access restrictions	No	All parts of the site were accessible

3 Results

3.1 Flora

3.1.1 Floristic Summary

A total of 86 native and 9 non-native (exotic) taxa were recorded within the site, representing 31 families and 69 genera. The dominant families containing mostly native taxa were Fabaceae (11 native taxa, one exotic taxon), Myrtaceae (7 native taxa), Cyperaceae (7 native taxa), and Proteaceae (10 native taxa). Most exotic species were grasses (Poaceae, three exotic taxa). For a complete species list and the individual site data refer to Appendix A and Appendix B, respectively.

3.1.2 Threatened and Priority Flora

No Threatened Flora pursuant to the *Biodiversity Conservation Act* (2016) nor the *EPBC Act* (1999) were recorded during the survey.

One species listed as Priority Flora by the PWS was recorded during the survey. *Haemodorum loratum* (P3) was recorded at two sites, M01 and M05, and in adjacent areas of the *Eucalyptus wandoo* open woodland in the south eastern part of the site and the *Corymbia calophylla* woodland (Table 4). Approximately 50 individuals were counted in each habitat. A more accurate count was not possible as *Haemodorum discolor* was also recorded during the survey, and non-flowering individuals are difficult to discern with certainty. The described upper limit of leaf width for *Haemodorum discolor* is similar to the lower limit for *Haemodorum loratum*.

Table 4: Locations of sampling plots with *Haemodorum loratum* (P3) present (GDA94, Zone 50).

Plot	Easting	Northing
M01	406871	6503674
M05	406796	6504183

3.2 Vegetation

3.2.1 Plant Associations

The survey identified two native plant communities within the site (Figure 2):

Corymbia calophylla open woodland (Plates 2 and 3)

Woodland of *Corymbia calophylla* over shrubland of *Xanthorrhoea preissii, Hibbertia hypericoides* subsp. *septentrionalis* and *Bossiaea eriocarpa* over herbland of *Mesomelaena pseudostygia, Caustis dioica* and *Banksia dallanneyi* var. *dallanneyi* on light brown clay loams.

This unit occurs in the lower ground in the northern part of the site. Other common species include *Allocasuarina humilis, Acacia pulchella* subsp. *pulchella, Desmocladus fasciculatus, Lepidosperma asperatum* and *Conostylis aculeata* subsp. *aculeata.*

Eucalyptus wandoo open low woodland (Plate 4)

Low open woodland of *Eucalyptus wandoo* subsp. *wandoo* over shrubland of *Xanthorrhoea preissii, Bossiaea eriocarpa* and *Hibbertia hypericoides* subsp. *septentrionalis* over herbland of *Tetraria octandra, Banksia dallanneyi* var. *dallanneyi* and *Lepidosperma pubisquameum* in brown gravelly clay loams on laterite.

This unit occurs on upper and mid-slopes within the site. Other common species include *Hakea stenocarpa, Gastrolobium acutum, Hakea lissocarpha* and *Desmocladus fasciculatus.*

3.2.2 Vegetation Condition

The vegetation condition within the site reflects past and current pastoral and quarrying activity within the site with the vegetation adjacent to the quarry area in poorer condition than that within vegetation remnants (Figure 3). Pastured areas, infrastructure areas for the horse stud and extractive industries, formed tracks and stands where the understorey has been replaced by exotic species have been rated as 'Completely Degraded'. The largest stand in this category is approximately 66 ha of Lots 204 and 205, which are used for pastures with paddock trees of *Corymbia calophylla* and the supporting infrastructure of the horse stud. Also rated as 'Completely Degraded' is the area at the southern extremity of Lots 202 and 203 where an open tree layer of *Eucalyptus wandoo* and *Corymbia calophylla* remains but the understorey consists almost entirely of **Ehrharta calycina* and **Avena barbata* (Plate 3). Stands where the vegetation structure has been significantly altered but retain more native species are rated as 'Degraded' and occur on the southern edge of the quarry area. Adjacent to an area undergoing rehabilitation in the northern part of Lots 202 and 203 (Plate 4) is a stand of 'Good' vegetation where the vegetation is sparser from previous disturbance but still retains its basic structure.

The *Corymbia calophylla* woodland in the north-eastern part of the site has been rated as 'Very Good', largely due to the disturbance from drainage channels constructed through it. The shrub layer in this community is lower and sparser than could be expected in undisturbed vegetation.

Areas of 'Excellent' condition vegetation occur in the *Eucalyptus wandoo* woodland in the south-eastern part of the site. These stands have retained most of their vertical structure and native species richness (e.g. 36 native taxa at Plot M01).

3.2.3 Weeds

Nine of the taxa recorded during the survey are exotics (weeds), none of which are Declared Pests under the *Biosecurity and Agriculture Management Act* 2007. The most abundant weeds in native remnants were **Ehrharta calycina* and **Avena barbata,* recorded in the more degraded areas of the site.

4 Discussion

4.1 Flora

No species of Threatened Flora were recorded during the survey. One species of Priority Flora was recorded from two plots, one each in the *Corymbia calophylla* and the *Eucalyptus wandoo* woodlands. *Haemodorum loratum* (P3) occurs from Eneabba to Perth on the eastern side of the Swan Coastal Plain and adjacent slopes of the Dandaragan Plateau. Its usual habitat is in grey and yellow sands in low heath, and eucalypt and banksia woodlands. The soil within the *Corymbia calophylla* woodland was generally a light brown clay loam, and in the *Eucalyptus wandoo* woodland a brown loamy clay. The local population was difficult to count accurately as *Haemodorum discolor* was also recorded for the site and the upper limit of leaf width for this species is similar to the lower limit for *Haemodorum loratum.* Non-flowering individuals, therefore, could not consistently be identified to species level.

4.2 Plant Communities

The search of DBCA's databases for Threatened and Priority communities showed that the Commonwealth-listed Endangered community 'Banksia-dominated woodlands of the Swan Coastal Plain IBRA region' or its buffer zone is mapped as occurring within the site. To be considered a part of this community, a vegetation stand must include at least one of the diagnostic species *Banksia attenuata, Banksia menziesii, Banksia prionotes* or *Banksia ilicifolia.* None of these species were recorded within the site and neither the *Corymbia calophylla* woodland nor the *Eucalyptus wandoo* woodland can be considered part of the 'Banksia-dominated woodlands of the Swan Coastal Plain IBRA region' community. The species assemblages recorded for each community type within the site also do not match the other conservation-coded communities that are known to occur nearby.

The *Corymbia calophylla* woodland shows some similarity to the *Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands TEC, but *Bossiaea eriocarpa* is present in this unit within the site and that species is a contra-indicator for this particular TEC.

Corymbia calophylla woodland is generally in 'Very Good' condition with few exotic species present. The condition of the *Eucalyptus wandoo* woodland ranged from 'Degraded' to 'Excellent'. The poorer condition areas were mostly adjacent to tracks or active work areas and been disturbed previously or were experiencing weed invasion.

Mapping of vegetation complexes for the Swan Coastal Plain places much of the site within the Reagan Complex, which is described as varying from a low open woodland of Banksia species and/or *Eucalyptus todtiana* (Pricklybark) to a closed heath, depending on the depth of soil (Webb *et al.* 2016). This description does not accurately describe the vegetation for the site and is likely due to variance from the scale of mapping as the site is situated on the lower Gingin Scarp and near the boundary between the vegetation complex mapping for the Swan Coastal Plain and that of the southwest forests.

5 Summary

One species of Priority Flora was recorded from within the site. The local population of *Haemodorum loratum* (P3) is estimated to be approximately 50 plants. Neither the *Corymbia calophylla* woodland nor the *Eucalyptus wandoo* woodland are listed as PECs or TECs. The vegetation condition of the site varies from 'Completely Degraded' in cleared areas and tracks, to 'Excellent' in intact woodland patches that support few invasive weed species.

6 References

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Figures

Figure 1

LOCATION

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Figure 2

PLANT COMMUNITIES

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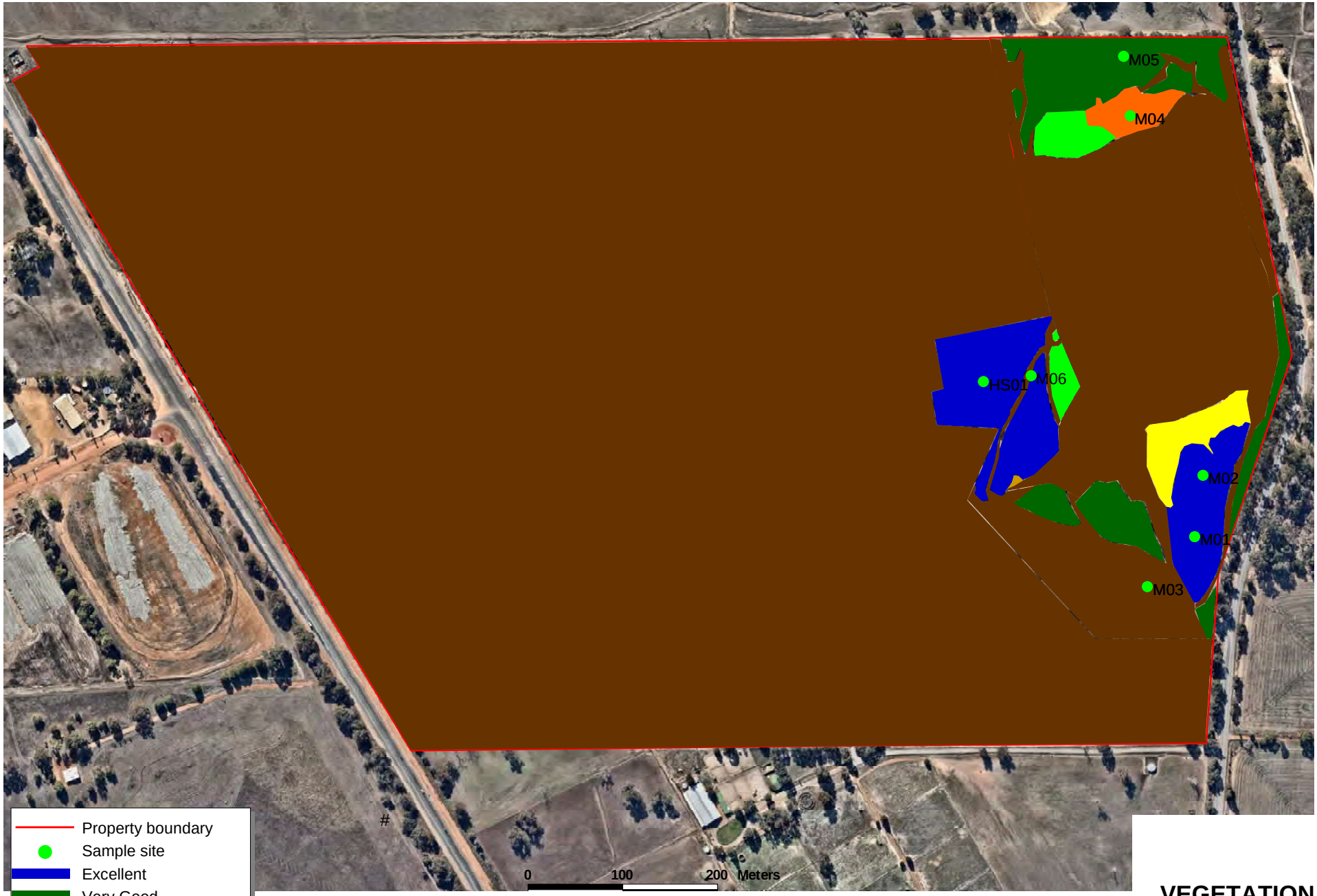

Figure 3

VEGETATION CONDITION

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Plates

Plate 1: View of Eucalyptus wandoo woodland (Plot M01).

Plate 2: Another view of Eucalyptus wandoo woodland at Plot 2.

Plate 3: View of 'Completely Degraded' at Plot M03.

Plate 4: View of rehabilitation area in the northern section of the site.

Plate 5: View of *Corymbia calophylla* woodland at Plot M05.

Plate 6: View of *Eucalyptus wandoo* woodland at Plot M06.

Plate 7: View of *Eucalyptus wandoo* woodland at Plot HS01.

Appendix A

List of flora recorded within the survey area

NB: * indicates introduced flora

Family	Taxon Name
Zamiaceae	*Macrozamia riedlei*
Lauraceae	*Cassytha glabella*
Colchicaceae	*Burchardia congesta*
Iridaceae	* *Gladiolus caryophyllaceus* *Patersonia juncea* * *Romulea rosea*
Xanthorrhoeaceae	*Xanthorrhoea preissii*
Asparagaceae	*Laxmannia ramosa* subsp. *ramosa* *Lomandra caespitosa* *Lomandra hermaphrodita* *Lomandra preissii* *Lomandra sericea*
Hemerocallidaceae	*Agrostocrinum hirsutum* *Agrostocrinum scabrum* *Tricoryne elatior*
Haemodoraceae	*Anigozanthos manglesii* *Conostylis aculeata* subsp. *aculeata* *Conostylis* sp. *Haemodorum discolor* *Haemodorum loratum* (P3)
Cyperaceae	*Caustis dioica* *Lepidosperma asperatum* *Lepidosperma pubisquameum* *Mesomelaena graciliceps* *Mesomelaena pseudostygia* *Mesomelaena tetragona* *Tetraria octandra*
Restionaceae	*Desmocladus fasciculatus* *Desmocladus flexuosus*
Poaceae	*?Amphipogon debilis* *Austrostipa ?hemipogon* *Austrostipa elegantissima* * *Avena barbata* * *Briza maxima* * *Ehrharta calycina* *Neurachne alopecuroidea* *Rytidosperma setaceum*

Family	Taxon Name
Proteaceae	*Banksia armata* var. *armata*
	Banksia bipinnatifida subsp. *multifida*
	Banksia dallanneyi var. *dallanneyi*
	Banksia sessilis
	Grevillea synapheae
	Hakea lissocarpha
	Hakea stenocarpa
	Hakea undulata
	Petrophile striata
	Stirlingia latifolia
Dilleniaceae	*Hibbertia hypericoides*
	Hibbertia sp.
	Hibbertia spicata subsp. *spicata*
	Hibertia hypericoides subsp. *septentrionalis*
Halorogaceae	*Glischrocaryon aureum*
	Gonocarpus cordiger
Fabaceae	*Acacia applanata*
	Acacia lasiocarpa subsp. *sedifolia*
	Acacia pulchella var. *pulchella*
	Bossiaea eriocarpa
	* *Chamaecytisus palmensis*
	Cristonia biloba subsp. *biloba*
	Daviesia decurrens
	Daviesia hakeoides subsp. *hakeoides*
	Daviesia preissii
	Dillwynia laxiflora
	Gastrolobium acutum
	Gompholobium marginatum
Polygalaceae	*Comesperma ciliatum*
Rhamnaceae	*Trymalium angustifolium*
Casuarinaceae	*Allocasuarina fraseriana*
	Allocasuarina humilis
Elaeocarpaceae	*Tetratheca nuda*
Phyllanthaceae	*Phyllanthus calycinus*
Proteaceae	*Isopogon asper*
Myrtaceae	*Calothamnus sanguineus*
	Corymbia calophylla
	Eucalyptus marginata
	Eucalyptus wandoo subsp. *wandoo*
	Hypocalymma angustifolium

Family	Taxon Name
Myrtaceae	*Lambertia multiflora* var. *darlingensis*
	Melaleuca clavifolia
Malvaceae	*Thomasia foliosa*
Thymeleaceae	*Pimelea imbricata* var. *piligera*
Primulaceae	* *Lysimachia arvensis*
Rubiaceae	*Opercularia vaginata*
Stylidiaceae	*Stylidium affine*
	Stylidium piliferum
	Stylidium purpureum
Goodeniaceae	*Dampiera linearis*
	Goodenia caerulea
	Lechenaultia biloba
	Scaevola glandulifera
Asteraceae	* *Hypochaeris glabra*
	Trichocline spathulata
	* *Ursinia anthemoides*
Pittosporaceae	*Billardiera ?variifolia*
	Marianthus drummondianus

Appendix B

Sampling plot raw data

NB: Only taxa recorded within sampling plots included in table.

Taxon Name	Plot						
	M01	M02	M03	M04	M05	M06	HS01
?Amphipogon debilis	0.1	0.1	0	0	0	0	0
Acacia applanata	0.2	0.1	0	0	0	0.2	0
Acacia pulchella var. *pulchella*	0.4	0.5	0	0	0.3	0	0.5
Agrostocrinum hirsutum	0.3	0.2	0	0	0	0	0
Agrostocrinum scabrum	0	0	0	0	0	0	0.1
Allocasuarina fraseriana	1	0	0	0	0	0	0
Allocasuarina humilis	0.5	0	0	0	0.5	0	0
Austrostipa ?hemipogon	0	0.1	0	0	0	0	0
Austrostipa elegantissima	0	0.1	0	0	0	0	0
Avena barbata	0	0	10	0	0	0	0
Banksia armata var. *armata*	1	0	0	0	0	0.3	0
Banksia bipinnatifida subsp. *multifida*	0.2	0.3	0	0	0	0	0.5
Banksia dallanneyi var. *dallanneyi*	0.3	0.5	0	0	5	1	1
Billardiera ?variifolia	0	0	0	0	0	0	0.1
Bossiaea eriocarpa	1	1	0	0	4	2	1
Briza maxima	0.1	0	0	0	0	0.1	0.3
Burchardia congesta	0	0	0	0	0.3	0	0
Calothamnus sanguineus	0	0	0	0	0	0.5	0
Cassytha glabella	0.1	0.1	0	0	0.1	0	0.1
Caustis dioica	0	0	0	0	2	0	0
Chamaecytisus palmensis	0	0	3	0	0	0	0
Conostylis aculeata subsp. *aculeata*	0	0	0	0	0.2	0	0
Conostylis sp.	0	0	0	0	0.1	0	0
Corymbia calophylla	0	0	1	0	20	1	5
Daviesia decurrens	0	0	0	0	0.3	0	0
Daviesia hakeoides subsp. *hakeoides*	0.2	0.3	0	0	0	0	0
Desmocladus fasciculatus	0.7	0.3	0	0	0.5	0.3	0.5
Desmocladus flexuosus	0	0.2	0	0	0.5	0	0
Ehrharta calycina	0.1	0	20	0	0	0	0.5
Eucalyptus marginata	0	0	0	0	0	0.5	0
Eucalyptus wandoo subsp. *wandoo*	11	10	5	10	0	8	15
Gastrolobium acutum	2	0	0	0	0	0.3	8
Gladiolus caryophyllaceus	0.1	0	0	0	0.2	0.2	0.1
Gompholobium marginatum	0.2	0.2	0	0	0	0.2	0
Goodenia caerulea	0.1	0.1	0	0	0	0.1	0
Grevillea synapheae	0	0.2	0	0	0	0	0
Haemodorum loratum (P3)	0.2	0	0	0	0.3	0	0
Hakea lissocarpha	0.2	0.5	0	0	0.3	0.3	2
Hakea stenocarpa	0.5	0	0	0	0	0.5	0.5
Hakea undulata	0.7	1	0	0	0	0	0
Hibbertia hypericoides	0.5	1	0	0	0	0	0.3
Hibbertia sp.	0.2	0.3	0	0	0	0	0
Hibbertia spicata subsp. *spicata*	1	0	0	0	0	0	0
Hibertia hypericoides subsp. *septentrionalis*	1	1	0	0	1	1	1
Hypocalymma angustifolium	0	0	0	0	0	0.2	0
Hypochaeris glabra	0	0	0	0	0	0	0.1
Isopogon asper	0.3	0	0	0	0	0	0
Lambertia multiflora var. *darlingensis*	0	0	0	0	0.1	0	0
Laxmannia ramosa subsp. *ramosa*	0.1	0	0	0	0	0	0
Lechenaultia biloba	0	0.2	0	0	0	0.3	0.1

Taxon Name	Plot						
	M01	**M02**	**M03**	**M04**	**M05**	**M06**	**HS01**
Lepidosperma asperatum	0.1	0.2	0	0	1	0	0
Lepidosperma pubisquameum	0.3	0.5	0	0	0	1	0.5
Lomandra caespitosa	0	0	0	0	0	0	0.1
Lomandra hermaphrodita	0.2	0	0	0	0	0	0
Lomandra preissii	0	0	0	0	0	0	0.1
Lomandra sericea	0	0	0	0	0	0	0.1
Melaleuca clavifolia	0.2	0	0	0	0	0.3	0
Mesomelaena graciliceps	0	0	0	0	0.1	0	0
Mesomelaena pseudostygia	0	0	0	0	8	0	0
Mesomelaena tetragona	0.3	0	0	0	0	0	0
Neurachne alopecuroidea	0	0.1	0	0	0.1	0	0.1
Opercularia vaginata	0	0.1	0	0	0	0	0
Petrophile striata	0	0	0	0	0	0.3	0
Phyllanthus calycinus	0	0	0	0	0.2	1	0
Pimelea imbricata var. *piligera*	0	0.3	0	0	0	0	0
Stirlingia latifolia	0	0	0	0	0.3	0	0
Stylidium affine	0.1	0.1	0	0	0	0	0
Stylidium piliferum	0	0	0	0	0	0.1	0
Stylidium purpureum	0	0.1	0	0	0	0	0
Tetraria octandra	0.2	0.3	0	0	0	0.5	0.3
Tetratheca nuda	0	0	0	0	0	0	0.1
Trichocline spathulata	0.1	0.2	0	0	0	0.1	0.5
Tricoryne elatior	0	0	0	0	0	0.1	0.1
Trymalium angustifolium	0	0	0	0	0	0.1	0
Ursinia anthemoides	0	0	0	0	0	0	0.2
Xanthorrhoea preissii	4	6	2	0	4	5	2

Appendix C

Sampling Plot Environmental Data and Vegetation Structural Data

Plot	Date	Latitude	Longitude	Easting	Northing	UTM Zone	Aspect (classes)
M01	13/11/2019	-31.598258	116.0183277	406871.7153	6503674.938	50	S
M02	13/11/2019	-31.597675	116.0184214	406880.0246	6503739.64	50	SSW
M03	13/11/2019	-31.5987326	116.0177956	406821.7069	6503621.879	50	S
M04	13/11/2019	-31.5942336	116.017641	406802.5598	6504120.429	50	N/A
M05	13/11/2019	-31.5936641	116.0175812	406796.3191	6504183.503	50	N/A
M06	13/11/2019	-31.5967054	116.0165093	406697.6536	6503845.483	50	S
HS01	13/11/2019	-31.5967634	116.0159869	406648.1499	6503838.608	50	SW

Plot	Placement strategy	Plot Type	Plot Size (m^2)	Plot Width (m)	Plot Length (m)	Stand Age	Slope (%)
M01	Preferential	Quadrat	100	10	10	>3	3
M02	Preferential	Quadrat	100	10	10	>3	5
M03	Preferential	Recce	100	10	10	N/A	2
M04	Preferential	Recce	N/A	N/A	N/A	>3	0.5
M05	Preferential	Quadrat	100	10	10	>3	0
M06	Preferential	Quadrat	N/A	N/A	N/A	>3	3
HS01	Preferential	Quadrat	100	10	10	>3	3

Plot	Bare Ground (%)	Bare Rock (%)	Litter (%)	Landform	Soil Colour	Soil Texture	Rock Type
M01	2	N/A	35	Mid slope	Brown	Clay Loam	N/A
M02	5	N/A	40	Upper slope	Light brown	Loamy clay	N/A
M03	N/A	N/A	N/A	Lower slope	Brown	Gravelly loam	N/A
M04	50	N/A	25	Rehabilitation	Light brown	Loamy clay	N/A
M05	1	N/A	35	Flat	Light brown	Clay Loam	N/A
M06	5	N/A	25	Upper slope	Brown	Gravelly clay loam	N/A
HS01	1	N/A	55	Mid slope	Brown	Loam	N/A

Plot	Vegetation Condition	Cover Trees (%)	Cover Shrubs (%)	Cover Ground Layer (%)	Remarks
M01	Excellent	12	35	10	
M02	Excellent	10	30	15	
M03	Completely Degraded	N/A	N/A	N/A	
M04	Rehabilitation	N/A	N/A	N/A	
M05	Very Good	20	20	40	Some influence from drains
M06	Excellent	18	50	20	
HS01	Excellent	20	50	15	

Appendix B

Flora List

Lots 202-203 Wandena Rd and Lots 204-205 Great Northern Highway, Muchea
Consolidated Flora Species List
From 360 Environmental (2015) and Plantecology (2020)

Native Taxa
Acacia applanata
Acacia lasiocarpa subsp. sedifolia
Acacia pulchella var. pulchella
Acacia saligna
Agrostocrinum hirsutum
Agrostocrinum scabrum
Allocasuarina fraseriana
Allocasuarina huegeliana
Allocasuarina humilis
?Amphipogon debilis
Anigozanthos manglesii
Austrostipa ?hemipogon
Austrostipa elegantissima
Banksia armata var. armata
Banksia bipinnatifida subsp. multifida
Banksia dallanneyi var. dallanneyi
Banksia nivea
Banksia sessilis
Billardiera ?variifolia
Billardiera fraseri
Bossiaea eriocarpa
Burchardia congesta
Calothamnus sanguineus
Cassytha glabella
Caustis dioica
Comesperma ciliatum
Conostylis aculeata subsp. aculeata
Conostylis sp.
Corymbia calophylla
Cristonia biloba subsp. biloba
Cyathochaeta sp.
Dampiera alata
Dampiera linearis
Daucus glochidiatus
Daviesia decurrens
Daviesia hakeoides subsp. hakeoides
Daviesia preissii
Daviesia triflora
Desmocladus fasciculatus
Desmocladus flexuosus
Dillwynia laxiflora
Eucalyptus accedens
Eucalyptus marginata
Eucalyptus wandoo subsp. wandoo
Gastrolobium acutum
Gastrolobium capitatum

Glischrocaryon aureum
Gompholobium marginatum
Gonocarpus cordiger
Goodenia caerulea
Grevillea synapheae
Haemodorum discolor
Haemodorum loratum (P3)
Hakea lissocarpha
Hakea stenocarpa
Hakea undulata
Hibbertia hypericoides subsp. septentrionalis
Hibbertia sp.
Hibbertia spicata subsp. spicata
Hypocalymma angustifolium
Hypocalymma robustum
Isopogon asper
Lambertia multiflora var. darlingensis
Laxmannia ramosa subsp. ramosa
Lechenaultia biloba
Lechenaultia sp.
Lepidosperma asperatum
Lepidosperma leptostachyum
Lepidosperma pubisquameum
Lepidosperma sp.
Lomandra caespitosa
Lomandra hermaphrodita
Lomandra preissii
Lomandra sericea
Lomandra sonderi
Macrozamia riedlei
Marianthus drummondianus
Melaleuca clavifolia
Melaleuca sp.
Mesomelaena graciliceps
Mesomelaena pseudostygia
Mesomelaena tetragona
Neurachne alopecuroidea
Opercularia vaginata
Patersonia juncea
Petrophile macrostachya
Petrophile striata
Phyllanthus calycinus
Pimelea imbricata var. piligera
Pultenaea reticulata
Rytidosperma setaceum
Scaevola glandulifera
Stirlingia latifolia
Stylidium affine
Stylidium piliferum
Stylidium purpureum
Tetraria octandra
Tetratheca nuda
Thomasia foliosa
Trichocline spathulata

Tricoryne elatior
Trymalium angustifolium
Xanthorrhoea preissii

Introduced Taxa

*Avena barbata
*Briza maxima
*Chamaecytisus palmensis
*Cynodon dactylon
*Ehrharta calycina
*Eragrostis curvula
*Gladiolus caryophyllaceus
*Hypochaeris glabra
*Lupinus sp.
*Lysimachia arvensis
*Romulea rosea
*Ursinia anthemoides

Appendix C

Aboriginal Sites Search Report and DPLH Advice

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

Search Criteria

1 Registered Aboriginal Sites in Coordinates - Area (ab site coords.csv) - 405602mE, 6504194mN (MGA50) : 406903mE, 6504201mN (MGA50) : 406974mE, 6503867mN (MGA50) : 406894mE, 6503635mN (MGA50) : 406882mE, 6503458mN (MGA50) : 406040mE, 6503450mN (MGA50)

Disclaimer

The *Aboriginal Heritage Act 1972* preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

The information provided is made available in good faith and is predominately based on the information provided to the Department of Planning, Lands and Heritage by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at AboriginalHeritage@dplh.wa.gov.au and we will make every effort to rectify it as soon as possible.

South West Settlement ILUA Disclaimer

Your heritage enquiry is on land **within or adjacent to** the following Indigenous Land Use Agreement(s): Whadjuk People Indigenous Land Use Agreement.

On 8 June 2015, six identical Indigenous Land Use Agreements (ILUAs) were executed across the South West by the Western Australian Government and, respectively, the Yued, Whadjuk People, Gnaala Karla Booja, Ballardong People, South West Boojarah #2 and Wagyl Kaip & Southern Noongar groups, and the South West Aboriginal Land and Sea Council (SWALSC).

The ILUAs bind the parties (including 'the State', which encompasses all State Government Departments and certain State Government agencies) to enter into a Noongar Standard Heritage Agreement (NSHA) when conducting Aboriginal Heritage Surveys in the ILUA areas, unless they have an existing heritage agreement. It is also intended that other State agencies and instrumentalities enter into the NSHA when conducting Aboriginal Heritage Surveys in the ILUA areas. It is recommended a NSHA is entered into, and an 'Activity Notice' issued under the NSHA, if there is a risk that an activity will 'impact' (i.e. by excavating, damaging, destroying or altering in any way) an Aboriginal heritage site. The Aboriginal Heritage Due Diligence Guidelines, which are referenced by the NSHA, provide guidance on how to assess the potential risk to Aboriginal heritage.

Likewise, from 8 June 2015 the Department of Mines, Industry Regulation and Safety (DMIRS) in granting Mineral, Petroleum and related Access Authority tenures within the South West Settlement ILUA areas, will place a condition on these tenures requiring a heritage agreement or a NSHA before any rights can be exercised.

If you are a State Government Department, Agency or Instrumentality, or have a heritage condition placed on your mineral or petroleum title by DMIRS, you should seek advice as to the requirement to use the NSHA for your proposed activity. The full ILUA documents, maps of the ILUA areas and the NSHA template can be found at https://www.wa.gov.au/organisation/department-of-the-premier-and-cabinet/south-west-native-title-settlement.

Further advice can also be sought from the Department of Planning, Lands and Heritage at AboriginalHeritage@dplh.wa.gov.au.

Copyright

Coordinate Accuracy

Coordinates (Easting/Northing metres) are based on the GDA 94 Datum. Accuracy is shown as a code in brackets following the coordinates.

Terminology (NB that some terminology has varied over the life of the legislation)

Place ID/Site ID: This a unique ID assigned by the Department of Planning, Lands and Heritage to the place.

Status:

- **Registered Site**: The place has been assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972.*
- **Other Heritage Place which includes:**
  - **Stored Data / Not a Site:** The place has been assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972.*
  - **Lodged:** Information has been received in relation to the place, but an assessment has not been completed at this *stage* to determine if it meets Section 5 of the *Aboriginal Heritage Act 1972.*

Access and Restrictions:

- **File Restricted = No:** Availability of information that the Department of Planning, Lands and Heritage holds in relation to the place is not restricted in any way.
- **File Restricted = Yes:** Some of the information that the Department of Planning, Lands and Heritage holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Planning, Lands and Heritage receives written approval from the informants who provided the information. To request access please contact AboriginalHeritage@dplh.wa.gov.au.
- **Boundary Restricted = No:** Place location is shown as accurately as the information lodged with the Registrar allows.
- **Boundary Restricted = Yes:** To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least 4km²) provides a general indication of where the place is located. If you are a landowner and wish to find out more about the exact location of the place, please contact the Department of Planning, Lands and Heritage.
- **Restrictions:**
  - **No Restrictions:** *Anyone* can view the information.
  - **Male Access Only:** Only *males* can view restricted information.
  - **Female Access Only:** *Only* females can view restricted information.

Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place. This has been replaced by the Place ID / Site ID.

Basemap Copyright

Aboriginal Heritage Inquiry System

List of Registered Aboriginal Sites

ID	Name	File Restricted	Boundary Restricted	Restrictions	Status	Type	Knowledge Holders	Coordinate	Legacy ID
3525	ELLEN BROOK: UPPER SWAN	Yes	Yes	No Gender Restrictions	Registered Site	Mythological	*Registered Knowledge Holder names available from DAA	Not available when location is restricted	S02516

Department of Planning, Lands and Heritage

Aboriginal Heritage Inquiry System

Map of Registered Aboriginal Sites

For further important information on using this information please see the Department of Planning, Lands and Heritage's Disclaimer statement at https://www.dplh.wa.gov.au/about-this-website

Legend

- Registered Aboriginal Site
- Search Area
- Town
- Road
- River
- Local Government Authority

0.51 kilometres

Map Scale 1 : 15,500

MGA Zone 50 (GDA94)

Phil Bayley

From: Sammy Hamill [sammy.hamill@dplh.wa.gov.au]
Sent: Wednesday, 27 May 2020 3:36 PM
To: bayley@iinet.net.au
Subject: FW: Aboriginal Heritage Site enquiry
Attachments: Search Results Report and Map.pdf

Good afternoon Phil

Thank you for your enquiry to the Department of Planning, Lands and Heritage (DPLH) in regard to property in the Shire of Chittering comprising Lots 202-203 Wandena Rd and Lots 204-205 Great Northern Highway.

A review of the Register of Places and Objects as well as the DPLH Aboriginal Heritage Database concludes that the subject land intersects with the public boundary of Aboriginal site ID 3525 (ELLEN BROOK: UPPER SWAN) but not the boundary as administered by the DPLH. Therefore based on the information held by the DPLH and the Snipimage.jpg supplied by you, **no approvals under the *Aboriginal Heritage Act 1972* (AHA) are required.**

DPLH encourages proponents to refer to the State's Aboriginal Heritage Due Diligence Guidelines (Guidelines) which can be found on the DPLH website at the following link:

https://www.dplh.wa.gov.au/information-and-services/aboriginal-heritage/land-use-under-the-aha

The Guidelines will allow proponents to undertake their own risk assessment regarding any proposal's potential impact on Aboriginal heritage.

Regards

Sammy

Sammy Hamill | Heritage Support Officer | Aboriginal Heritage Operations
Globe Building, 497 Wellington Street, Perth WA 6000
(08) 6552 4524
www.dplh.wa.gov.au

The department acknowledges the Aboriginal peoples of Western Australia as the traditional custodians of this land and we pay our respects to their Elders, past and present.

From: Aboriginal Heritage <AboriginalHeritage@dplh.wa.gov.au>
Sent: Tuesday, 19 May 2020 7:06 PM
To: Sammy Hamill <sammy.hamill@dplh.wa.gov.au>
Subject: FW: Aboriginal Heritage Site enquiry

For your action please.

Tanya Butler | Director Aboriginal Heritage Operations | Aboriginal Heritage Operations

Globe Building, 497 Wellington Street, Perth WA 6000
(08) 6551 8160 | 0427 998 365
www.dplh.wa.gov.au

The department acknowledges the Aboriginal peoples of Western Australia as the traditional custodians of this land and we pay our respects to their Elders, past and present.

From: Phil Bayley <bayley@iinet.net.au>
Sent: Tuesday, 19 May 2020 3:53 PM
To: Aboriginal Heritage <AboriginalHeritage@dplh.wa.gov.au>
Subject: RE: Aboriginal Heritage Site enquiry

Sorry, forgot to attach the report.

PB

From: Phil Bayley [mailto:bayley@iinet.net.au]
Sent: Tuesday, 19 May 2020 3:53 PM
To: 'AboriginalHeritage@dplh.wa.gov.au'
Subject: Aboriginal Heritage Site enquiry

Hello,

I am working on a rezoning of a property in the Shire of Chittering comprising Lots 202-203 Wandena Rd and Lots 204-205 Great Northern Highway. The DPLH online Aboriginal Sites Database shows one registered Aboriginal site, 3525 Ellenbrook: Upper Swan, as present on the study site (see attached).

I'm aware that the online database mapping is deliberately vague and may not represent the actual boundaries of the registered site. Could you therefore advise whether the registered site actually does impinge on the study site?

Thanks and regards,

Phil Bayley
bayley environmental services
30 Thomas Street
SOUTH FREMANTLE 6162
tel: 08 9335 9160
fax: 08 9335 9160
mob: 0427 808 633
www.bayleyenvironmental.com.au

Appendix D

Local Water Management Strategy

LOTS 202 & 203 WANDENA ROAD
AND
LOTS 204 & 205 GREAT NORTHERN HIGHWAY
CHITTERING

LOCAL WATER MANAGEMENT STRATEGY

Prepared for

Focus Demolition Pty Ltd
and
Mr David Weightman Smith

Draft Report No. J19018b
18 May 2021

BAYLEY ENVIRONMENTAL SERVICES
30 Thomas Street
SOUTH FREMANTLE WA 6162

Sundowner Nominees Pty Ltd as trustee for the Bayley Cook Family Trust ABN 20 822 598 897
trading as Bayley Environmental Services

EXECUTIVE SUMMARY

The owners of Lots 202 & 203 Wandena Road and Lots 204 & 205 Great Northern Highway, Chittering (the site) have applied to the Shire of Chittering for the lots to be rezoned from Agricultural Resource to General Industry. The draft Muchea Industrial Park Structure Plan 2019 (MIPSP) shows Lots 204 and 205 as part of Precinct 2 (General Industry Core) and Lots 202 and 203 as part of Precinct 4 (Light Industry following completion of quarrying). The total area of the rezoning is approximately 82 hectares.

The MIPSP concept for Precincts 2 and 4 is for industries with a minimum lot size of one hectare, with effluent disposed on site using secondary treatment systems such as aerobic treatment units.

The Local Structure Plan for Lots 202-205 has been submitted to the Department of Planning, Lands & Heritage and the Shire of Chittering, and is currently being considered by those agencies.

EXISTING ENVIRONMENT

Rainfall

Muchea, like the rest of the greater Perth region, has a strongly seasonal rainfall, with most of the annual rain falling between May and September in association with winter cold fronts. Occasional heavy falls may occur from summer thunderstorms. The long-term average annual rainfall for Pearce RAAF Base (located 6.5km south of the site) is 679.7mm, of which 77% falls between the months of May and September.

Physiography

The site extends from a very gently sloping plain in the west to low hills in the east. The elevation ranges from 58m AHD in the south-west to 101m AHD on the eastern boundary. The north-eastern quarter of the site, comprising Lot 202 and the northern half of Lot 203, is significantly higher and steeper than the rest of the site.

The site is located on the eastern edge of the Pinjarra Plain and the western colluvial outwash zone of the Dandaragan Scarp. The soils in the west are pebbly silts belonging to the Guildford Formation, which originated as alluvial deposits washed from the Dandaragan Plateau by rivers and streams. In the eastern part the soils are colluvial silty sands and sands, and Leederville Formation siltstone eroded from the scarp.

The permeability of the site soils will vary depending on the clay content. Test pumping during sampling of one on-site bore (WB3) indicated a hydraulic conductivity in the

depth range of 2.6m to 5.1m in the order of 0.14 m/day. Constant-head testing by Douglas Partners (2020) at six sites at depths of 0.2 – 0.8 metres returned permeabilities ranging from 0.9 – 8.6 m/day, with a mean of 3.3 m/day and a median of 4.75 m/day.

For preliminary drainage and effluent design purposes, a conservative permeability of 1 m/day has been assumed.

The DBCA maps the site as Low to Nil risk of Acid Sulphate Soils (ASS). The nearest mapped High ASS risk area is a palusplain about 600m to the south.

Bore sampling between July 2016 and September 2020 found no significant indications of potential or actual ASS in the groundwater. No further investigation of ASS is considered to be necessary.

Hydrology

Groundwater occurs at shallow depth across the lower-lying western parts of the site (Lots 204 and 205) in winter. The depth to groundwater varies from over 18 metres in the east of the site to less than two metres in winter in the west. The DWER maps minimum groundwater levels at 48-53m AHD (13-48m below ground), flowing south-west towards Ellen Brook.

In wet winters, rainfall infiltration may be impeded by the low-permeability soils, creating temporary surface saturation in the lower parts of the site. There is no evidence in the water measurements or soil profiles of the occurrence of a seasonally perched water table.

There are no natural defined drainage channels within the site, although several artificial drains have been cut in and around the quarry on Lots 202 and 203. The relatively low permeability soils of the soils would result in sheet flow across the ground surface during high rainfall events.

Water enters the project area from one 36ha external catchment to the east via a culvert beneath Wandena Road. This water flows into a sump within Lot 202, which overflows to a farm dam on the adjoining lot and then into a drain that flows west to Great Northern Highway and ultimately into Ellen Brook.

All drainage from the site flows eventually into Ellen Brook, the major drainage feature of the region.

The project area is within the Eclipse Hill sub-area of the Gingin Groundwater Area for the surficial and superficial aquifers, the Southern Scarp sub-area for the semi-confined (Mirrabooka) aquifer, the Cowalla sub-area for the confined Leederville-Parmelia aquifer and the Chandala sub-area for the Yarragadee aquifer.

Under the plan Gingin Groundwater Areas Allocation Plan (DoW, 2015), the Eclipse Hill (superficial), Southern Scarp (Mirrabooka) and Cowalla (Leederville) sub-areas are over-allocated and no new allocations are available.

The DWER Water Register (https://maps.water.wa.gov.au/#/webmap/register) shows one groundwater licence for Lot 205 (GWL 152031, expiring November 2023), which is licensed to abstract up to 1,500 KL/yr from the Leederville aquifer via a bore on the adjacent Lot 206.

Groundwater quality within the project area is moderate, which is to be expected given the soil types and the history of agriculture. Nitrogen and phosphorus concentrations are generally low to moderate

The groundwater shows mostly low acidity and sulphate contents, indicating that there is no evidence of acid sulphate soils. Dissolved metals concentrations are mostly low except for aluminium and zinc, which are slightly elevated across much of the site.

Vegetation

The project area is largely cleared of native vegetation, consisting mostly of farm paddocks and current and former quarries. All of Lot 204, most of Lot 205 and the southern part of Lot 203 are cleared paddocks with some scattered mature trees, either native or planted. Native vegetation is present in the central east of Lot 205, the northern end of Lot 202 and the north of Lot 203. The site does not contain any vegetation dependent on wetlands or shallow groundwater.

Land Uses and Potential Contamination

Historic Landgate aerial photography shows that the project area has been largely cleared and used for farming since at least 1965. Quarrying has been underway on Lots 202 and 203 since before 1977.

The DWER Contaminated Sites Database shows no record of any contaminated sites in the project area.

The former clay quarry on Lots 202 and 203 is currently being backfilled with inert waste such as building rubble prior to rehabilitation. The backfilling and rehabilitation are being undertaken under the terms of a DWER Licence (L9181/2018/1), which carries conditions including control of waste acceptance and prevention of pollution.

WATER USE SUSTAINABILITY

Water will be required for both potable and non-potable purposes. The Leederville aquifer is likely to be the preferred source for potable supply due to its generally higher quality and lower risk of contamination. Non-potable groundwater demand is likely to be

limited to landscape irrigation, particularly within Precinct 4 (Lots 204-205), as industries within this precinct will be restricted to those with low water usage.

Potable water will be supplied to the project area by a licensed water provider. A proposed water project for the Lower Chittering Valley is currently in development by Aqua Ferre Pty Ltd, which includes construction of a water treatment facility on Lot 2 Reserve Rd, Chittering. Aqua Ferre is in the process of applying for a Water Service Provider's Licence from the Economic Regulation Authority (ERA). Aqua Ferre has confirmed that it has the capacity within its proposed licence to supply Precinct 3 with potable water. Discussions with Aqua Ferre are ongoing.

For non-potable uses, purchase of water entitlements from existing licensed users within or outside of the project area is likely to be necessary. The landowners will negotiate with existing licence holders within and outside of the project area with a view to purchasing an existing groundwater allocation, and will submit a groundwater licence application to the DWER in due course.

Precinct 2 (Lots 204-205) will be designed as a low-water-use precinct. Only industries with low water consumption will be permitted in this precinct. Precinct 4 (Lots 202-203) will accommodate general industry with less restrictions on water use or wastewater generation; however, industries will need to demonstrate that they can safely dispose of waste water on site. Water use will effectively be restricted by the limited availability and corresponding cost of groundwater in the area.

Potable water use within the project area will be limited to consumption for domestic use in toilets, bathrooms and kitchens. Cossill & Webley (2018) estimated total potable water demand for Lots 202-205 at 96ML per year, based on a study by GHD for the Karratha Gap Industrial Estate.

Groundwater will be used mainly for irrigation of landscape plantings and swales. These areas will be irrigated only during the establishment stage (one or two years). The Landscape Master Plan estimates total plantings of 13.7ha of sedges, shrubs and trees within the project area.

ON-SITE EFFLUENT DISPOSAL

All effluent generated within the subdivision will be treated and disposed by means of individual on-site effluent disposal systems. All lots in low-lying areas will be required to employ nutrient-attenuating alternative systems such as aerobic treatment units (ATUs) with high-PRI irrigation areas or modified leach drain systems (e.g. Filtrex). Lots in higher areas or with deeper groundwater may employ conventional septic systems and leach drains.

The ATU irrigation area or leach drain length on each lot will be sized to suit the expected population of the lot. The effluent disposal requirements of each lot will vary

depending on the soil profile, groundwater depth, risk of saturation and expected site population. Site testing on each lot prior to development will be required to determine the location and type of effluent disposal system.

STORMWATER MANAGEMENT STRATEGY

The drainage system will be designed to maintain surface flow rates and volumes within and from the developed site at or below their pre-development levels.

The existing drainage line entering at the north-east of Lot 202 will be realigned and consolidated in a vegetated swale within a road reserve. The swale will be sized to accommodate the flow from a 100-year ARI critical storm from both the upstream and internal catchments.

Runoff from roofs, paved surfaces and hardstand areas within private lots from storms up to 1-year ARI 1-hour duration (about 15mm) will be retained and infiltrated within each lot in soakwells, basins and/or landscaping areas. The in-lot drainage structures will also be sized to capture and detain the runoff from roofs, paved surfaces and hardstand areas from critical storms up to 100-year ARI.

Overflows from the basins will run into roadside bioretention swales, either directly or via drainage easements for those lots that do not have a downslope road frontage. Lots will be filled as necessary adjacent to the roads to enable lot drainage to enter the roadside swales.

Runoff from public roads from up to the 1-year ARI 1-hour storm will be retained and infiltrated in roadside swales. The inverts of the swales will be at or above the AAMGL. The swales will be constructed with low internal weirs set at a height that captures the 1-year 1-hour storm.

Road runoff from larger storms will overtop the weirs and flow along the swales to the western boundary, where it will enter the roadside drains and culverts on Great Northern Highway. The rate and volume of drainage out of the site will be controlled to be no greater than those existing before development.

The drainage from the site flows beneath Great Northern Highway via five culverts. The culverts have sufficient capacity to carry the flow from a 100-year ARI critical storm without upstream ponding.

Surface Water Quality Management

The drainage system will be designed to maximise on-site retention of nitrogen and phosphorus. This will be achieved by:

- Retaining and infiltrating all lot runoff from storms up to 1-year ARI within the lots.

- Infiltrating all road runoff from storms up to 1-year ARI 1-hour duration (estimated by the DWER to carry more than 99% of total flows and nutrients) in vegetated bioretention swales with a minimum soil PRI of 15.

- Conveying all runoff from storms between 1-year and 100-year ARI in densely vegetated bioretention swales to allow suspended particles to be filtered out.

GROUNDWATER MANAGEMENT STRATEGY

The drainage system for the site is designed to minimise changes to the existing groundwater regime. Roadside swales and subsoil drains will be set with their inverts at or above the AAMGL. Subsoil drainage within lots will be limited to filled areas used for buildings or effluent disposal.

Subsoil drainage may be employed within some lots where necessary to maintain existing maximum groundwater levels beneath building pads and effluent disposal areas. The subsoil drains will discharge into roadside swales via free-draining outlets.

Subsoil drains may also be employed within road reserves to prevent groundwater rise from damaging the road base and pavement.

All subsoil drains will be set with their invert at or above the AAMGL. Therefore, changes to the groundwater hydrology of the site will be minimal.

Groundwater quality will be protected by measures including:

- regular street sweeping to remove accumulated contaminants; and
- selection of native species with low water and fertiliser requirements for public open space and landscape areas.

LANDSCAPING STRATEGY

Landscaping of the site will focus on the use of species with low water demand. Plantings will include bioretention swales and basins, landscape buffers (to a minimum of 10% of the area of each lot), effluent irrigation areas and street trees. The plantings will not be irrigated after the establishment phase. No turf grass will be planted.

The plantings in swales, basins and effluent irrigation areas will include a high proportion of species recommended in the Monash University (2014) *Vegetation Guidelines for Stormwater Biofilters in the South-West of Western Australia*.

Fertiliser use will be minimal. New tube stock plantings will be fertilised with slow-release nitrogen and phosphorus tablets on establishment and thereafter will be unfertilised.

The bioretention basins and swales will be densely planted with inundation-tolerant species including sedges and low shrubs in order to stabilise the basins and maximise their ability to take up nitrogen from the water.

MONITORING

Groundwater levels and quality will be monitored and compared against baseline levels and relevant guidelines. Water quality in surface drains will be monitored upstream and downstream of the project area to determine what (if any) impacts the development may be having on the watercourses.

Water quality sampling will be conducted nominally once a year in late winter. Detailed water monitoring and response procedures will be developed as part of the Urban Water Management Plans to be prepared for each stage of subdivision.

IMPLEMENTATION AND FURTHER MANAGEMENT PLANS

Further planning and subdivision of the subject land will be carried out in accordance with the general water management principles set out in this LWMS. Subdivision of lots in the structure plan area may be carried out by individual owners as they see fit, in accordance with the framework of the LWMS.

An Urban Water Management Plan (UWMP) will be prepared as a condition of subdivision approval for each stage of subdivision. The UWMP will present the detailed design of the stormwater drainage system within that stage.

The developer of each stage of subdivision will maintain the drainage system, landscaped areas and water monitoring program within that stage until two years after that stage of subdivision is completed. At the end of that time the responsibility for monitoring and management will be handed over to the Shire of Chittering.

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1.0 INTRODUCTION

1.1 Background

The owners of Lots 202 & 203 Wandena Road and Lots 204 & 205 Great Northern Highway, Chittering (the site) have applied to the Shire of Chittering for the lots to be rezoned from Agricultural Resource to General Industry. The draft Muchea Industrial Park Structure Plan 2019 (MIPSP) shows Lots 204 and 205 as part of Precinct 2 (General Industry Core) and Lots 202 and 203 as part of Precinct 4 (Light Industry following completion of quarrying). Figure 1 shows the location of the site within the draft Muchea Industrial Park Structure Plan area.

The total area of the rezoning is approximately 82 hectares. Figure 2 shows the boundaries of the site. Figure 3 shows a preliminary conceptual plan of subdivision.

The MIPSP concept for Precincts 2 and 4 is for industries with a minimum lot size of one hectare, with effluent disposed on site using secondary treatment systems such as aerobic treatment units.

The Local Structure Plan for Lots 202-205 has been submitted to the Department of Planning, Lands & Heritage and the Shire of Chittering, and is currently being considered by those agencies.

1.2 Previous Studies

1.2.1 Water Management Strategy – Muchea Employment Node

A Water Management Strategy (WMS) was prepared by Connell Wagner in 2008 in support of the District Structure Plan for the Muchea Employment Node. The WMS documented the existing environment of the MEN in broad terms, including soils and geology, topography, hydrology, vegetation and land uses. The WMS examined:

- the possible impacts of development on surface water and groundwater
- water demand and supply options;
- wastewater treatment and disposal, including leach drains, evaporation ponds and reuse.

The WMS recommended, among other things:

- Groundwater monitoring over at least two winter seasons should be undertaken to provide information on groundwater levels and quality.

- The preferred method of effluent disposal, based on desktop studies, was treatment by Aerobic Treatment Units (ATU) followed by disposal in evaporation ponds.

- Development should be set back from waterways in accordance with Water and Rivers Commission Note 23: *Determining Foreshore Reserves* (2001), with a default minimum setback of 30m.

- Stormwater runoff from lots and roads should be managed by infiltration and detention so that the runoff from a 1-year 1-hour storm is retained and infiltrated, and that peak flows from critical storms up to 100-year ARI are limited to pre-development rates.

- Water sensitive urban design measures should be implemented to meet catchment water quality targets as set out in the Swan-Canning Water Quality Improvement Plan (2009).

1.2.2 Regional Water Management Strategy – Muchea

The Muchea Regional Water Management Strategy (RWMS) was prepared by Emerge Associates for the Department of Planning, Lands & Heritage in 2019. The RWMS deals with the entire Muchea Employment Node, covering an area of 6,580 hectares.

The RWMS identifies environmental values, documents the hydrological regime and identifies requirements for wastewater management. The RWMS recommends further assessments prior to development including geotechnical, flora and fauna, wetlands, waterways, land capability and flooding.

1.3 Relevant Guidelines and Policies

1.3.1 State Planning Policy 2.9

State Planning Policy 2.9: *Water Resources* (WAPC, 2006) lists the following key principles for total water cycle management:

- Consideration of all water sources (including wastewater) in water planning, maximising the value of water resources.

- Integration of water and land use planning.

- Sustainable and equitable use of all water sources, having consideration of the needs of all water users including the community, industry and the environment.

- Integration of water use and natural water processes.

- A whole-of-catchment integration of natural resource use and management.

SPP 2.9 also lists the following general objectives for water-sensitive urban design:

- to manage a water regime;

- to maintain and, where possible, enhance water quality;
- to encourage water conservation;
- to enhance water-related environmental values; and
- to enhance water-related recreational and cultural values.

Element 5 of *Liveable Neighbourhoods* Edition 3 (WAPC, 2004) identifies specific objectives and requirements for Urban Water Management. These are based on Best Planning Practices which are defined as the best practical approach for achieving water resource management objectives within an urban framework.

1.3.2 Better Urban Water Management

Better Urban Water Management (WAPC, 2008) sets out the following objectives for water sensitive urban design:

Water Conservation

- Consumption of 100kL/p/yr including less than 40-60 kL/p/yr scheme water.

Water Quantity

- Ecological Protection – Maintain pre-development flow rates and volumes for the 1 year ARI event. Maintain or restore desirable environmental flows and/or hydrological cycles.
- Flood Management – Maintain pre-development flow rates and volumes for the 100 year ARI event.

Water Quality

- Maintain pre-development nutrient outputs (if known) or meet relevant water quality guidelines (e.g. ANZECC & ARMCANZ, 2000).
- Treat all runoff in the drainage network prior to discharge consistent with the Stormwater Management Manual.
- As compared to a development that does not actively manage stormwater quality, achieve:
  - at least 80% reduction of Total Suspended Solids;
  - at least 60% reduction of Total Phosphorus;
  - at least 45% reduction of Total Nitrogen; and
  - at least 70% reduction of gross pollutants.

Mosquitoes and Midges

- Design detention structures so that, between the months of November and May, stormwater is fully infiltrated within 96 hours.

- Design permanent water bodies (where accepted by DWER) to maximise predation of mosquito larvae by native fauna.

1.3.3 Shire of Chittering Town Planning Scheme No. 6

"The following development requirements shall apply to the development and subdivision of land within industrial zones and to industrial land uses –

(a) the effect on the environment by means of discharge of pollutants or contaminants into the air, ground and water be avoided, or managed within acceptable limits;

(b) where an on-site wastewater disposal system is proposed –

i. land capability assessment may be required to demonstrate the capability of the site to manage wastewater and the suitability of the proposed system;
ii. the use of fill and drains to achieve the required separation from groundwater is to be limited; and
iii. a suitable and unencumbered land application area is to be set aside to distribute treated sewage, where required;

(c) within sewerage sensitive areas secondary treatment systems with nutrient removal are to be utilised;

(d) notwithstanding any other provisions of this scheme, industrial development not connected to reticulated sewerage (for treatment on-site or off-site) is to be restricted to 'dry industry' being land uses that intend to dispose of wastewater on site to the environment of a kind and volume ordinarily discharged from a habitable building at a daily volume of less than 540 litres per 1,000m^2 of the site area [R10 equivalent];

(e) where trade waste is to be managed and/or disposed of on-site or off-site the associated risks must be identified and addressed, including the vulnerability of the receiving environment where relevant."

Schedule 11 of the Scheme contains the following provisions that apply to the Muchea Employment Node:

"2.2 Environmental Management Plans

The following Environmental Management Plans shall be prepared and used to inform the design and proposed subdivision and development within the Structure Plan area. They

shall be submitted as an additional detail of a Structure Plan unless otherwise determined by the Western Australian Planning Commission.

2.2.1 Local Water Management Strategy

The developer shall submit to the Local Authority a Local Water Management Strategy (LWMS) for approval as an additional detail of a Structure Plan pursuant to clause 5.19 in order to ensure that surface and ground waters are managed with the aim of maintaining the natural water balance. The Local Authority must notify and consult with the authority responsible for water and the environment on the proposed strategy in advertising the Local Structure Plan(s) pursuant to Part 4 of the deemed provisions.

The LWMS shall be prepared in accordance with Better Urban Water Management or its successor document.

The Structure Plan design shall respond to the LWMS required by 2.2.1 and shall be implemented to the satisfaction of the Local Authority, having regard to any advice from the Department of Water."

1.3.4 Government Sewerage Policy

The Government Sewerage Policy (2019) requires that all new subdivision and development should be deep-sewered unless exempt for one of several reasons. For exempt developments, the policy establishes minimum site capability requirements and, where appropriate, density limits. In these cases, on-site effluent disposal may be approved where the responsible authority is satisfied that:

- each lot is capable of accommodating on-site sewage disposal without endangering public health or the environment; and
- the minimum site requirements for on-site sewage disposal as set out in the Policy can be met.

The Policy designates certain areas as Sewage Sensitive Areas (SSAs), including land:

- within the coastal catchment of the Swan Estuary; and
- within 1km upgradient or 250m downgradient (or overall 1km where the groundwater gradient is unknown) of a significant wetland.

Additional restrictions and requirements apply to on-site effluent disposal in SSAs, including:

- a minimum lot size of one hectare (unless exempted on a case-by-case basis);
- minimum vertical separation of 1.5m from the discharge point of effluent disposal systems to the highest groundwater table level; and
- secondary effluent treatment systems with nutrient removal.

The Policy shows all of Lots 203 and 204, most of Lot 205 and the southern part of Lot 202 within an SSA associated with the Ellen Brook catchment. Lot 203, the southern part of Lot 205 and the northern half of Lot 202 are also shown within SSAs associated with significant wetlands. Figure 1 shows the mapped SSAs.

In the case of Lot 202 and the north-east of Lot 205, the SSA mapping is considered to be erroneous. The wetland in question (a Conservation category dampland) is located upgradient of the site, is maintained by surface flow and/or locally perched groundwater (the mapped permanent groundwater table is 45-50m below the ground surface) and is separated from the site by several watercourses, drains and deep excavations, so that there is no possibility of groundwater flow from the site to the wetland. This matter is examined further in Section 4.1.

1.3.5 DoW Operational Policy 4.3: Identifying and Establishing Waterways Foreshore Areas

DoW Operational Policy 4.3 was published in 2012 and sets out the Department of Water's policy on defining and protecting foreshore reserves. It is intended to apply to all natural waterways within development areas. The policy sets out procedures for identifying, delineating and protecting foreshore areas.

The procedure may vary depending on the size and nature of the waterway and the nature of the proposed adjacent development. The policy provides for standard or nominal foreshore widths to be employed in some cases, such as small subdivisions and/or minor tributary creeks where the waterway is adequately protected and the proposed development poses an insignificant additional risk to the waterway.

1.3.6 DoW Interim Guideline: Developing a Local Water Management Strategy

The DoW LWMS guideline was published in 2008 and sets out the DoW's preferred format and content for LWMS documents. The guideline expands on the LWMS guidance provided in *Better Urban Water Management* (2008).

This LWMS has been prepared in accordance with the principles set out in the DoW guideline. Appendix A shows a completed checklist from the DWER guideline.

1.4 Scope of the LWMS

The scope of this LWMS is to:

- Document the existing environment on the site, in relation to soils, drainage, erosion, watercourses, groundwater and water-dependent ecosystems.
- Briefly describe the proposed development in relation to water management.

- Examine the capability of the site for on-site effluent disposal.
- Address relevant regulatory requirements and design criteria for water harvesting, setbacks to watercourses, groundwater management and drainage.
- Describe the strategies to be implemented for water conservation, watercourse protection, groundwater management and stormwater drainage.
- Outline the proposed monitoring program.
- Outline what is to be addressed in future Urban Water Management Plans.

1.5 Design Objectives

Table 1.1 summarises the water-related design objectives for Lots 202-205 and the means by which they will be achieved in the LWMS and subsequent management plans.

Table 1.1 Design Objectives

Design Aspect	*Design Objective*	*How Objective is to be Achieved*
Water Conservation	Ensure efficient and sustainable use of water resources	Only low water use industries permitted in Precinct 2 (Lots 204-205). Use water efficient fixtures. Limit wastewater generation in Precinct 2 to 5.4 KL/ha/day. Use non-potable water for irrigation. Purchase groundwater licence(s) from existing holders within or outside the project area. Use water-efficient native species for landscaping. Irrigate landscape plantings only for 2 years.
Groundwater Management	Minimise impacts on groundwater level and flows Minimise impacts on groundwater quality	Subsoil drains set at or above pre-existing AAMGL, with fill used to provide additional clearance if required. Finished floor levels of habitable buildings set at least 0.5m above controlled groundwater level. Treat runoff from minor storms in bioretention swales. Minimise fertiliser and chemical use in landscaping areas. Use nutrient-removing alternative treatment systems for effluent disposal.
Surface Water Management	Minimise impacts on surface water flow rates, volumes and quality	Retain and infiltrate runoff from 1-year ARI 1-hour storms in bioretention swales. Detain runoff from larger storms and control release from lots and overall site to pre-development flow rates. Convey existing flows through the site in roadside swales at pre-development rates. Set effluent disposal facilities at least 100m back from natural waterways. Sweep streets regularly to remove accumulated contaminants.

2.0 EXISTING ENVIRONMENT

2.1 Rainfall

Muchea, like the rest of the greater Perth region, has a strongly seasonal rainfall, with most of the annual rain falling between May and September in association with winter cold fronts. Occasional heavy falls may occur from summer thunderstorms. The long-term average annual rainfall for Pearce RAAF Base (located 6.5km south of the site) is 679.7mm, of which 77% falls between the months of May and September.

Figure 4 shows a rainfall occurrence chart for Pearce RAAF. Table 2.1 shows rainfall intensity, frequency and duration for Muchea.

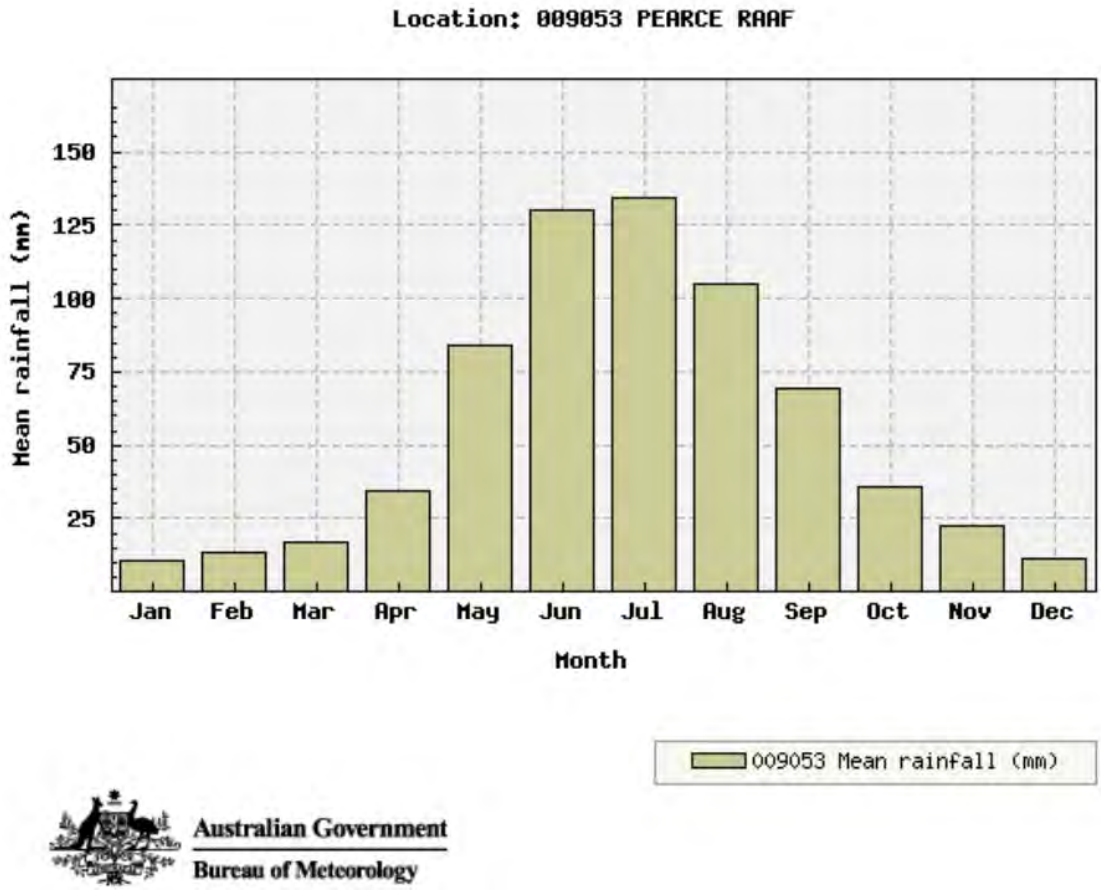

Figure 4 Pearce RAAF Mean Rainfall

IFD Design Rainfall Depth (mm) Issued: 31 October 2018

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.51	1.68	2.26	2.69	3.14	3.77	4.29
2 min	2.61	2.89	3.82	4.49	5.18	6.18	7.00
3 min	3.52	3.90	5.17	6.11	7.07	8.47	9.62
4 min	4.28	4.75	6.34	7.50	8.72	10.5	11.9
5 min	4.92	5.48	7.34	8.71	10.1	12.2	13.9
10 min	7.23	8.07	10.9	13.0	15.2	18.2	20.8
15 min	8.75	9.76	13.2	15.7	18.3	22.0	25.1
20 min	9.90	11.0	14.9	17.7	20.6	24.8	28.2
25 min	10.8	12.1	16.2	19.3	22.5	27.0	30.7
30 min	11.6	13.0	17.4	20.7	24.0	28.8	32.8
45 min	13.6	15.1	20.1	23.9	27.7	33.3	37.9
1 hour	15.1	16.7	22.2	26.4	30.7	36.9	42.1
1.5 hour	17.4	19.3	25.6	30.4	35.4	42.8	49.1
2 hour	19.3	21.3	28.3	33.6	39.4	47.8	55.1
3 hour	22.3	24.6	32.7	39.0	45.9	56.3	65.2
4.5 hour	25.8	28.5	37.9	45.4	53.8	66.4	77.6
6 hour	28.7	31.6	42.1	50.6	60.1	74.7	87.7
9 hour	33.1	36.5	48.7	58.7	70.0	87.5	103
12 hour	36.6	40.3	53.9	65.0	77.5	96.9	114
18 hour	42.0	46.3	61.7	74.2	88.1	110	129
24 hour	46.1	50.8	67.5	80.8	95.3	118	138
30 hour	49.5	54.5	72.1	85.8	101	124	143
36 hour	52.4	57.7	75.9	89.8	105	128	147
48 hour	57.2	62.9	82.1	96.1	111	133	152
72 hour	64.9	71.2	91.5	106	120	141	158
96 hour	71.4	78.2	99.4	114	128	148	164
120 hour	77.4	84.6	107	122	136	157	173
144 hour	83.4	91.0	115	131	146	168	185
168 hour	89.4	97.3	123	140	157	181	200

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

Table 2.1 Rainfall Intensity for Muchea

2.2 Physiography

2.2.1 Topography

The site extends from a very gently sloping plain in the west to low hills in the east. The elevation ranges from 58m AHD in the south-west to 101m AHD on the eastern boundary. The north-eastern quarter of the site, comprising Lot 202 and the northern half of Lot 203, is significantly higher and steeper than the rest of the site.

The slope is generally to the south-west, with gradients ranging from less than 1% in the north-west to over 40% in places on the eastern boundary. Excavation in the quarry on Lots 202 and 203 has produced some steeper gradients, but these are expected to be reduced

in the filling and rehabilitation of the quarry. Figure 5 shows the existing topography of the site.

2.2.2 Geology, Landforms and Soils

The site is located on the eastern edge of the Pinjarra Plain and the western colluvial outwash zone of the Dandaragan Scarp. The soils in the west are pebbly silts belonging to the Guildford Formation, which originated as alluvial deposits washed from the Dandaragan Plateau by rivers and streams. In the eastern part the soils are colluvial silty sands and sands, and Leederville Formation siltstone eroded from the scarp.

The Guildford Formation soils are described by the Geological Survey of Western Australia (Gozzard, 1982) as "Mgs_1: Strong brown silt with common fine to occasionally coarse grained, sub-rounded quartz, heavily weathered granite pebbles, some fine to medium-grained quartz sand, of alluvial origin".

The colluvial soils are described as:

- "Msg: Strong brown, firm, friable, dispersive in part, occasional pebbly horizons with little matrix, containing quartzite, quartz, granite, laterite of colluvial origin";
- "S_5: Very pale brown, medium to coarse-grained, well sorted, little fines, sub-angular to rounded quartz and feldspar, of colluvial origin"; and
- "S_6: Light grey, fine to coarse, angular to sub-rounded, quartz with some feldspar, moderately sorted, loose, of colluvial origin".

The Leederville Formation siltstone in the north-east is described as "ST_1: White, thinly bedded, well laminated, fine-grained, some large ferruginous concretions and laminae, occasionally micaceous".

Drilling by BES at four sites on Lots 204 and 205 in March 2020 showed a pebbly silty sand to pebbly silty clay profile in the top 5.5m, which corresponds to the GSWA description for the Guildford Formation. Previous drilling by Bowman & Associates Pty Ltd (2016) at four sites on Lots 202 and 203 found a silty clay profile with ironstone commonly occurring at between 5m and 18m, which corresponds generally with the GSWA descriptions for Leederville Formation and colluvium.

Figure 5 shows the site geology. Soil logs from the drilling are attached in Appendix B.

2.2.3 Soil Permeability

The permeability of the site soils will vary depending on the clay content. Test pumping during sampling of one on-site bore (WB3) indicated a hydraulic conductivity in the depth range of 2.6m to 5.1m in the order of 0.14 m/day. The permeability of the top 2m of the soil profile is expected to be higher.

Douglas Partners (2020) undertook constant-head permeability testing at six sites at depths of 0.2 – 0.8 metres. The tests returned permeabilities ranging from 0.9 – 8.6 m/day, with a mean of 3.3 m/day and a median of 4.75 m/day. The geotechnical report is attached in Appendix C.

For preliminary drainage and effluent design purposes, a conservative permeability of 1 m/day has been assumed. Further constant-head permeability tests in accordance with the method set out in Australian Standard AS1547:2012: – *On-site Domestic Wastewater Management* will be undertaken prior to subdivision.

2.2.4 Acid Sulphate Soils

The DBCA maps the site as Low to Nil risk of Acid Sulphate Soils (ASS). The nearest mapped High ASS risk area is a palusplain about 600m to the south.

Bore sampling between July 2016 and September 2020 found no significant indications of potential or actual ASS in the groundwater. No further investigation of ASS is considered to be necessary.

2.2.5 Phosphorus Retention Index

Previous experience has shown that the gravelly and silty clay soils of the Guildford Formation and other alluvial and colluvial soils generally have moderate to very high PRI.

PRI is a measure of the ability of a soil to adsorb and retain phosphorus from solution. A high PRI indicates that a soil is unlikely to leach phosphorus to the water table. Typical ranges for PRI values in soils are as follows:

PRI Range	*Rating*	*Typical soils*
0 – 0.5	Very Low	Bassendean Sand
2 – 4	Low – Moderate	Karrakatta Sands
5 – 12	Moderate – High	Cottesloe Sands
12 – 20	High	Crushed Limestone, Limesand
20 – 1000+	Very High	Clay

The DWER recommends a minimum PRI of 15 for soils beneath infiltration basins and swales. The site soils are expected to meet or exceed this requirement. PRI testing of soils beneath proposed infiltration basins will be undertaken before subdivision.

2.3 Hydrology

2.3.1 Groundwater

Groundwater occurs at shallow depth across the lower-lying western parts of the site (Lots 204 and 205) in winter. The depth to groundwater varies from over 18 metres in the east of the site to less than two metres in winter in the west. The DWER maps minimum groundwater levels at 48-53m AHD (13-48m below ground), flowing south-west towards Ellen Brook.

In wet winters, rainfall infiltration may be impeded by the low-permeability soils, creating temporary surface saturation in the lower parts of the site. There is no evidence in the water measurements or soil profiles of the occurrence of a seasonally perched water table.

Groundwater measurements in 14 bores in and around the site in August 2020 (Figure 6), during a drier than average winter, gave the water depths and levels shown in Table 2.2. Appendix D shows all groundwater measurements collected from the site since 2004.

Simultaneous measurements of DWER bores located 680m south (Swan GWA 2-98) and 800m north (Gnangara Monitoring GD20) enabled Average Annual Maximum (AAMGL) and Maximum (MGL) groundwater levels at the site to be calculated. Figure 6 shows the calculated AAMGL and depth to AAMGL contours across the site. Figure 7 shows the hydrographs of the DWER bores.

Table 2.2 shows that the groundwater levels measured on 21 August 2020 were about 0.4m below the AAMGL. The winter of 2020 was drier than average, and the levels measured on 21 August are considered to approximate the peak for the year.

Table 2.2 shows that the AAMGL is within one metre of the ground surface in parts of the north-west and south-west of the site. However, the pattern of groundwater levels is not uniform: Bore WB1 on the western boundary has an indicated depth to the AAMGL of over 4.5m.

Table 2.2 also suggests that the MGL will intersect the ground surface in the north-west and south-west of the site.

Table 2.2 Groundwater Depths and Levels 21 August 2020

Bore	*Depth (mbgl)*	*Level (m AHD)*	*AAMGL (m AHD)*	*MGL (m AHD)*	*Depth to AAMGL (m)*	*Depth to MGL (m)*
MW1	>17.44	<74.76	<75.19	<75.77	>17.01	>16.43
MW2	16.14	78.26	78.69	79.27	15.63	15.05
MW3	12.55	70.67	71.10	71.68	12.12	11.54
MW4	14.45	64.33	64.76	65.34	14.02	13.44
WB1	>4.68	<56.55	<56.98	<57.56	>4.25	>3.67
WB2	>4.98	65.89	<66.32	<66.90	>4.55	>3.97
WB3	1.58	67.51	67.94	68.52	1.15	0.57
WB4	2.34	59.53	59.96	60.54	1.91	1.33
TB7	1.14	57.26	57.69	58.27	0.71	0.13
TB8	1.11	64.14	64.57	65.15	0.68	0.10
TB9	0.56	74.24	74.67	75.25	0.13	-0.45
MB5	0.77	56.02	56.45	57.03	0.34	-0.24
MB7	0.65	54.86	55.29	55.87	0.22	-0.36
GD20	0.88	60.6	59.85	61.35	1.63	0.13
2-98	2.12	56.17	56.6	57.18	1.69	1.11

2.3.2 Surface Drainage

There are no natural defined drainage channels within the site, although several artificial drains have been cut in and around the quarry on Lots 202 and 203. The relatively low permeability soils of the soils would result in sheet flow across the ground surface during high rainfall events.

Water enters the project area from one 36ha external catchment to the east via a culvert beneath Wandena Road. This water flows via a constructed drain into a sump within Lot 202, which overflows to a farm dam on the adjoining lot and then into a drain that flows west to Great Northern Highway and ultimately into Ellen Brook. The land to the east is expected to remain as farmland for the foreseeable future, so this water inflow is not expected to change significantly in rate, volume or quality.

All drainage from the site flows eventually into Ellen Brook, the major drainage feature of the region. The Ellen Brook catchment is the largest sub-catchment of the Swan-Canning River system, contributing 6% of the total annual flow, and is the largest single contributor of nutrients to the system (WA Govt, 2011).

Ellen Brook has a surface catchment of 715km^2 (WRC, 2012). The Brook rises as Chandala Brook about 22km north-northwest of the site. The Brook is seasonal, flowing generally between May and November with an annual flow ranging from 2.1 to 48.6 GL (SRT, 2009).

2.3.3 Water Resources

The project area is within the Eclipse Hill sub-area of the Gingin Groundwater Area for the surficial and superficial aquifers, the Southern Scarp sub-area for the semi-confined (Mirrabooka) aquifer, the Cowalla sub-area for the confined Leederville-Parmelia aquifer and the Chandala sub-area for the Yarragadee aquifer. Groundwater allocations within the Gingin Groundwater Area are managed under the Gingin Groundwater Areas Allocation Plan (DoW, 2015).

Under the plan (as of 2015), the Eclipse Hill (superficial), Southern Scarp (Mirrabooka) and Cowalla (Leederville) sub-areas are over-allocated and no new allocations are available.

The DWER Water Register (https://maps.water.wa.gov.au/#/webmap/register) shows one groundwater licence for Lot 205 (GWL 152031, expiring November 2023), which is licensed to abstract up to 1,500 KL/yr from the Leederville aquifer via a bore on the adjacent Lot 206.

2.4 Water Quality

2.4.1 Groundwater

Groundwater samples have been collected from 13 bores within and around the site on various occasions since 2016. The sampling and analysis results are summarised in Tables 2.3 , 2.4 and 2.5.

Groundwater quality within the project area is moderate, which is to be expected given the soil types and the history of agriculture. Nitrogen and phosphorus concentrations are generally low to moderate

The groundwater shows mostly low acidity and sulphate contents, indicating that there is no evidence of acid sulphate soils. Dissolved metals concentrations are mostly low except for aluminium and zinc, which are slightly elevated across much of the site.

2.4.2 Surface Water

There was no flowing surface water anywhere on the subject land during any of the site inspections, so no surface water quality data for the site are available.

Table 2.3 Groundwater Quality – Physico-Chemical Parameters

Bore (Figure 6)	*Date*	*pH*	*EC (ms/m)*	*Salinity (ppm)*	*Hardness (mg/l $CaCO_3$)*	*Acidity (mg/L $CaCO_3$)*	*Alkalinity (mg/L $CaCO_3$)*	*Acidity/Alkalinity Ratio*	*Cl (mg/L)*	*SO_4 (mg/L)*	*Cl/SO_4 Ratio*
MW1	12/7/16	**3.9**	4.72			96	< 20	>4.8	1700	58	29.3
	2/9/16	**4.6**	2.8						430	190	2.3
	28/9/16	**4.5**	2.8						430	200	2.2
	22/11/16	**4.3**	2.8						500	600	0.8
	12/1/18	**4.3**	2.7						720	210	3.4
	30/5/19	**4.40**	2.30						420	570	0.7
MW2	12/7/16	**4.6**	2.8			59	< 20	>2.95	430	190	2.3
	2/9/16	**3.9**	5.8						1700	57	29.8
	28/9/16	**3.8**	5.7						1400	57	24.6
	22/11/16	**4.3**	5.5						1600	170	9.4
	12/1/18	**3.9**	5.5						1900	59	32.2
	30/5/19	**3.9**	4.70						1700	190	8.9
MW3	12/7/16	**5.8**	7.6			57	25	2.28	2100	130	16.2
	2/9/16	**5.5**	14						5200	180	28.9
	28/9/16	**4.6**	17						5000	180	27.8
	22/11/16	**4**	2.1						4800	480	10.0
	12/1/18	**3.9**	12						4300	140	30.7
	30/5/19	**4**	9.6						3400	370	9.2
MW4	12/7/16	**4.7**	8.73			67	< 20	3.35	4100	120	34.2
	2/9/16	**5.9**	6.4						1700	130	13.1
	28/9/16	**5.4**	6.5						1800	120	15.0
	22/11/16	**5.5**	7.1						2100	390	5.4
	12/1/18	**5.6**	7.2						2400	130	18.5
	30/5/19	**5.2**	6.70						2200	440	5.0
TB7	17/8/17	6.6	0.49	294	59	19	50	0.38	100	17	5.9

TB8	17/8/17	7	0.55	330	63	7	38	0.18	110	40	2.8
TB9	17/8/17	7.4	0.63	378	48	7	67	0.10	130	23	5.7
MB5	22/8/18	6.6	0.25	150	52	15	27	0.29	44	12	3.7
MB7	22/8/18	**6.3**	3.5	2100	170	77	65	0.45	1100	130	8.5
WB3	2/10/20	6.1	0.23	138	32	20	18	1.11	40	9	4.44
WB4	2/10/20	6.1	7.9	4740	620	24	19	0.95	1800	540	3.33
Aquatic Ecosystems[a]		6.5-8.0	0.12-0.3	72-180	ng	40[c]	ng	1[c]	ng	ng	
Irrigation[b]		6-8.5	1.3	780	60-350	ng	ng		350	ng	
Notes	ng denotes "no guideline". a. ANZECC (2000) Aquatic Ecosystem trigger values (Nutrient, pH and Conductivity are for lowland rivers; Dissolved Metals are for freshwater ecosystems 90% species protection) b. ANZECC (2000) Irrigation trigger values (long-term irrigation up to 100 years) c. DEC(20__) Oxidation indicator triggers for ASS-affected groundwater.										

Table 2.4 Groundwater Quality – Nutrients

Bore (Figure 6)	*Date*	*TN*	*TKN*	*NH_3*	*NOx*	*TP*	*FRP*
MW1	12/7/16	0.6	0.3	<0.01	**0.27**	**0.15**	
	2/9/16	**5.0**	0.7	0.02	**4.3**	**0.2**	
	28/9/16	**4.88**	0.6	<0.01	**4.3**	<0.25	
	22/11/16	**4.9**	0.9	0.01	**4**	**0.29**	
	12/1/18	**4.7**	0.2	0.02	**4.5**	-	
	30/5/19	**4.7**	0.3	<0.01	**4.4**	-	
MW2	12/7/16	**3.7**	<0.2	<0.01	**3.7**	**0.35**	
	2/9/16	0.5	0.3	<0.01	**0.24**	**0.1**	
	28/9/16	0.35	<0.2	<0.01	**0.35**	**0.27**	
	22/11/16	0.6	0.3	0.03	**0.33**	**0.2**	
	12/1/18	0.9	<0.2	0.04	**0.29**	-	
	30/5/19	0.28	<0.2	<0.01	**0.28**	-	
MW3	12/7/16	**1.5**	0.9	0.12	**0.56**	<0.05	
	2/9/16	0.8	0.6	0.24	**0.19**	**0.13**	
	28/9/16	**1.8**	1.6	0.35	**0.2**	**0.33**	
	22/11/16	0.5	0.4	0.13	0.09	0.05	
	12/1/18	<0.2	<0.2	0.08	<0.05	-	
	30/5/19	<0.2	<0.2	0.04	<0.05	-	
MW4	12/7/16	**1.7**	1.1	0.03	**0.63**	**0.32**	
	2/9/16	**2.2**	0.4	0.05	**1.8**	<0.05	
	28/9/16	**2.3**	0.4	0.02	**1.9**	**0.31**	
	22/11/16	1.1	0.4	0.08	**0.71**	**1.8**	
	12/1/18	0.5	<0.2	0.18	**0.45**	-	
	30/5/19	0.43	0.4	0.13	0.06	-	
TB7	17/8/17	0.6	0.4		**0.18**	0.04	<0.01

TB8	17/8/17	1.2	1		**0.25**	**0.3**	<0.01
TB9	17/8/17	**6.2**	2.4		**3.8**	**3.5**	<0.01
MB5	22/8/18	**2**	<0.2		**2**	**0.2**	<0.01
MB7	22/8/18	1.2	1		**0.21**	**0.2**	0.02
WB3	2/10/20	1.2	0.0		1	0.03	<0.01
WB4	2/10/20	1.4	0.3		0.12	0.03	<0.01
Aquatic Ecosystems[a]		1.2	ng		0.15	0.065	0.04
Irrigation[b]		5	ng		ng	0.05	ng
Notes	ng denotes "no guideline". a. ANZECC (2000) Aquatic Ecosystem trigger values (Nutrient, pH and Conductivity are for lowland rivers; Dissolved Metals are for freshwater ecosystems 90% species protection) b. ANZECC (2000) Irrigation trigger values (long-term irrigation up to 100 years).						

Table 2.5 Groundwater Quality – Metals

Bore (Figure 6)	*Date*	*Al*	*As*	*Ca*	*Cd*	*Cr*	*Cu*	*Fe*	*K*	*Hg*	*Mg*	*Mn*	*Na*	*Ni*	*Pb*	*Zn*
MW1	12/7/16	**18**	0.014	8	<0.0002	**0.085**		48		<0.0001		0.038		-	**0.017**	**0.037**
	2/9/16	**0.29**	<0.001	3.4	<0.0002	<0.001		<0.05		<0.0001		0.006		0.003	<0.001	**0.032**
	28/9/16	**0.2**	<0.001	<5	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.002	<0.001	**0.019**
	21/11/16	**0.52**	<0.001	2.4	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.002	<0.001	**0.017**
	12/1/18	**6.5**	0.009	<5	<0.0002	**0.047**		20		<0.0001		0.01		0.005	0.005	**0.026**
	30/5/19	**0.21**	<0.001	2	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.002	<0.001	0.012
MW2	12/7/16	**93**	0.072	4	<0.0002	**0.43**		360		<0.0001		0.087		-	**0.05**	**0.11**
	2/9/16	**4.3**	<0.001	11	<0.0002	<0.001		<0.05		<0.0001		0.028		**0.019**	<0.001	**0.056**
	28/9/16	**3.8**	<0.001	7.2	<0.0002	<0.001		<0.05		<0.0001		0.023		0.013	<0.001	**0.031**
	21/11/16	**4.1**	<0.001	8.3	<0.0002	<0.001		0.06		<0.0001		0.029		**0.016**	<0.001	**0.049**
	12/1/18	**5.3**	0.002	8.8	0.0002	**0.018**		5		<0.0001		0.028		**0.016**	0.003	**0.031**
	30/5/19	**3.3**	<0.001	7.8	<0.0002	<0.001		<0.05		<0.0001		0.025		0.013	<0.001	<0.005
MW3	12/7/16	**29**	0.029	38	<0.0002	**0.26**		170		<0.0001		0.012		-	**0.023**	**0.038**
	2/9/16	**0.35**	<0.001	110	<0.0002	<0.001		<0.05		<0.0001		0.11		0.009	<0.001	**0.054**
	28/9/16	**1.1**	<0.001	66	<0.0002	<0.001		<0.05		<0.0001		0.27		**0.015**	<0.001	**0.07**
	21/11/16	**5**	<0.001	37	<0.0002	0.001		0.47		<0.0001		0.12		0.012	0.003	**0.023**
	12/1/18	**3.6**	<0.001	32	<0.0002	0.001		<0.05		<0.0001		<0.005		0.009	**0.01**	0.013
	30/5/19	**3.6**	<0.001	35	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.008	<0.05	0.012
MW4	12/7/16	**130**	0.05	76	<0.001	**0.71**		360		<0.0005		0.11		-	**0.098**	**0.16**
	2/9/16	<0.05	<0.001	28	<0.0002	<0.001		<0.05		<0.0001		0.005		0.002	<0.001	**0.033**
	28/9/16	<0.05	<0.001	20	<0.0002	<0.001		<0.05		<0.0001		0.005		0.003	<0.001	**0.02**
	21/11/16	**0.1**	<0.001	35	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.004	<0.001	**0.032**
	12/1/18	**0.72**	0.002	44	<0.0002	**0.011**		2.8		<0.0001		<0.005		0.002	<0.001	0.011
	30/5/19	**3.6**	<0.001	42	<0.0002	<0.001		<0.05		<0.0001		<0.005		0.013	<0.05	<0.005
TB7	17/8/17	<0.1	<0.001	5.6	<0.002	<0.01	<0.01	0.04	0.9	<0.0002	11	-	54	<0.01	<0.01	0.01

TB8	17/8/17	<0.1	<0.001	9.1	<0.002	<0.01	<0.01	0.02	3.8	<0.0002	9.9		60	<0.01	<0.01	<0.01
TB9	17/8/17	0.3	<0.001	7.2	<0.002	<0.01	<0.01	0.16	6.6	<0.0002	7.2		80	<0.01	<0.01	<0.01
MB5	22/8/18	0.1	<0.002	17	<0.002	<0.002	<0.01	0.08	2.3	<0.0002	8.8		29	<0.01	<0.01	<0.01
MB7	22/8/18	0.2	<0.002	54	<0.002	0.003	<0.01	4.3	8	<0.0002	67		630	0.01	<0.01	**0.07**
WB3	2/10/20	0.03	<0.002	4.5	<0.0001	<0.001	<0.001	0.01	4.2	<0.0001	5		22	0.002	<0.001	<0.005
WB4	2/10/20	<0.01	<0.002	18	<0.0001	<0.001	<0.001	<0.01	4.5	<0.0001	140		1200	0.008	<0.001	0.013
Aquatic Ecosystems[a]		0.08	0.136	ng	0.0004	0.006	0.0018	ng	ng	0.0019	ng		ng	0.013	0.0056	0.015
Irrigation[b]		5	0.1	ng	0.01	0.1	0.2	10	ng	0.002	ng		230	0.2	2	2
Notes	ng denotes "no guideline". a. ANZECC (2000) Aquatic Ecosystem trigger values (Nutrient, pH and Conductivity are for lowland rivers; Dissolved Metals are for freshwater ecosystems 90% species protection) b. ANZECC (2000) Irrigation trigger values (long-term irrigation up to 100 years).															

2.5 Vegetation

The project area is largely cleared of native vegetation, consisting mostly of farm paddocks and current and former quarries. All of Lot 204, most of Lot 205 and the southern part of Lot 203 are cleared paddocks with some scattered mature trees, either native or planted. Native vegetation is present in the central east of Lot 205, the northern end of Lot 202 and the north of Lot 203.

Plantecology (2020) surveyed the vegetation and flora of the project area in November 2019. 360 Environmental (2015) undertook a vegetation survey of Lots 202 and 203 in March 2015. Neither survey found any vegetation dependent on wetlands or shallow groundwater.

2.6 Land Uses and Potential Contamination

Historic Landgate aerial photography shows that the project area has been largely cleared and used for farming since at least 1965. Quarrying has been underway on Lots 202 and 203 since before 1977.

The DWER Contaminated Sites Database (https://dow.maps.arcgis.com/apps/webappviewer/index.html?id=c2ecb74291ae4da2ac32c441819c6d47) shows no record of any contaminated sites in the project area. The nearest mapped contaminated site is a service station in Muchea, 3.3km north-west of the project area. There is no potential for this contamination to directly affect the project area.

The former clay quarry on Lots 202 and 203 is currently being backfilled with inert waste such as building rubble prior to rehabilitation. The backfilling and rehabilitation are being undertaken under the terms of a DWER Licence (L9181/2018/1), which carries conditions including control of waste acceptance and prevention of pollution.

There is no visual or photographic evidence of any contaminating activities now or in the past within the project area.

3.0 WATER USE SUSTAINABILITY

3.1 Water Supply

Water will be required for both potable and non-potable purposes. The Leederville aquifer is likely to be the preferred source for potable supply due to its generally higher quality and lower risk of contamination. Non-potable groundwater demand is likely to be limited to landscape irrigation, particularly within Precinct 4 (Lots 204-205), as industries within this precinct will be restricted to those with low water usage.

Potable water will be supplied to the project area by a licensed water provider. A proposed water project for the Lower Chittering Valley is currently in development by Aqua Ferre Pty Ltd, which includes construction of a water treatment facility on Lot 2 Reserve Rd, Chittering. Aqua Ferre is in the process of applying for a Water Service Provider's Licence from the Economic Regulation Authority (ERA). Aqua Ferre has confirmed that it has the capacity within its proposed licence to supply Precinct 3 with potable water. Discussions with Aqua Ferre are ongoing. A letter from Aqua Ferre confirming this understanding is attached in Appendix E.

For non-potable uses, purchase of water entitlements from existing licensed users within or outside of the project area is likely to be necessary. The landowners will negotiate with existing licence holders within and outside of the project area with a view to purchasing an existing groundwater allocation, and will submit a groundwater licence application to the DWER in due course.

3.2 Water Efficiency Measures

Precinct 2 (Lots 204-205) will be designed as a low-water-use precinct. Only industries with low water consumption will be permitted in this precinct. This is driven largely by the hydrology of the site and its proximity to Ellen Brook, which demands that wastewater disposal be minimised. Precinct 4 (Lots 202-203) will accommodate general industry with less restrictions on water use or wastewater generation; however, industries will need to demonstrate that they can safely dispose of waste water on site. Water use will effectively be restricted by the limited availability and corresponding cost of groundwater in the area.

Potable water use within the project area will be limited to consumption for domestic use in toilets, bathrooms and kitchens. The Shire of Chittering Town Planning Scheme No. 6 limits wastewater generation in industrial zones to 5,400 litres per hectare per day. If it is assumed that all potable water used will ultimately become wastewater, it can be calculated that the maximum allowable potable water demand for the 185ha precinct will be approximately 1,000 KL per day.

Cossill & Webley (2018) estimated total potable water demand for Lots 202-205 at 96ML per year, based on a study by GHD for the Karratha Gap Industrial Estate.

Groundwater will be used mainly for irrigation of landscape plantings and swales. These areas will be irrigated only during the establishment stage (one or two years). The Landscape Master Plan estimates total plantings of 13.7ha of sedges, shrubs and trees within the project area.

The water demand for irrigation in a given year will depend on the staging of subdivision and development. If the project area were developed over ten years, the demand for irrigation water (at the DWER's default rate of 4,500 KL/ha/yr) over that ten year period would be in the order of 6.2 ML/yr, decreasing in subsequent years.

4.0 LAND CAPABILITY FOR ON-SITE EFFLUENT DISPOSAL

4.1 Published Land Capability Ratings and Constraints

King & Wells (1990) mapped the western part of the project area as Guildford Formation (Gf2): "Plain with imperfectly drained yellow duplex soils with sand to sandy loam topsoil", and the eastern part as Reagan (Re2): "Gentle slopes with deep, well drained brownish or earthy sands situated below Re1". They rated the capability of these landform types for on-site effluent disposal as follows:

Landform	*Capability*	*Limiting Factor(s)*
Gf2	Fair	Microbial purification ability, soil absorption ability
Re2	High	None

The limitations on the capability of the Gf2 landform unit relate to the imperfect drainage of the unit due to its silty soils and sometimes occurrence of clay horizons. The drilling carried out in March 2020 showed that the soils in this unit on the site possessed a sandy or pebbly silt profile to more than 2m depth, suggesting that they were well drained. Permeability testing at six locations by Douglas Partners (2020) showed permeability in the top metre of soil ranging from 0.9 to 8.6 m/day, with an average of 3.3m/day and a median of 4.75m/day. These findings suggest that the capability of the Gf2 soils on the site is higher than the average for the unit, and poses no significant constraint to effluent disposal.

The Government Sewerage Policy maps most of the project area as being within a Sewage Sensitive Area (SSA) due to its location within the catchment of the Swan-Canning Estuary and/or within 1km of significant wetlands. The Policy places additional site requirements in terms of groundwater clearance and lot density on effluent disposal within SSAs, including a lower lot size limit of 1ha. Figure 1 shows the SSA boundaries over the subject land.

The northern part of Lot 202 and the north-east of Lot 205 are mapped as SSA by the GSP under the category of land "…within one kilometre up-groundwater-gradient and 250 metres down-groundwater-gradient of a significant wetland; or where the groundwater gradient is unknown or seasonably variable within one kilometre of the significant wetland…". Closer inspection shows that the wetland in question, a Conservation Category dampland located 815m north of the project area, is upgradient of the site and maintained by surface water inflow from further upgradient. There appears to be no way that effluent disposal at the site could affect this dampland, and therefore the SSE mapping in this case is considered invalid. The GSP allows for SSE mapping to be refined through site-specific investigations as in this case.

4.2 Soil Permeability

Australian Standard AS1947:2012 - *On-site Domestic Wastewater Management* recommends a minimum hydraulic conductivity of 0.06m/day for on-site effluent disposal without special design. The testing method set out in the *Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974* implies a minimum conductivity of 0.11m/day without specific approval by the Director-General of Public Health. Permeabilities of this order are generally found in weakly structured or massive clays.

Douglas Partners (2020) undertook constant-head permeability testing at six sites and at depths of 0.2 – 0.8 metres. The tests returned permeabilities ranging from 0.9 – 8.6 m/day, with a mean of 3.3m/day and a median of 4.75m/day. Test pumping during sampling of one on-site bore (WB3) indicated a hydraulic conductivity in the depth range of 2.6m to 5.1m in the order of 0.14 m/day. This decline in permeability with soil depth is to be expected.

4.3 Phosphorus Retention Index

The Health Department's draft *Code of Practice for Onsite Sewage Management* (2012) recommends a PRI of at least 20 for soils beneath effluent irrigation areas.

Previous experience has shown that the gravelly and silty clay soils of the Guildford Formation and other alluvial and colluvial soils generally have moderate to very high PRI.

Fill used in effluent disposal areas will have a PRI of at least 20, in line with the Health Department's draft Code of Practice (2012).

4.4 Depth to Groundwater

The Government Sewerage Policy (GSP) (WA Govt, 2019) requires that land used for effluent disposal in sewage sensitive areas must have a minimum clearance of 1.5m from the effluent discharge point (e.g. base of leach drain or ATU drip lines) to the highest groundwater level. Under the Policy, the required clearance can be achieved by filling but not by drainage. Outside of sewage sensitive areas, the minimum groundwater clearance requirement for loams and heavy soils is 0.6m.

The groundwater measurements carried out in August 2018 indicate that the average annual maximum groundwater level (AAMGL) is more than 1.5m below the ground surface across the site (Figure 6). On-site effluent disposal in accordance with the GSP should be possible without filling. This will be confirmed by further groundwater measurements prior to subdivision.

4.5 Slope

The Government Sewerage Policy prohibits on-site effluent disposal on land with a slope of more than 1 in 5 (20%), in order to prevent runoff of effluent.

The slope of the subject land is mostly less than 5% but does exceed 20% in some parts of Lots 202 and 203. Areas of greater than 20% will be excluded from effluent disposal or will be recontoured before construction to reduce the slope to less than 20%.

4.6 Watercourse Setbacks

The Department of Water & Environmental Regulation (DWER, 2016) recommends that effluent disposal systems should be located at least 100m from waterways and wetlands. The Government Sewerage Policy requires a 100m setback from waterways, significant wetlands and drains discharging directly into waterways or significant wetlands without treatment.

For the purposes of these requirements, “waterway” is defined as a natural watercourse as defined in the *Rights in Water and Irrigation Act 1914*. Based on site inspections and historical aerial photography as described in Section 2.3.2, there are no waterways within the project area.

The Government Sewerage Policy provides that reduced setbacks from drains may be allowed where it can be demonstrated that the reduced setbacks will not have a significant impact on the environment or public health. In this case, a reduced setback of 6m from subsoil drains is considered necessary and justified because:

- the subsoil drains will be located upslope of the effluent disposal fields (Section 4.8) and will drain only clean groundwater that has been filtered through the soil profile;
- all effluent disposal in high-groundwater areas will be by means of alternative effluent disposal systems with nutrient removal capability (Section 4.7);
- the drained water will be treated by infiltration and vegetation uptake within the roadside swales before being released to downstream watercourses (Section 5.2.2);
- a greater separation would reduce the effectiveness of the subsoil drains in limiting groundwater rise within the effluent disposal areas; and
- the clayey soils and high PRI of the site (Section 2.2.5) mean that the drained water will be of high quality.

Setbacks of less than 100m from surface drains (roadside bioretention swales) are considered acceptable and necessary because:

- all effluent disposal within 100m of drains will be by means of alternative effluent disposal systems with nutrient removal capability (Section 4.7);

- the clayey soils and high PRI of the site (Section 2.2.5) mean that leachate emanating from the effluent disposal systems will be of high quality;
- the water in the roadside swales will be treated by infiltration, vegetation uptake and soil adsorption before it reaches any downstream water body (Section 5.2.2); and
- imposing a requirement for 100m setbacks would severely constrain and in some cases prevent the siting of effluent disposal systems on lots.

The differing sized lots within the subject site will offer a range of options for siting of development elements and effluent disposal systems within each lot. At the time of subdivision and development approval, the siting of individual effluent disposal systems will be subject to review and approval by the Shire of Chittering and other agencies.

It is concluded that the proposed system of effluent disposal in the project area will pose minimal risk to the environment or public health and will meet all setback requirements set out in current government policies.

4.7 System Selection and Location

All effluent generated within the subdivision will be treated and disposed by means of individual on-site effluent disposal systems. All lots in low-lying areas will be required to employ nutrient-attenuating alternative systems such as aerobic treatment units (ATUs) with high-PRI irrigation areas or modified leach drain systems (e.g. Filtrex). Lots in higher areas or with deeper groundwater may employ conventional septic systems and leach drains.

ATU irrigation areas will be filled if necessary in order to provide 1.5m clearance from the AAMGL to the effluent drip lines as required under the Government Sewerage Policy (2019), allowing for 0.3m groundwater mounding and 0.2m soil cover over the drip lines. Fill used for this purpose will be either sourced from on site or imported. The soil will be tested to confirm a PRI of at least 20.

The ATU irrigation area or leach drain length on each lot will be sized to suit the expected population of the lot. As a rough rule of thumb, each full-time employee on site will require approximately 23m^2 of effluent irrigation area or 4.4m of leach drain. Treated ATU effluent may be disposed of via leach drains, which may reduce the area required for disposal by up to two thirds at the cost of a greater height of fill.

The effluent disposal requirements of each lot will vary depending on the soil profile, groundwater depth, risk of saturation and expected site population. Site testing on each lot prior to development will be required to determine the location and type of effluent disposal system.

4.8 Subsoil Drainage

If fill is used on any lots to created raised pads for effluent disposal, subsoil drains will be placed upslope of the filled pad to minimise groundwater rise into the fill. The drains will be placed at least 6m upslope from the drip lines or leach drains. The drains will be set with their inverts at or above the AAMGL and will discharge via free-draining outlets into the roadside swales, where the water will be further treated by infiltration and vegetation uptake within the swales. Because the water will be draining from high-PRI soil (see Section 2.2.5), it will be of high quality.

5.0 STORMWATER MANAGEMENT STRATEGY

5.1 Principles and Objectives

The stormwater management strategy aims to comply with the principles and objectives for stormwater management identified in the *Stormwater Management Manual for WA* (DoW, 2004) and *Better Urban Water Management* (WAPC, 2008).

Nutrient concentrations and loads in water leaving the site will be managed to comply with the targets of the draft *Swan Canning Water Quality Improvement Plan* (SRT, 2009) for the Ellen Brook catchment, as follows:

- Winter median TP concentration: 0.1 mg/L
- Winter median TN concentration: 1.0 mg/L
- Annual TP yield: 0.03 kg/ha
- Annual TN yield: 0.31 kg/ha.

5.2 Drainage Management System

The drainage system will be designed to maintain surface flow rates and volumes within and from the developed site at their pre-development levels. The drainage design presented here is conceptual and will be refined in the detailed subdivision designs. Figure 8 shows an overview of the conceptual drainage design.

The priorities for managing the various sizes of storm event will be:

- 1 year ARI Infiltrate all flows as close to the source as possible. Maintain pre-development flow rates and volumes. Minimise export of nutrients and sediments.

- 5 year ARI Detain water prior to discharge. Maintain pre-development flow rates and volumes. Maintain amenity and serviceability. Prevent scouring and damage.

- 100 year ARI Maintain pre-development flow rates and volumes. Prevent flooding and damage.

5.2.1 Through Drainage

The existing drainage line entering at the north-east of Lot 202 will be realigned and consolidated in a vegetated swale within a road reserve. The swale will be sized to accommodate the flow from a 100-year ARI critical storm from both the upstream and internal catchments. The swale will be configured as described in Section 5.2.2.

5.2.2 Lot Drainage

Runoff from roofs, paved surfaces and hardstand areas within private lots from storms up to 1-year ARI 1-hour duration (about 15mm) will be retained and infiltrated within each lot in soakwells, basins and/or landscaping areas. These will be subject to detailed design on individual lots.

The in-lot drainage structures will also be sized to capture and detain the runoff from roofs, paved surfaces and hardstand areas from critical storms up to 100-year ARI. In most cases the critical storm (producing the highest peak flow rate) will be of less than twenty minutes' duration, and the volume of flow will be less than that from the 1-year 1-hour storm.

All runoff from within each lot will be directed to the bioretention/detention basin. Overflows from the basins will run into the roadside bioretention swales, either directly or via drainage easements for those lots that do not have a downslope road frontage.

On lots that front a public road on the downslope side, the part of the lot near the road will be filled if and as necessary to raise its level above the outer embankment of the roadside swale and allow overflow drainage to flow into the roadside swale. The height of filling will generally be between 0m and 0.8m. Depending on the slope of the lot, the filling will extend between about 10m and 90m from the lot boundary. This filling will be carried out by the subdivider/developer during the construction of the roads. Figure 9 shows a conceptual layout and profile of a typical lot in this situation.

On lots that adjoin another lot on the downslope side (i.e. that do not have a downslope road frontage), the in-lot basin will overflow via a drainage channel or bund along the downslope lot boundaries to the nearest roadside swale. Where the flow needs to cross another lot before reaching the road reserve, an easement nominally 10m wide will be created in favour of the Shire of Chittering. Swales and/or bunds may be created within the easements as necessary to direct the overflow. These swales and bunds will be constructed by the developer at the time of creation of the lots. Figure 7 shows the conceptual layout of the drainage easements. Figure 9 shows a conceptual layout of a typical lot of this type.

5.2.3 Internal Road Drainage

Runoff from public roads from up to the 1-year ARI 1-hour storm will be retained and infiltrated in roadside swales. The inverts of the swales will be at or above the AAMGL. Figure 8 shows the preliminary layout of the roadside swale network.

The swales will be constructed with low internal weirs set at a height that captures the 1-year 1-hour storm. The configuration of the swales and internal weirs will be subject to detailed design including:

- the height of the swale inverts at or above the AAMGL;

- the width and composition of the swale floors, designed to maximise nutrient uptake;
- planting of the swales with dense sedges and shrubs to maximise nutrient uptake; and
- the possible inclusion of underdrains within the swales to promote infiltration of 1-year ARI flows.

Figure 10 shows conceptual profiles of the roadside swales.

5.2.4 Major Storm Drainage

Road runoff from larger storms will overtop the weirs and flow along the swales to the western boundary, where it will enter the roadside drains and culverts on Great Northern Highway. The rate and volume of drainage out of the site will be controlled to be no greater than those existing before development.

Figure 8 shows the overall drainage layout and the 100-year ARI flow paths. Table 5.1 summarises the expected 100-year flows in the swales, including both runoff from road reserves and overflows from lots (conservatively assuming all lots are developed fully to hardstand). The flow calculations are detailed in Appendix F.

The drainage from the site flows beneath Great Northern Highway via five culverts, as shown on Figure 8. These were constructed in the context of a rural setting, in which culverts may be designed to allow some ponding upstream on adjacent land during major storms.

Survey of the culverts adjacent to the site, coupled with data provided by Main Roads WA from its IRIS database, enabled the flow capacities of he culverts to be calculated using Manning's Open Channel Flow Formula. The calculations show that, under current land uses, all of the culverts have sufficient capacity to carry the flow from a 100-year ARI critical storm without upstream ponding. As the post-development flows will be controlled to be no greater than the pre-development flows, these too will be within the capacity of the culverts. Table 5.2 shows the culvert flow calculations.

Table 5.1 Preliminary Swale Sizing – 100 yr ARI Critical Storm

Swale Segment (Figure 8)	*Contributing Segments*	*Contributing Lots*	*Segment Cumulative Peak Flow (L/s)*[1]	*Lots Cumulative Peak Flow (L/s)*[2]	*Total Cumulative Peak Flow (L/s)*	*Long Slope*[3]	*Height in Channel (m)*[4]	*Height Over 0.4m Weir (m)*[4]
A1	A1,C1	2,3	81.46	292.30	373.76	0.0054	0.48	0.21
A2	A2-A5	1,6,13-18,23N,24N	245.56	1413.11	1658.67	0.0202	0.70	0.33
A3	A3-A5	13-18,23N,24N	180.71	1071.36	1252.07	0.0021	0.75	0.47
A4	A4,A5	14-18,23N,24N	98.01	903.74	1001.75	0.0221	0.55	0.21
A5	A5	18,24N	41.52	257.38	298.90	0.0522	0.25	0.09
B1	B1	7-10	95.85	583.34	679.19	0.0063	0.61	0.24
B2	B1,B2	7-10	152.98	583.34	736.32	0.0204	0.49	0.18
C1	C1	4	32.62	314.51	347.13	0.0033	0.52	0.20
D1	D1	19-22,23S,31	117.72	903.62	1021.34	0.0122	0.63	0.25
D2	D1-D7	11,12,19-22,23S,24S,25-32,47-52	605.90	4094.58	4700.49	0.0223	0.80	0.50
D3	D3-D7	24S,25-30,47-52	346.64	2322.34	2668.98	0.0091	1.02	0.47
D4	D4,D5	49-52	132.34	703.90	836.24	0.0631	0.39	0.14
D5	D5	51,52	44.03	346.82	390.85	0.0321	0.32	0.13
D6	D6	47,48	82.48	379.06	461.53	0.0504	0.31	0.12
D7	D4-D7	47-52	265.38	1082.96	1348.34	0.0211	0.63	0.25
D8	D8	42	50.18	160.67	210.85	0.0294	0.24	0.09
D9	D9	33-38	39.48	957.54	997.02	0.0003	1.38	0.64
D10	D10	41, 43-46		901.21	901.21	0.0384	0.63	
D11	D8,D9,D10,D11	33-46		2378.94	2378.94	0.0093	0.57	
E1	E1	53,54	68.42	319.46	387.89	0.0205	0.36	0.13
E2	E2,E3	55-58	47.41	671.56	718.98	0.0282	0.44	0.17
E3	E3		48.44		48.44	0.0162	0.13	0.07

1. Based on runoff coefficient for the 100-year ARI storm of 0.85.
2. Based on 100% development of lots to hardstand with runoff coefficient for the 100-year storm of 0.85.
3. Based on existing topography; this may change with filling and levelling of Lots 202-203.
4. Calculated using Manning's Open Channel Flow Formula (Fang, 2000) for a trapezoidal channel with 1m base and 1:3 side slopes, and Manning's *n* between 0.04 and 0.4 depending on flow depth vs vegetation height (DoW, 2004).

Table 5.2 Culvert Flows

Culvert Figure 8)	*No. & Size*	*Length*	*Slope*	*Capacity (m^3/s)[1]*	*Flow (m^3/s)[1]*		
					1yr	*4.48yr*	*100yr*
CH34.79	4 x 1.2x0.75	25.7	0.0098	14.28	1.54	2.21	4.28
CH34.50	2 x 1.2x0.75	34.2	0.0118	7.93	0.06	0.11	0.21
CH34.23	2 x 0.45	33.4	0.0096	0.61	0.08	0.13	0.24
CH33.70	3 x 1.2x0.6	16	0.0108	8.38	1.26	2.16	4.15

1. Calculated by Manning's Open Channel Flow Equation as set out in Fang (2000) using pipe roughness coefficient of 0.012 (wet-cast concrete).

5.3 Surface Water Quality Management

The drainage system will be designed to maximise on-site retention of nitrogen and phosphorus. This will be achieved by:

- Retaining and infiltrating all lot runoff from storms up to 1-year ARI within the lots.
- Infiltrating all road runoff from storms up to 1-year ARI 1-hour duration (estimated by the DWER to carry more than 99% of total flows and nutrients) in vegetated bioretention swales with a minimum soil PRI of 15.
- Conveying all runoff from storms between 1-year and 100-year ARI in densely vegetated bioretention swales to allow suspended particles to be filtered out.

5.4 Maintenance

The drainage system has been designed to require minimal maintenance. The following will be required to ensure that the system continues to function as designed:

- Regular (possibly annual) cleaning of side entry and junction pits, inlet pits and small culverts. More frequent cleaning may be required during the construction phase.
- Tending and maintenance of swales and other vegetated drainage features to remove litter, control weeds and encourage the growth of native species.
- Pruning, mulching or removal of vegetation in swales as necessary to maintain ground fuel loads below 8 tonnes/ha.

6.0 GROUNDWATER MANAGEMENT STRATEGY

6.1 Groundwater Levels

The drainage system for the site is designed to minimise changes to the existing groundwater regime. Roadside swales and subsoil drains will be set with their inverts at or above the AAMGL. Subsoil drainage within lots will be limited to filled areas used for buildings or effluent disposal.

6.2 Subsoil Drainage

Subsoil drainage may be employed within some lots where necessary to maintain existing maximum groundwater levels beneath building pads and effluent disposal areas. The subsoil drains will discharge into roadside swales via free-draining outlets.

Subsoil drains may also be employed within road reserves to prevent groundwater rise from damaging the road base and pavement.

All subsoil drains will be set with their invert at or above the AAMGL. Therefore, changes to the groundwater hydrology of the site will be minimal.

6.3 Groundwater Quality

The sampling undertaken to date indicates that the groundwater beneath the site contains low to moderate concentrations of nitrogen and phosphorus. This is to be expected given the nature of the soils and the land use history of the site.

The relationship between nutrient inputs and exports is complex, especially in the case of phosphorus, which travels through the soil profile as a “front” in a complex series of adsorption and desorption reactions. Nitrogen is subject to denitrification and mineralisation in the soil and groundwater. As a result, nutrient exports from the site at present will be a reflection of nutrient inputs over the last several decades, modified by soil hydrology and nutrient retention capacity.

The aim of nutrient management will be to limit nutrient inputs to the site so that nutrient outputs are minimised. As an industrial precinct, the area of fertilised gardens and lawns will be small. Landscaping areas including street trees, swales and vegetation buffers will be established with minimal fertilisers and irrigation.

Measures available to minimise nutrient inputs and exports in the development will include:

- regular street sweeping to remove accumulated contaminants; and
- selection of native species with low water and fertiliser requirements for public open space and landscape areas.

7.0 LANDSCAPING STRATEGY

Landscaping of the site will focus on the use of species with low water demand. Plantings will include bioretention swales and basins, landscape buffers (to a minimum of 10% of the area of each lot), effluent irrigation areas and street trees. The plantings will not be irrigated after the establishment phase. No turf grass will be planted.

The plantings in swales, basins and effluent irrigation areas will include a high proportion of species recommended in the Monash University (2014) *Vegetation Guidelines for Stormwater Biofilters in the South-West of Western Australia*.

Fertiliser use will be minimal. New tube stock plantings will be fertilised with slow-release nitrogen and phosphorus tablets on establishment and thereafter will be unfertilised.

The bioretention basins and swales will be densely planted with inundation-tolerant species including sedges and low shrubs in order to stabilise the basins and maximise their ability to take up nitrogen from the water.

The total area to be planted is approximately 13.7 hectares. If all of this area were planted simultaneously during the establishment phase, approximately 62 ML of water would be required to irrigate the new plantings for the first year. As the project area is likely to be developed in a number of stages, the requirement for irrigation water is likely to be spread out over a number of years, with only a small part of the total demand being required in any one year.

The density of planting will be controlled to keep flammable ground fuel loads below 8 tonnes/ha, in accordance with the Bushfire Hazard Assessment (Eco logical Australia, 2020).

Figure 11 shows the conceptual landscaping strategy.

8.0 MONITORING

Baseline water quality results for the site are shown in Tables 2.3, 2.4 and 2.5. Groundwater levels and quality will continue to be monitored and compared against baseline levels and relevant guidelines. Water quality in surface drains will be monitored upstream and downstream of the project area to determine what (if any) impacts the development may be having on the watercourses.

Water quality sampling will be conducted nominally once a year in late winter. Detailed water monitoring and response procedures will be developed as part of the Urban Water Management Plans to be prepared for each stage of subdivision.

9.0 IMPLEMENTATION AND FURTHER MANAGEMENT PLANS

Further planning and subdivision of the subject land will be carried out in accordance with the general water management principles set out in this LWMS. Subdivision of lots in the structure plan area may be carried out by individual owners as they see fit, in accordance with the framework of the LWMS.

An Urban Water Management Plan (UWMP) will be prepared as a condition of subdivision approval for each stage of subdivision. The UWMP will present the detailed design of the stormwater drainage system within that stage.

The developer of each stage of subdivision will maintain the drainage system, landscaped areas and water monitoring program within that stage until two years after that stage of subdivision is completed. At the end of that time the responsibility for monitoring and management will be handed over to the Shire of Chittering.

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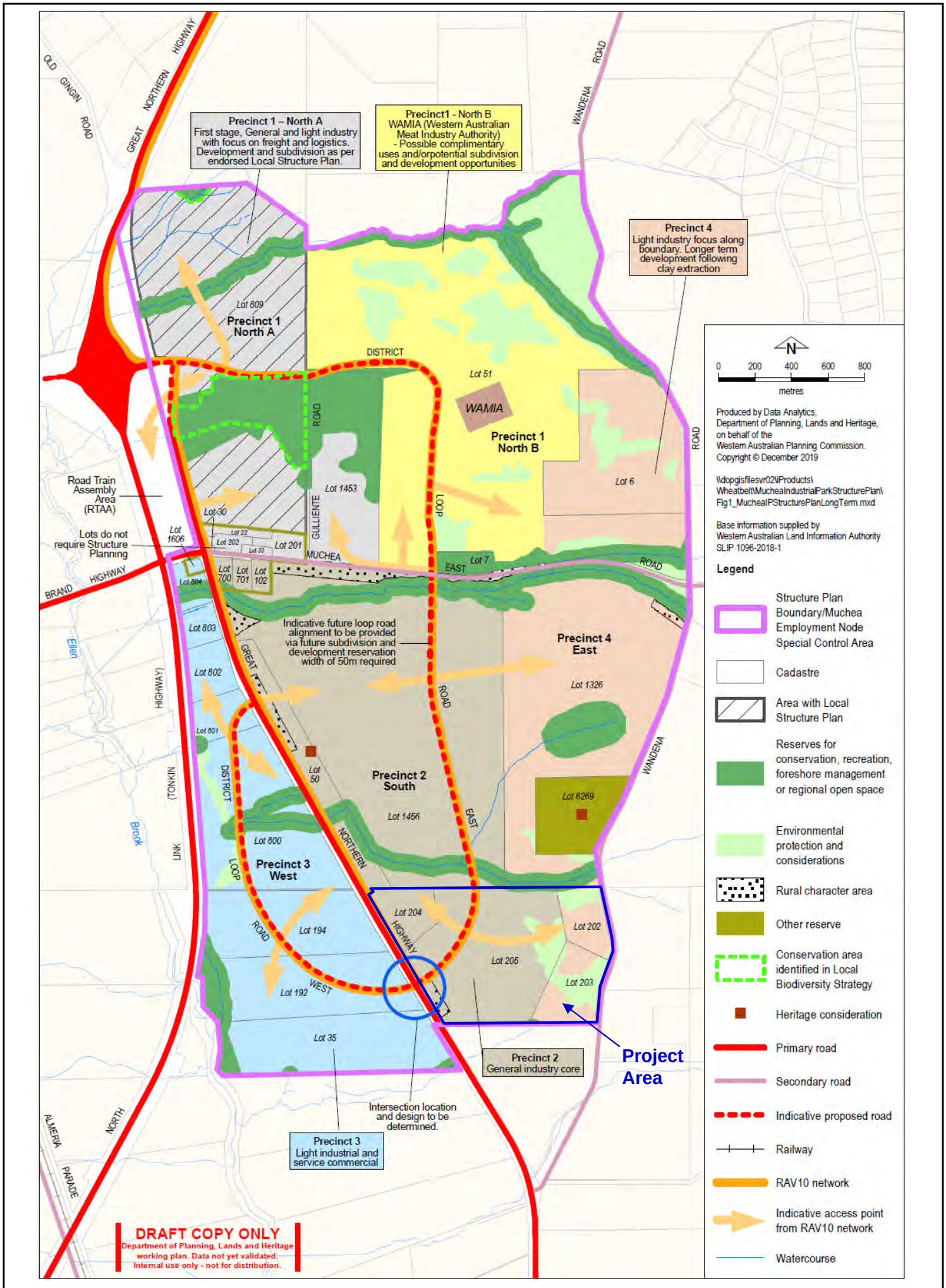
Figures



Source: WAPC, 2019

Figure 1

DRAFT MUCHEA INDUSTRIAL PARK STRUCTURE PLAN

bayley environmental services

Figure 2

THE SITE AND SURROUNDINGS

Image source: Google

bayley environmental services

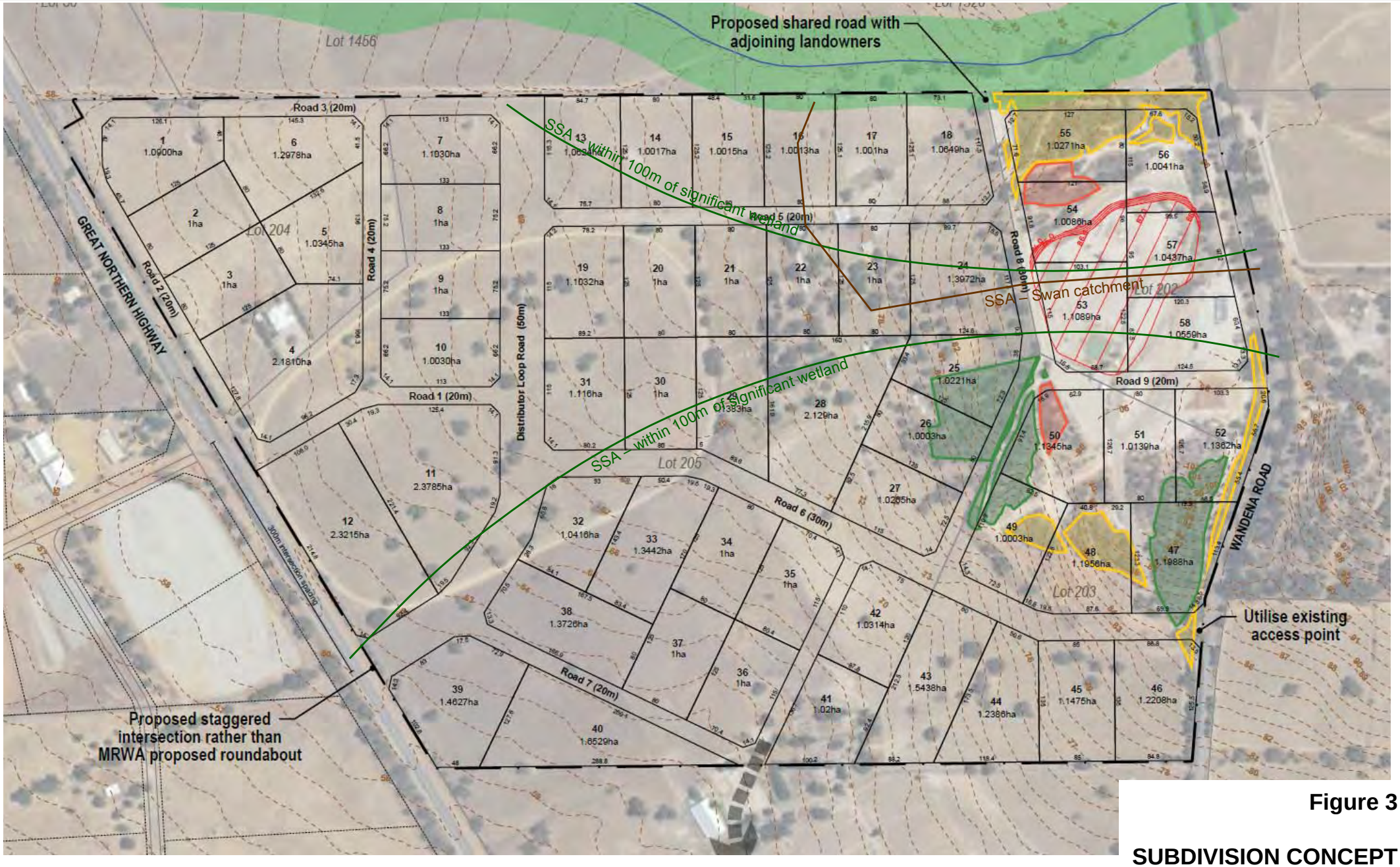


Figure 3

SUBDIVISION CONCEPT

bayley environmental services

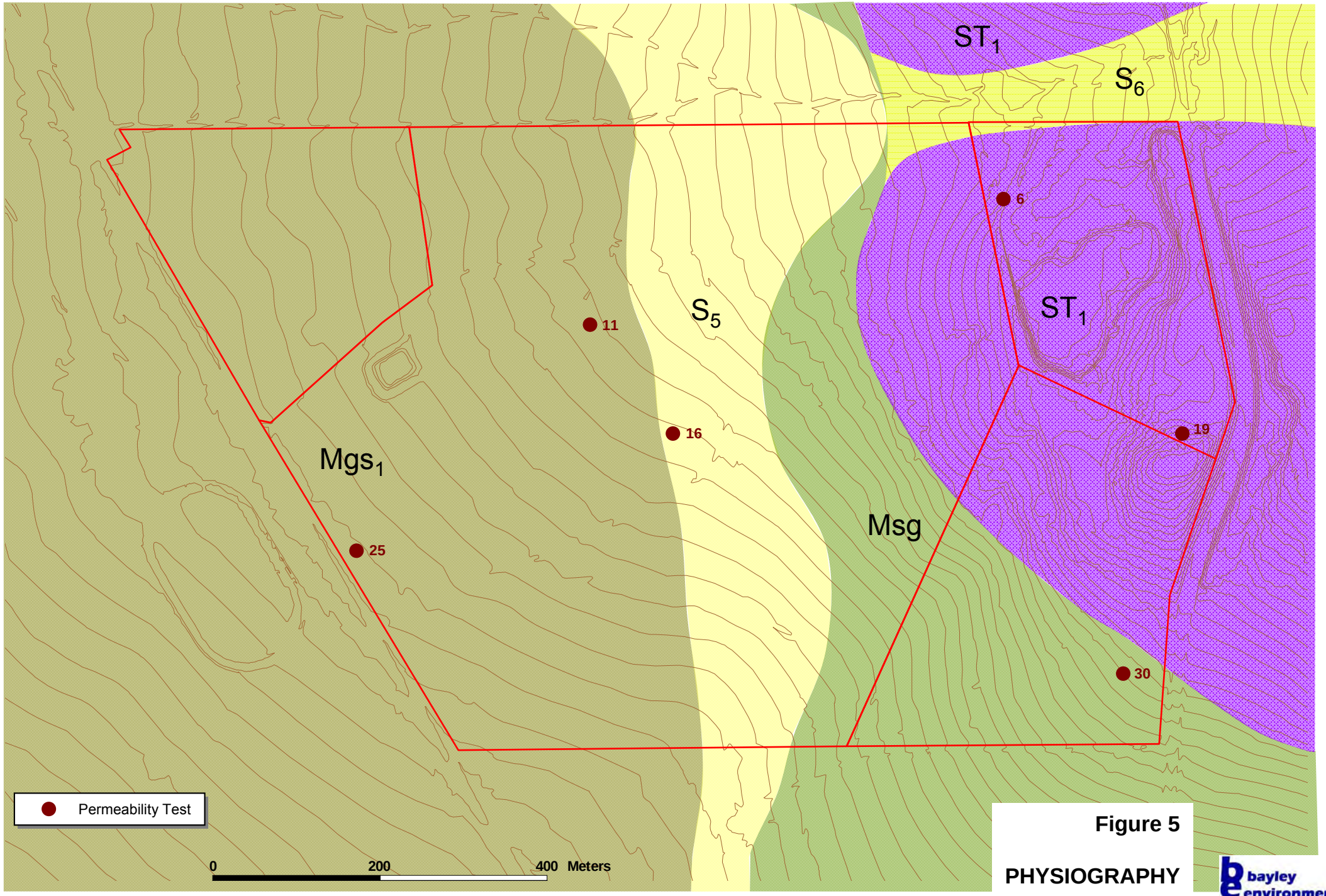


Figure 5

PHYSIOGRAPHY

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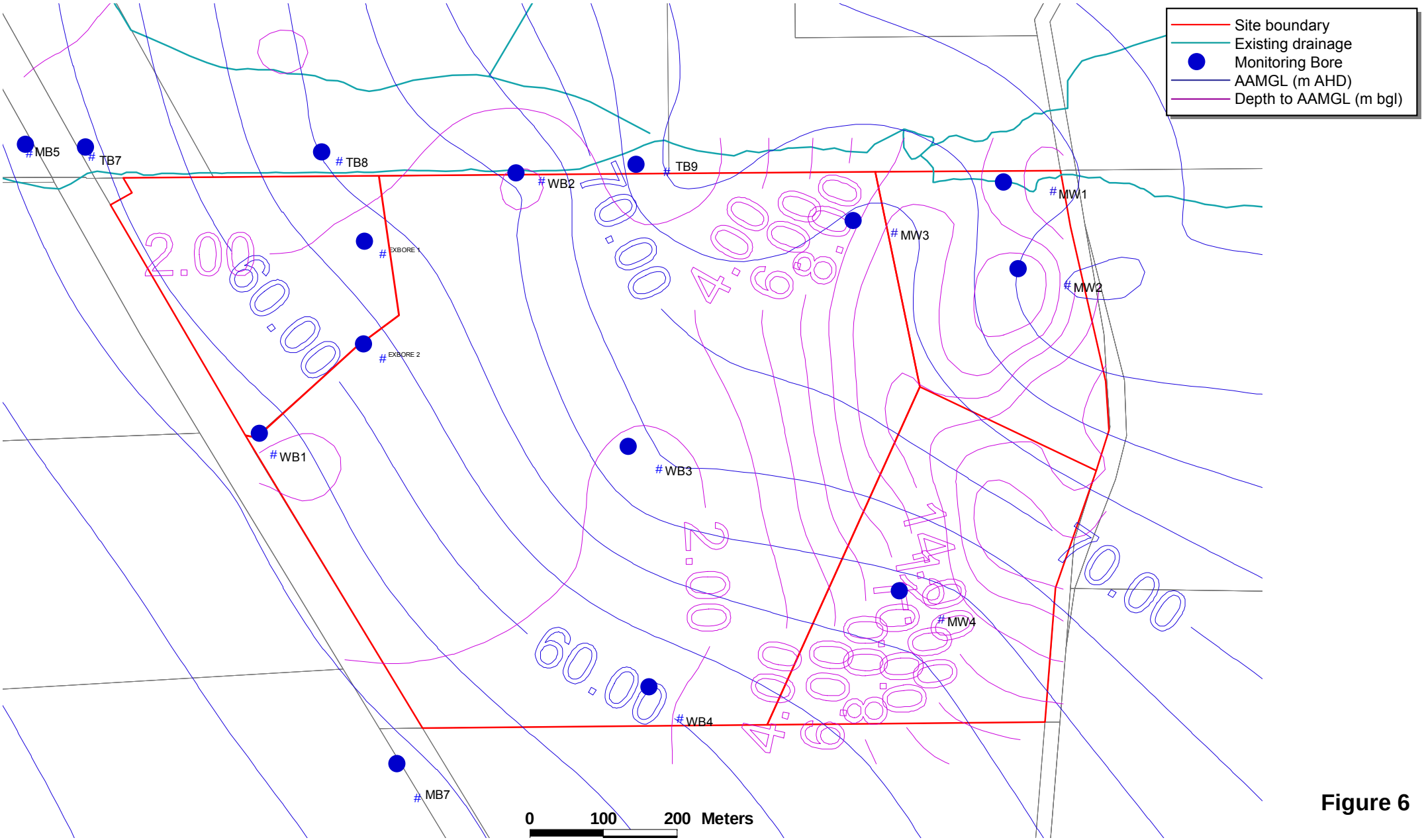

Figure 6

HYDROLOGY

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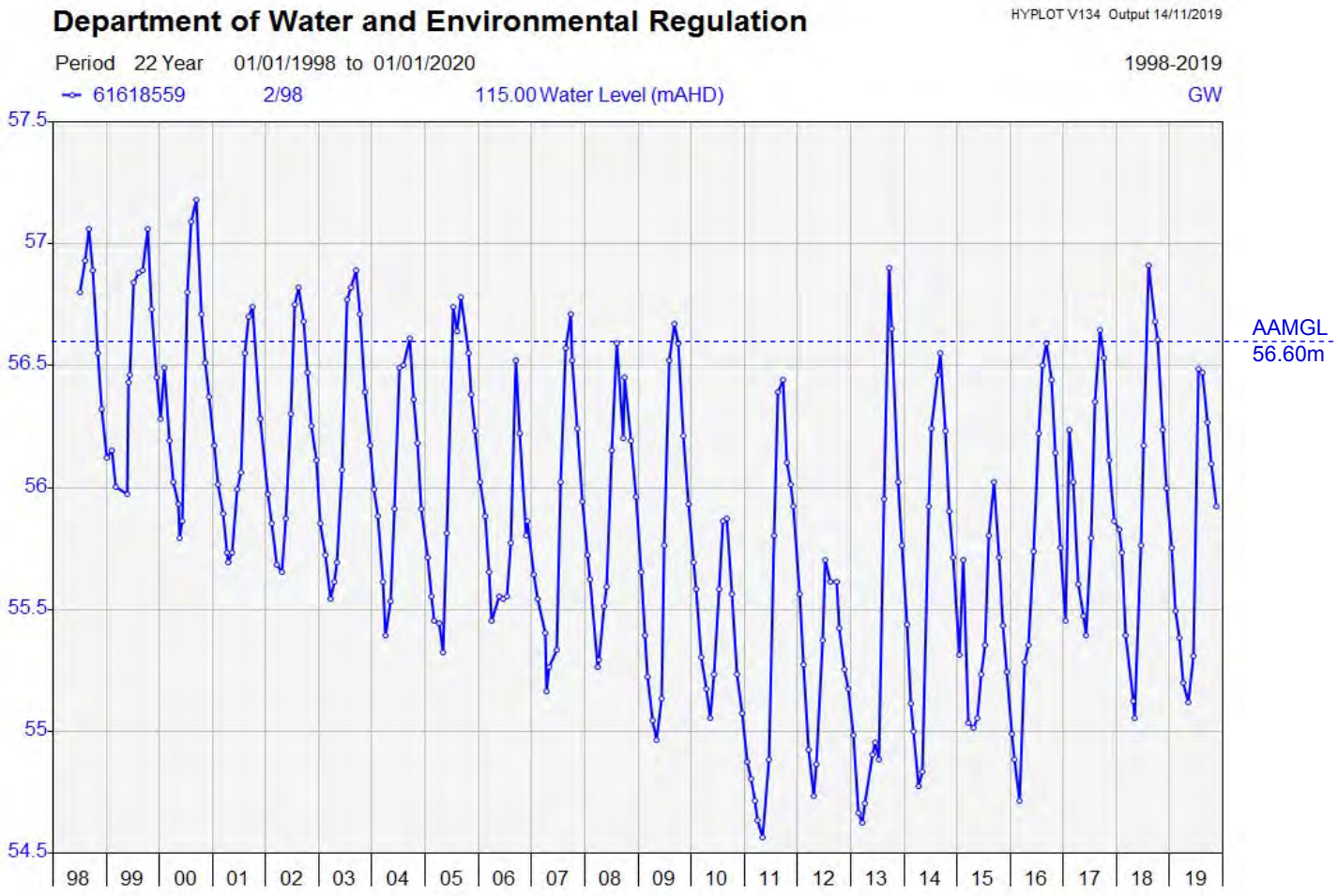


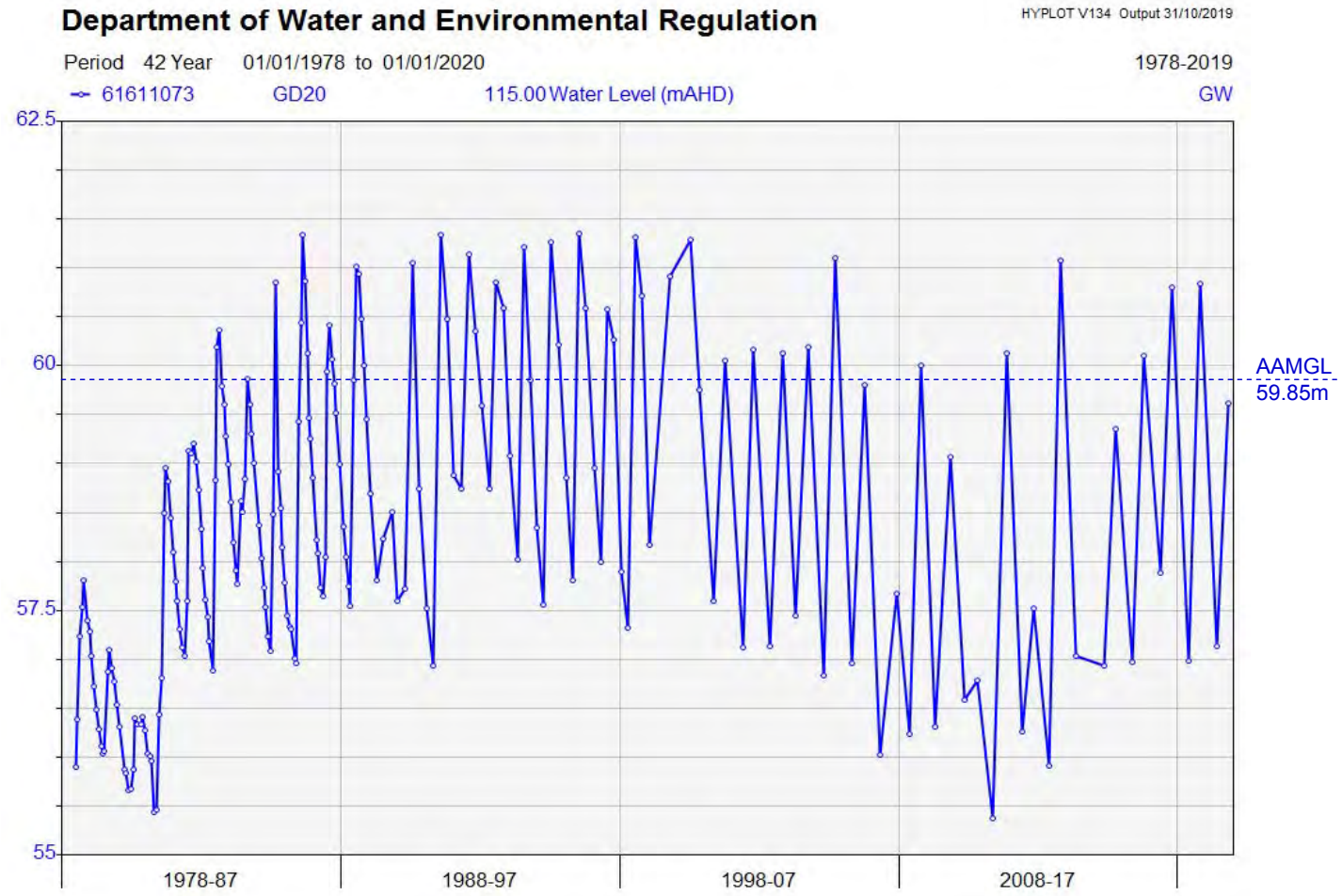


Figure 7

DWER BORE HYDROGRAPHS

bayley environmental services

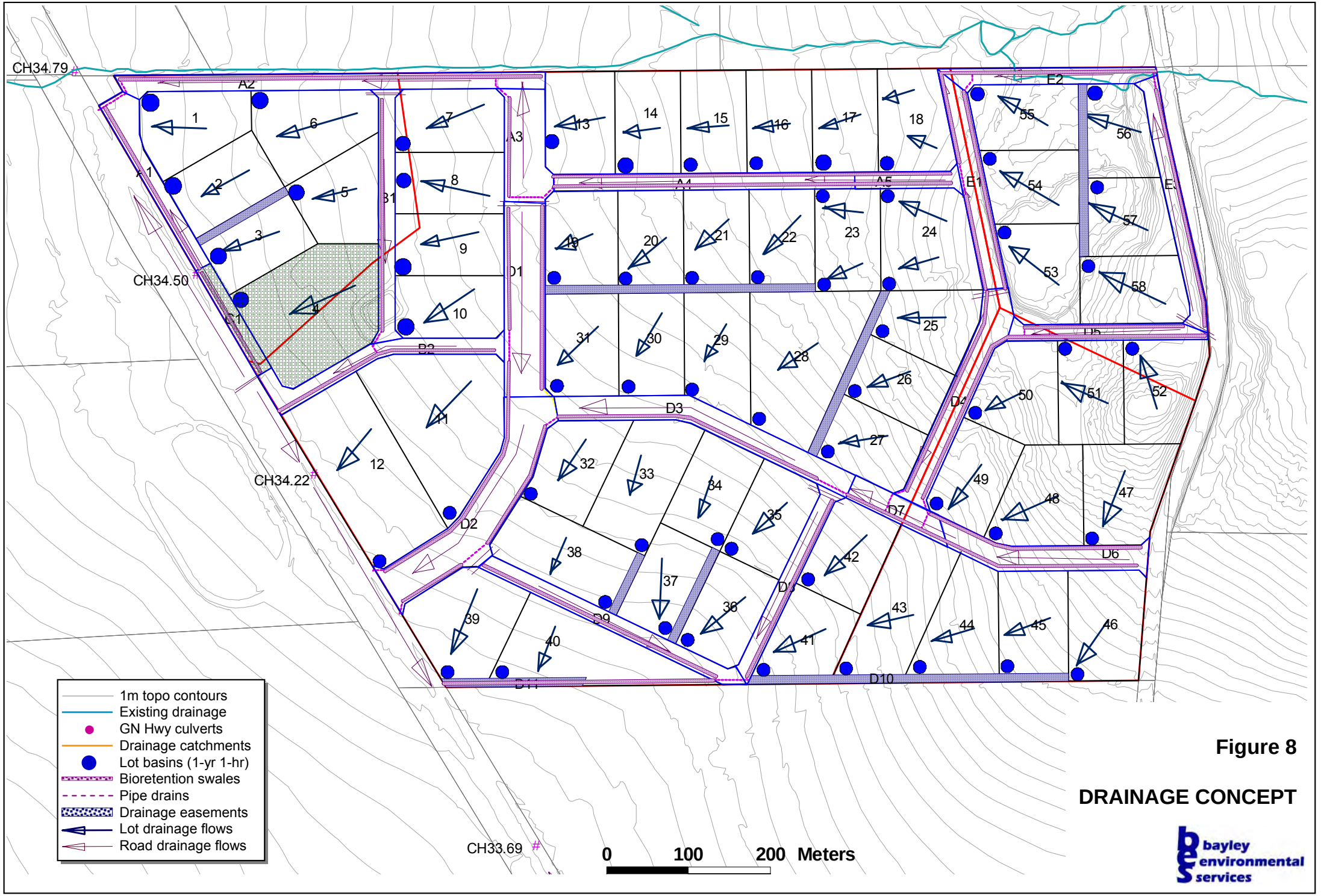
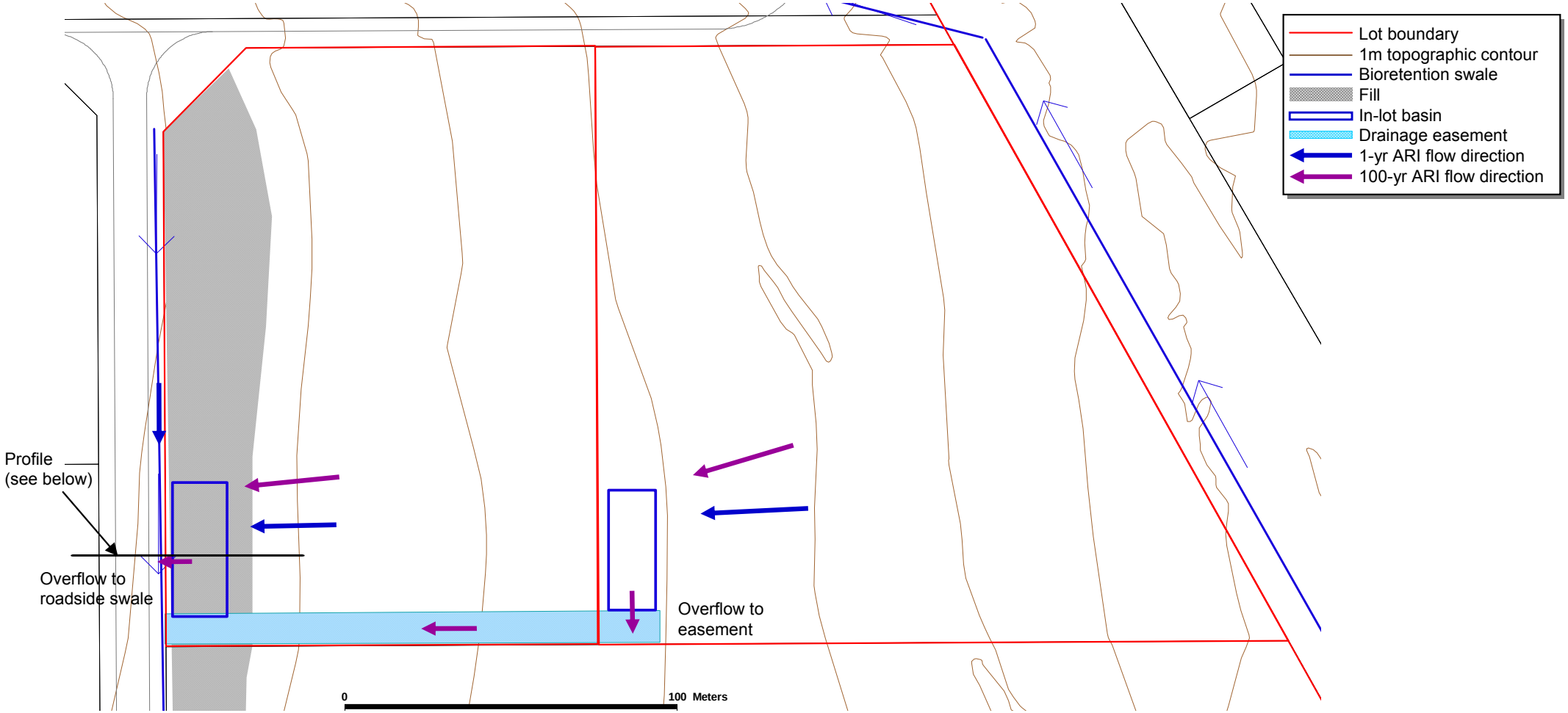


Figure 8

DRAINAGE CONCEPT

bayley environmental services



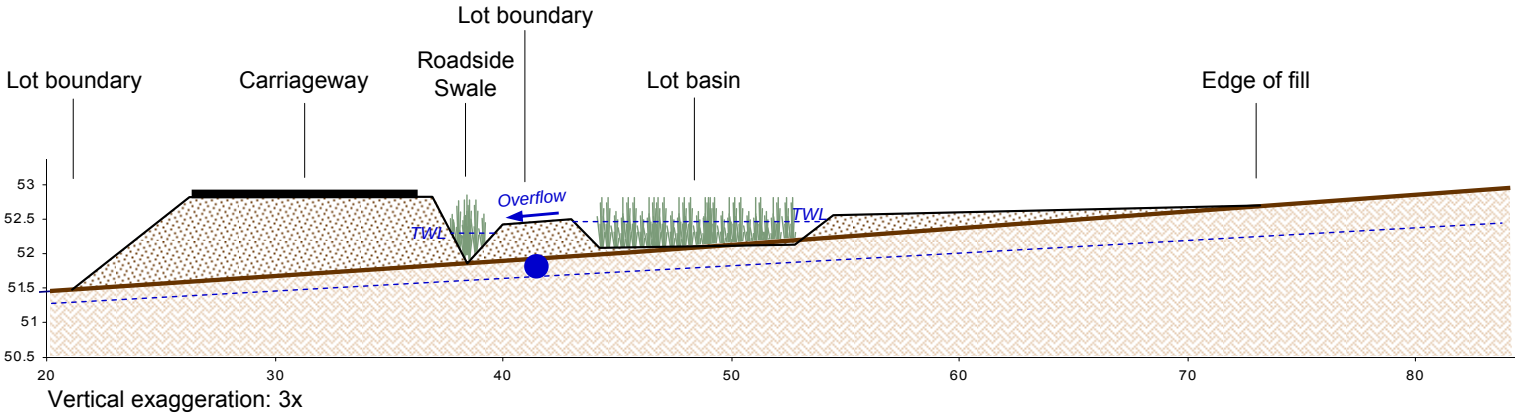


Figure 9

LOT DRAINAGE EXAMPLES

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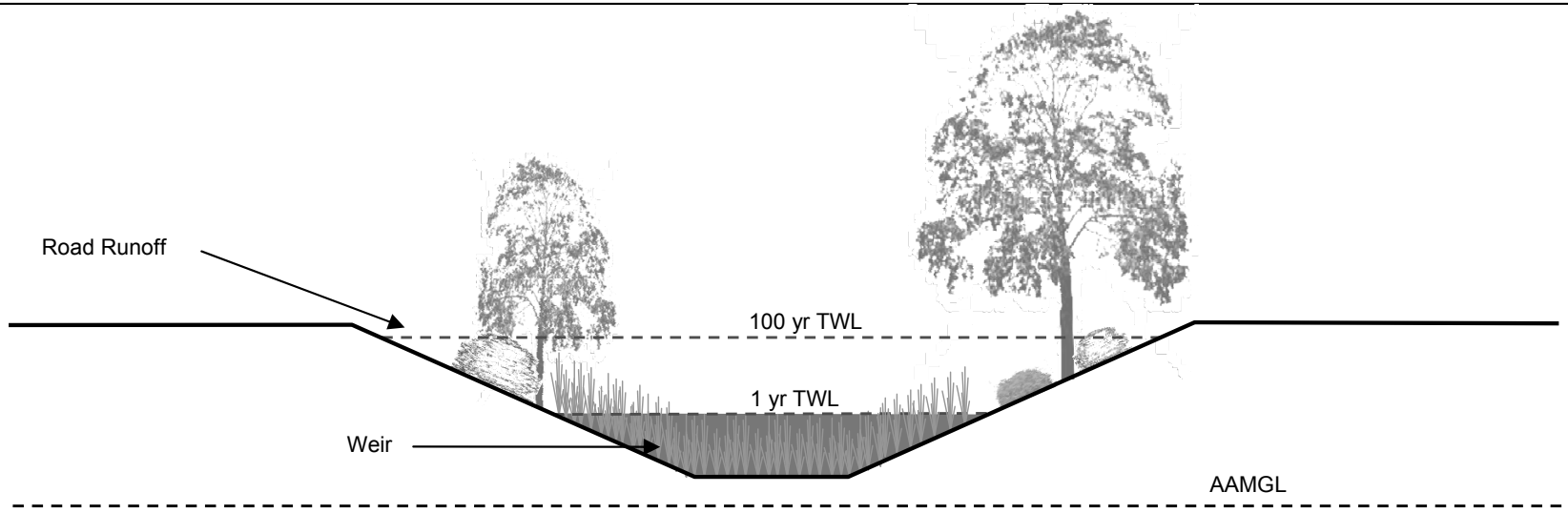

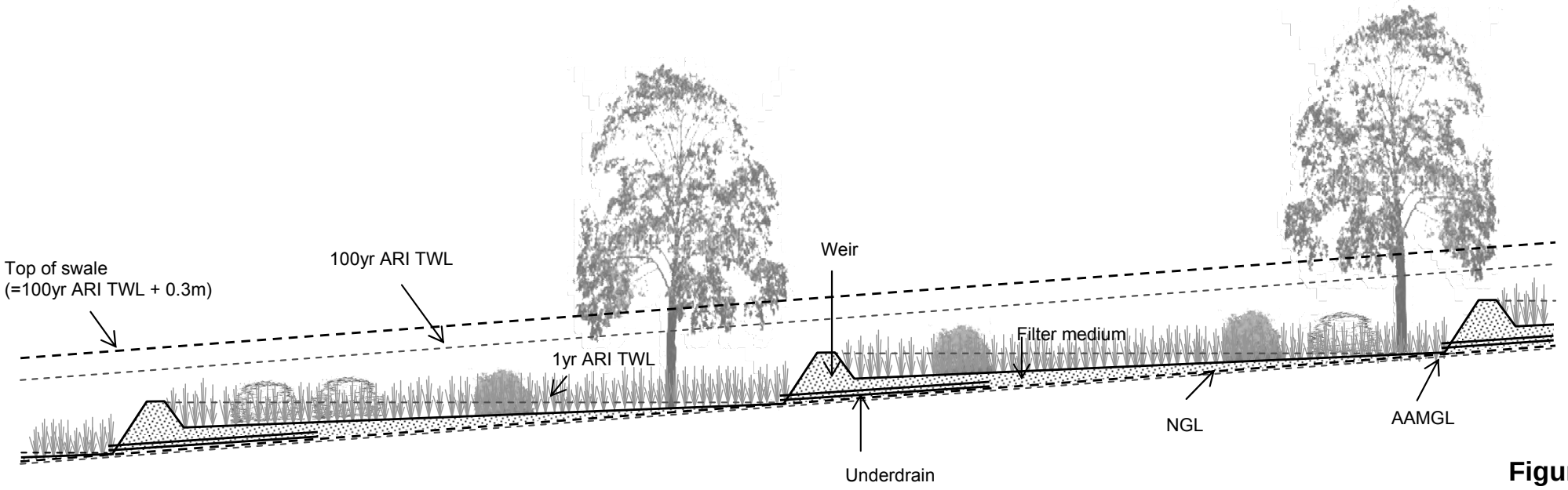

Figure 10

CONCEPTUAL SWALE PROFILES

bayley environmental services

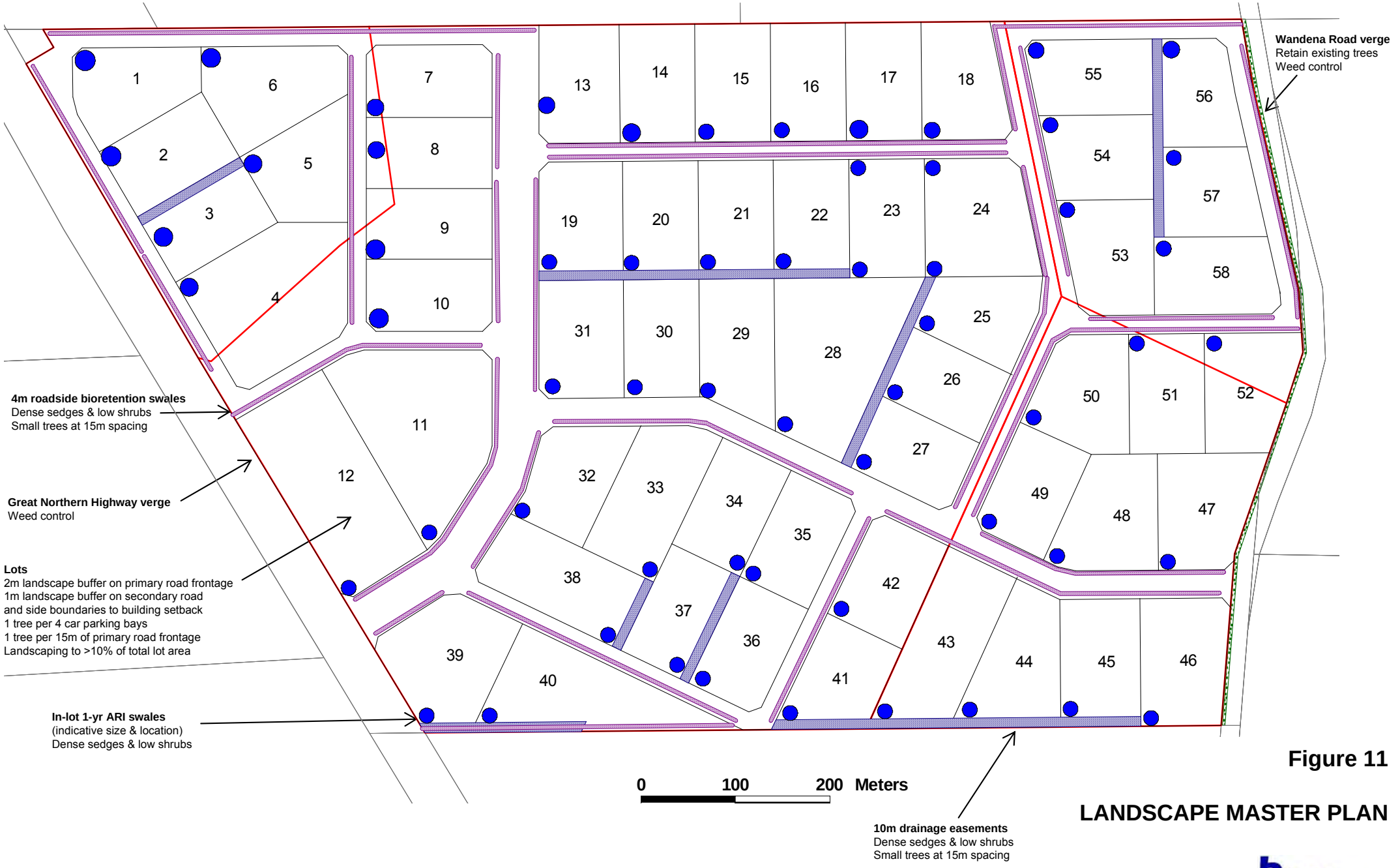

Figure 11

LANDSCAPE MASTER PLAN

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Appendix A

DWER LWMS Checklist

Appendix 2 Local water management strategy checklist

Local water management strategy item	Deliverable	☑	Notes
Executive summary			
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Table 1: Design elements and requirements for best management practices and critical control points	☑	Page 8
Introduction			
Total water-cycle management – principles and objectives Planning background Previous studies		☑	Section 1
Proposed development			
Structure plan, zoning and land use Key landscape features Previous land use	Site context plan Structure plan	☑ ☑	Figures 1-3 Section 2
Landscape – proposed public open space areas, public open space credits, water source, bore(s), lake details, irrigation areas (if applicable)	Landscape plan	☑	Sections 3, 7
Design criteria			
Agreed design objectives and source of objectives		☑	Section 1.5 Table 1.1
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		☑	Section 2
Site conditions – existing topography/contours, aerial photo underlay, major physical features	Site condition plan	☑	Section 2
Geotechnical – topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geotechnical plan	☑	Section 2
Environmental – areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental plan plus supporting data where appropriate	☑	Section 2
Surface water – topography, 100-year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface-water plan	☑	Section 2
Groundwater – topography, pre-development groundwater levels and water quality, test bore locations	Groundwater plan plus site investigations	☑	Section 2

Local water management strategy item	Deliverable	☑	Notes
Water sustainability initiatives			
Water efficiency measures – private and public open spaces including method of enforcement		☑	Section 3
Water supply (fit-for-purpose) strategy, agreed actions and implementation		☑	Section 3
Wastewater management		☑	Section 4
Stormwater management strategy			
Flood protection – peak flow rates, volumes and top water levels at control points, 100-year flowpaths and100-year detention storage areas	100-year-event plan Long section of critical points	☑ ☑	Section 5
Manage serviceability – storage and retention required for the critical 5-year ARI storm events Minor roads should be passable in the 5-year ARI event	5-year-event plan	☑	Section 5
Protect ecology – detention areas for the 1-year 1-hour ARI event, areas for water quality treatment and types of agreed structural and non-structural best management practices and treatment trains (including indicative locations). Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	1-year-event plan Typical cross sections	☑ ☑	Section 5
Groundwater management strategy			
Post-development groundwater levels, existing and likely final surface levels, outlet controls, and subsoil drain areas/exclusion zones	Groundwater/subsoil plan	☑	Section 6
Actions to address acid sulfate soils or contamination		☑	Sections 2.2.4 and 2.6
The next stage – subdivision and urban water management plans			
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required before detailed design.		☑	Section 9
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		☑	Section 8
Implementation			
Developer commitments		☑	Section 9
Roles, responsibilities, funding for		☑	Section 9

Local water management strategy item	Deliverable	☑	Notes
implementation			
Review		☑	Section 9

Appendix B

Soil Logs

SOIL PROFILE LOG

PROJECT NUMBER:	J19018
SITE ID:	WB1
EASTING:	405843
NORTHING:	6503819
METHOD:	Auger rig
TOTAL DEPTH (mbgl):	5.5
REFUSAL (Y/N):	N
DATE:	24/03/2020
DEPTH TO WATER (mbgl)	None encountered

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Pale yellow-brown sand		
0.5 - 1.5	Brown gravelly sand		
2	Orange pebbly silt		
2.5 - 3	Orange pebbly sandy silt		
3.5	Orange clayey silt		
4	Red-orange clayey silt		
4.5 - 5	Red silty clay		
5.5	Red gravelly clay		

SOIL PROFILE LOG

PROJECT NUMBER:	J19018
SITE ID:	WB2
EASTING:	406206
NORTHING:	6504189
METHOD:	Auger rig
TOTAL DEPTH (mbgl):	5.5
REFUSAL (Y/N):	N
DATE:	24/03/2020
DEPTH TO WATER (mbgl)	None encountered

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Pale yellow-brown pebbly silty sand		
0.5 - 2	Orange-brown gravelly sandy silt.		
2.2	Hard red/grey mottled clay		
2.5 - 3	Pale brown pebbly sandy silt		
3.5	Pink clayey silt		
4-4.5	Orange-brown pebbly clayey silt		
5-5.5	Red gravelly silty clay, hard		

SOIL PROFILE LOG

PROJECT NUMBER:	J19018
SITE ID:	WB3
EASTING:	406365
NORTHING:	6503799
METHOD:	Auger rig
TOTAL DEPTH (mbgl):	5.5
REFUSAL (Y/N):	N
DATE:	24/03/2020
DEPTH TO WATER (mbgl)	None encountered

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0 - 0.5	Pale yellow-brown pebbly silty sand		
1	Yellow pebbly sandy silt		
1.5	Orange-brown pebbly silt		
2 - 2.5	Orange pebbly silt		
3	Red-brown pebbly silt		
3.5	Redish pebbly silt		
4	Red-brown pebbly silty clay		
4.5 - 5	Red pebbly silty clay		
5.5	Red silty clay		

SOIL PROFILE LOG

PROJECT NUMBER:	J19018
SITE ID:	WB4
EASTING:	406393
NORTHING:	6503460
METHOD:	Auger rig
TOTAL DEPTH (mbgl):	5.5
REFUSAL (Y/N):	N
DATE:	24/03/2020
DEPTH TO WATER (mbgl)	None encountered

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0 - 0.5	Grey-brown silty sand		
1 - 2	Yellow-brown pebbly silty sand		
2.5	Yellow-brown pebbly silt		
3 - 3.5	Red-brown pebbly silt		
4	Yellow-brown pebbly silty sand		
4.5 - 5	Yellow-brown pebbly clayey silt		
5.5	Brown/grey mottled silty clay		

GEOTECH FIELD LOG

PROJECT No.:

TEST PIT/BOREHOLE No.: 1 MW 1

Client: Focus Demolition	Elevation: 103 m Eastings: 0406899 Northings: 6504175	Sheet of
Project: Wandena	Datum:	Date:
Location: Muchea	Machine:	Logged by:

MATERIAL INFORMATION

Excavation Information				Primary Component												Secondary Component					Minor Components		Strength	Moisture	IPT (%)	Sketch and Other Observations Structure, Geological Origin, Etc.	**SAMPLING & TESTING**		
Depth	Method	Resist	Water	Fill	UCS	Clayey	Silty	Sandy	Gravelly	Clay	Silt	Sand	Gravel	Plasticity or Grain Size	Colour	%	Plasticity or Grain Size	Fines	Sand	Gravel	With	Trace of					Sample No.	From	To
0 to 2	0-2							✔	✔	✔					Light Brown														
2 to 3									✔	✔					Light Brown														
3 to 5.5									✔		✔				Yellowish														
5.5 to 11									✔	✔					Reddish											Some cementing			
11 to 14.5										✔					Grey											Slightly Brown			
14.5 to 18						✔							✔		Red											Ironstone			
18 to 20.5						✔						✔			Brown								S			Cemented			

Method	**Water**	**Samples & Tests**	**Plasticity**	**Grain size**	**Moisture**	**Strength**	**Remarks:**
PT = Push Tube	>> = Water inflow	DS = Disturbed sample	NP = Non plastic	F = Fine	<< = much less than	VS Very soft Fb Friable	End of pit: 20.5 m
DPT = Dynamic push tube	<< = Water outflow	U50 = Thin wall undistirubed sample	LP = Low plastic	M = Medium	< = less than	S Soft VL Very Loose	**Groundwater**
AV = Auger - V bit	GWO = Water first observed	(diam indicated by numerals)	MP = Med plastic	C = Coarse	c = about	F Firm L Loose	Not encountered
AR = Auger - TC rock bit	SWL = Standing water level	SPT = Standard penetration test	HP = High plastic		> = greater than	St Stiff MD Medium Dense	Not observed
HA = Hand auger		N = number of blows/300 mm	VHP = V. High plastic		>> = much greater than	Vst Very Stiff D Dense	
BH = Backhoe		* = sample recovered	EHP = E. High plastic		PL = plastic limit	H Hard VD Very Dense	GWO at m
EX = Tracked excavator		PP = Pocket penetrometer			LL = liquid limit		SWL at 16.2 m
					D = dry		Casing Height 0.6m, slotted pipe to 14.5m
					M = moist		Gravel to 6.5m - Bentonite to 3.5m
					W = wet		

GEOTECH FIELD LOG

PROJECT No.:

TEST PIT/BOREHOLE No.: 2 MW 2

Client: Focus Demolition	Elevation: Eastings: Northings:	Sheet of
Project: Wandena	Datum:	Date:
Location: Muchea	Machine:	Logged by:

MATERIAL INFORMATION

Excavation Information				Primary Component												Secondary Component					Minor Components		Strength	Moisture	IPT (%)	Sketch and Other Observations Structure, Geological Origin, Etc.	**SAMPLING & TESTING**		
Depth	Method	Resist	Water	Fill	UCS	Clayey	Silty	Sandy	Gravelly	Clay	Silt	Sand	Gravel	Plasticity or Grain Size	Colour	%	Plasticity or Grain Size	Fines	Sand	Gravel	With	Trace of					Sample No.	From	To
0 to 5									✔	✔					Light Brown														
5 to 9									✔	✔					Grey											Hard Clay			
9 to 16							✔			✔					Yellow / Grey											Mottling of yellow oxidation			
16 to 18						✔							✔		Dark Red											Very well cemented iron stone			
18 to 25						✔						✔			Green / Brown											Fine/medium clayey sand			

Method	**Water**	**Samples & Tests**	**Plasticity**	**Grain size**	**Moisture**	**Strength**	**Remarks:**
PT = Push Tube	>> = Water inflow	DS = Disturbed sample	NP = Non plastic	F = Fine	<< = much less than	VS Very soft Fb Friable	End of pit: 22.4 m
DPT = Dynamic push tube	<< = Water outflow	U50 = Thin wall undistirubed sample	LP = Low plastic	M = Medium	< = less than	S Soft VL Very Loose	**Groundwater**
AV = Auger - V bit	GWO = Water first observed	(diam indicated by numerals)	MP = Med plastic	C = Coarse	c = about	F Firm L Loose	Not encountered
AR = Auger - TC rock bit	SWL = Standing water level	SPT = Standard penetration test	HP = High plastic		> = greater than	St Stiff MD Medium Dense	Not observed
HA = Hand auger		N = number of blows/300 mm	VHP = V. High plastic		>> = much greater than	Vst Very Stiff D Dense	

BH = Backhoe EX = Tracked excavator		* = sample recovered PP = Pocket penetrometer	EHP = E. High plastic		PL = plastic limit LL = liquid limit D = dry M = moist W = wet	H Hard VD Very Dense	GWO at m SWL at 18.4 m Casing height 0.6m, gravel pack to 15.4 m BGL Bentonite to 13.4 m BGL

GEOTECH FIELD LOG — PROJECT No.: — TEST PIT/BOREHOLE No.: 3 MW 3

Client: Focus Demolition	Elevation: 93 m Eastings: 0406684 Northings: 6504119	Sheet of
Project: Wandena	Datum:	Date:
Location: Muchea	Machine:	Logged by:

Excavation Information				MATERIAL INFORMATION: Primary Component												Secondary Component					Minor Components		Strength	Moisture	IPT (%)	Sketch and Other Observations Structure, Geological Origin, Etc.	SAMPLING & TESTING		
Depth	Method	Resist	Water	Fill	UCS	Clayey	Silty	Sandy	Gravelly	Clay	Silt	Sand	Gravel	Plasticity or Grain Size	Colour	%	Plasticity or Grain Size	Fines	Sand	Gravel	With	Trace of					Sample No.	From	To
0 to 0.9												✔			Yellow / Brown											Fine / Medium			
0.9 to 2.1								✔					✔		Brown														
2.1 to 4									✔	✔					Orange / Brown														
4 to 5							✔			✔					White											Bleached			
5 to 7									✔	✔					Red											Ironstone			
7 to 8.5									✔	✔					Red/white											Some Bleached Zones			
8.5 to 9.7															Red											Cemented Ironstone			
9.7 to 11							✔			✔					White/grey														
11 to 16.5								✔		✔					Red/Brown											Fine			
16.5 to 19.5								✔		✔					Brown														

Method
PT = Push Tube
DPT = Dynamic push tube
AV = Auger - V bit
AR = Auger - TC rock bit
HA = Hand auger
BH = Backhoe
EX = Tracked excavator

Water
>> = Water inflow
<< = Water outflow
GWO = Water first observed
SWL = Standing water level

Samples & Tests
DS = Disturbed sample
U50 = Thin wall undistirubed sample
(diam indicated by numerals)
SPT = Standard penetration test
N = number of blows/300 mm
* = sample recovered
PP = Pocket penetrometer

Plasticity
NP = Non plastic
LP = Low plastic
MP = Med plastic
HP = High plastic
VHP = V. High plastic
EHP = E. High plastic

Grain size
F = Fine
M = Medium
C = Coarse

Moisture
<< = much less than
< = less than
c = about
> = greater than
>> = much greater than
PL = plastic limit
LL = liquid limit
D = dry
M = moist
W = wet

Strength
VS Very soft Fb Friable
S Soft VL Very Loose
F Firm L Loose
St Stiff MD Medium Dense
Vst Very Stiff D Dense
H Hard VD Very Dense

Remarks:
End of pit: 18.5 m BGL
Groundwater
Not encountered
Not observed
GWO at m
SWL at m

GEOTECH FIELD LOG — PROJECT No.: — TEST PIT/BOREHOLE No.: 4 MW 4

Client: Focus Demolition	Elevation: Eastings: Northings:	Sheet of
Project: Wandena	Datum:	Date: 6/4/16
Location: Muchea	Machine:	Logged by:

Excavation Information				MATERIAL INFORMATION: Primary Component												Secondary Component					Minor Components		Strength	Moisture	IPT (%)	Sketch and Other Observations Structure, Geological Origin, Etc.	SAMPLING & TESTING		
Depth	Method	Resist	Water	Fill	UCS	Clayey	Silty	Sandy	Gravelly	Clay	Silt	Sand	Gravel	Plasticity or Grain Size	Colour	%	Plasticity or Grain Size	Fines	Sand	Gravel	With	Trace of					Sample No.	From	To
0 - 1								✔					✔	Brown											Colluvial			

1 - 3.5									✔	✔				Reddish													Ferricrete (slightly cemented)			
3 - 5.7									✔	✔				Ochre													Mottled (cementing w/ gravel)			
7 - 7.2														Reddish								H					Lens of iron oxide stone			
7.2 - 8										✔				White													Bleached Clay			
8 - 8.5														Red								H					Lens of iron oxide stone			
8.5 - 11.5										✔				White													Bleached clay			
11.5 - 12.5														Reddish								H					Lens of iron oxide stone			
12.5 - 14										✔				White/Grey													Bleached clay			
14 - 15														Reddish								H					Well-cemented iron oxide			
15 - 19.7								✔						Dark Red													moist sandy clay			

Method	**Water**	**Samples & Tests**	**Plasticity**	**Grain size**	**Moisture**	**Strength**	**Remarks:**
PT = Push Tube	>> = Water inflow	DS = Disturbed sample	NP = Non plastic	F = Fine	<< = much less than	VS Very soft Fb Friable	End of pit: 19.7 m
DPT = Dynamic push tube	<< = Water outflow	U50 = Thin wall undistirubed sample	LP = Low plastic	M = Medium	< = less than	S Soft VL Very Loose	**Groundwater**
AV = Auger - V bit	GWO = Water first observed	(diam indicated by numerals)	MP = Med plastic	C = Coarse	c = about	F Firm L Loose	Not encountered
AR = Auger - TC rock bit	SWL = Standing water level	SPT = Standard penetration test	HP = High plastic		> = greater than	St Stiff MD Medium Dense	Not observed
HA = Hand auger		N = number of blows/300 mm	VHP = V. High plastic		>> = much greater than	Vst Very Stiff D Dense	
BH = Backhoe		* = sample recovered	EHP = E. High plastic		PL = plastic limit	H Hard VD Very Dense	GWO at m
EX = Tracked excavator		PP = Pocket penetrometer			LL = liquid limit		SWL at 15.2 m BGL
					D = dry		
					M = moist		
					W = wet		

Appendix C

Geotechnical Report

Douglas Partners
Geotechnics | Environment | Groundwater

Integrated Practical Solutions

Report on
Preliminary Geotechnical Investigation

Proposed Industrial Development
Lots 202 & 203 Wandena Road and
204 & 205 Great Northern Highway, Muchea, WA

Prepared for
Focus Demolition & Asbestos Removal &
David Weightman Smith

Project 96712.00
October 2020

Douglas Partners
Geotechnics | Environment | Groundwater

Document History

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Project No.	96712.00	Document No.	R.001.Rev0
Document title	Report on Preliminary Geotechnical Investigation Proposed Industrial Development		
Site address	Lots 202 & 203 Wandena Road and 204 & 205 Great Northern Highway, Muchea, WA		
Report prepared for	Focus Demolition & Asbestos Removal & David Weightman Smith		
File name	96712.00.R.001.Rev0.Proposed Industrial Development		

Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	Damian Jagoe-Banks	Fred Verheyde	12 October 2020

Distribution of copies

Status	Issued to
Revision 0	James Wortley, Tomahawk Property

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		12 October 2020
Reviewer		12 October 2020

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Douglas Partners
Geotechnics | Environment | Groundwater

Table of Contents

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Report on Preliminary Geotechnical Investigation
Proposed Industrial Development
Lots 202 & 203 Wandena Road and 204 & 205 Great Northern Highway, Muchea, WA

1. Introduction

This report presents the results of a preliminary geotechnical investigation undertaken for a proposed industrial development at Lots 202 & 203 Wandena Road and 204 & 205 Great Northern Highway, Muchea, WA . The investigation was commissioned in an email dated 24 August 2020 from James Wortley of Tomahawk Property on behalf of Focus Demolition & Asbestos Removal & David Weightman Smith and was undertaken in accordance with Douglas Partners' proposal PER200244.Rev2 dated 21 July 2020.

Further to the scope of work detailed in the aforementioned proposal, a variation to assess stockpiled material within the site for its suitability for use as pavement construction material was requested by Focus Demolition & Asbestos Removal. The approval to proceed with this variation was provided via email on 16 September 2020.

It is understood that the land is currently zoned for agricultural resource and it is intended to rezone the land for future industrial use. This geotechnical report is to support the rezoning process by providing information on the typical ground conditions across the site, suitability of the soils for on-site effluent disposal and also to identify any geotechnically related opportunities or challenges with regard to future development of the land.

The purpose of the preliminary geotechnical investigation is to assess the ground conditions at the site and provide preliminary geotechnical comments on:

- The sub-surface conditions including identification of areas of problematic ground conditions, if encountered.
- The likely site classification for future development, in accordance with the requirements of AS 2870-2011.
- General site preparation requirements including comments on excavatability, material reuse and earthworks to suitably prepare the ground for the road pavement and industrial lots.
- Preliminary advice on the suitability of the soils at the site for on-site effluent disposal in accordance with AS 1547 and the Western Australian 2019 Government Sewerage Policy.
- The depth to groundwater, if encountered.
- Permeability of the encountered soils at the site.

The investigation included the excavation of 30 test pits, dynamic penetrometer testing, six in-situ infiltration tests using a constant head method and laboratory testing of selected samples. The details of the field work are presented in this report, together with comments and recommendations on the items listed above.

2. Site Description

The site is an 83 ha parcel of land, identified as Lots 202 and 203 Wandena Road and 204 and 205 Great Northern Highway in Muchea, WA. It is bound by Great Northern Highway to the West, Wandena Road to the East and rural land to the north and south.

At the time of the investigation, the eastern part of the was operating as a horse stud and the eastern part of the site was a partially backfilled quarry. The western part of the site was mostly covered in grassy paddocks with scattered mature trees. The surface across the eastern part of the site is generally gravelly and vegetation consists of scattered shrubs and trees. Figures 1 and 2 below show typical site conditions at the time of the investigation.

Figure 1: Typical site conditions in western part of the site.

Figure 2: Typical site conditions in eastern part of the site

Based on publicly available LiDAR information, site surface levels generally grade from approximately RL 100 m AHD at the eastern part of the site to RL 58m AHD in the south-western corner. A terrain slope analysis indicates that generally the surface levels in the western half of the site grade between 1° and 3° and the eastern part of the site has slope angles generally between 3° and 6° with isolated areas of up to 15°. Note that the slopes associated with the quarry pit have been ignored in the slope analysis.

The Muchea 1:50,000 scale geological mapping indicates the site is underlain by (in an east to west direction):

- ST1: Siltstone – located in the eastern part of the site, where surface levels are above RL 80 m AHD
- Msg: Colluvial Sandy Silt – located up to 150 m to the west of the siltstone
- S5: Colluvial Sand – located approximately 150 m to the west of the sandy silt; and
- Mgs1: Pebbly Silt of the Guildford Formation – located west sand, extending to the western boundary of the site.

The Perth Groundwater Atlas indicates groundwater levels were around 43 m AHD to 53 m AHD in 2003 (over 15 m below the lowest level on the site). Groundwater perched on low permeability soils or rock is anticipated during the wetter months of the year.

3. Field Work Methods

Field work was carried out between 15 and 17 September 2020 and comprised the excavation of 30 test pits, together with dynamic cone penetrometer (DCP) testing adjacent to each test pit and six in-situ infiltration tests.

The test pits (test locations 1 to 30) were excavated to depths of between 1.4 m and 2.5 m using an 8 tonne backhoe equipped with a 450 mm toothed bucket, and were logged in general accordance with AS 1726-2017 by a geotechnical engineer from Douglas Partners. Test pit termination prior to the target depth was experienced on hard soil at test locations 6, 9, 10, 17, 18, 20, 22, 24, and 29 (nine locations).

Dynamic cone penetrometer (DCP) and Perth sand penetrometer (PSP) tests were carried out adjacent to the test pits in accordance with AS 1289.6.3.2 and AS 1289.6.3.3 respectively, to assess the in-situ density and consistency of the subgrade soils.

Six in-situ infiltration tests were carried out at locations 6, 11, 16, 19, 25 and 30 using a constant head method in accordance with AS 1547-2012 Appendix 4.1F. Testing was undertaken at depths of between 0.2 m and 0.8 m to target characteristic soils across the site.

Test locations were determined using GPS coordinates and are marked on Drawing 1 in Appendix B. Surface elevations at each test location were obtained from publicly available LiDAR information, and are quoted relative to Australian Height Datum (AHD).

4. Field Work Results

4.1 Ground Conditions

Detailed logs of the ground conditions and results of the field testing are presented in Appendix B, together with notes defining descriptive terms and classification methods in Appendix A. A summary of the ground conditions encountered at the test locations is given below.

In summary, ground conditions generally comprise:

- **Unit 0A: Sandy topsoil (Silty SAND SM) –** generally 0.1 m thick, fine to medium grained, low plasticity, dark grey-brown, with gravel, with roots, at all locations except for 6 to 8 and 18 to 21.
- **Unit 0B: FILL (Gravelly, sandy soils and clayey soils) –** fill of varying consistency, density and colour, encountered from the surface to depths up to 2.1 m at test locations 6 to 8 and 18 to 21 (seven locations in the vicinity of the quarry).
- **Unit 1A: Granular soils (Sandy GRAVEL GP-GM and SAND SP-SM) –** fine to medium grained, dark grey-brown and grey-brown, sandy soils with varying gravel content encountered below the topsoil and fill to depths between 0.25 m and 0.95 m at test locations except for 7, 8, 19 and 30.
- **Unit 1B: Sandy SILT ML –** grey-brown sandy silt underlying the topsoil to a depth of 0.8 m at test location 30.
- **Unit 2: Cohesive, gravelly soils (Clayey Sandy GRAVEL GC)** – generally hard, orange-brown, clayey sandy gravel below Unit 1 to test pit termination depths up to 2.5 m at all locations except for 7 and 8 and 19 where siltstone was encountered at depths of approximately 2 m.

  Excavation was terminated at prior to 2.5 m deep due to slow digging in hard clayey, gravelly soils at locations 6, 9, 10, 17, 18, 20, 22, 24, and 29.
- **Unit 3**: **Rock (Siltstone)** – fine grained, pale red-white siltstone, moderately weathered, low to medium strength below the fill and possible fill at locations 7, 8 and 19 to test pit termination depth of 2.5 m.

4.2 Groundwater

Groundwater was observed at four test locations during the field work on 15 and 16 September 2020. The test pits were immediately backfilled following sampling, which precluded any longer-term monitoring of groundwater levels.

Table 1: Groundwater Observations on 15 and 16 September 2020

Test Location	Surface Level (m AHD)	Water Conditions	Water Depth (m)	Water Level (m AHD)
3	68.1	Water seepage	1.6	66.5
4	72.6	Water seepage	0.7	71.9
13	61.7	Large Inflow	1.1	60.6
22	69.2	Water seepage	1.9	67.3

It should be noted that groundwater levels are potentially affected by various factors such as climatic conditions and land usage and will therefore vary with time.

4.3 Results of Infiltration Testing

Six in-situ infiltration tests using the constant head method were undertaken within the site. The tests were undertaken in accordance with AS 1547 Appendix 4.1F and were undertaken at particular depths and locations to target all of the shallow soil types encountered during the investigation. The permeability results are summarised in Table 2.

Table 2: Summary of Permeability Analysis

Test Location	Depth (m)	Permeability		Material
		m/s	m/day	
6	0.3-0.5	9.0×10^{-5}	7.8	Unit 1A: Sandy GRAVEL, with silt
11	0.6-0.8	1.0×10^{-5}	0.9	Unit 2: Clayey, sandy GRAVEL
16	0.5-0.8	1.9×10^{-5}	1.6	Unit 2: Clayey, sandy GRAVEL
19	0.15-0.45	5.7×10^{-7}	0.05	Unit 0B: FILL/Sandy CLAY
25	0.2-0.4	1.0×10^{-4}	8.6	Unit 1A: Sandy GRAVEL, trace silt
30	0.3-0.5	1.2×10^{-5}	1.0	Unit 1B: Sandy SILT, trace gravel

5. Geotechnical Laboratory Testing

5.1 Soil Identification and Characteristics

A geotechnical laboratory testing programme was carried out on selected soil samples by a NATA registered laboratory, and comprised the determination of:

- The particle size distributions of four samples;
- The Atterberg limits and linear shrinkage of two samples;
- The Emerson Class of four samples; and
- the pH, electrical conductivity and cation exchange capacity index on two samples.

Detailed test report sheets are given in Appendix C and the results are summarised in Tables 3 and Table 4, next page.

Table 3: Results of Laboratory Testing for Soil Identification

Test Location	Depth (m)	Fines (%)	Sand (%)	Gravel (%)	LL (%)	PL (%)	PI (%)	LS (%)	Material
6	0.3-0.5	7	22	71	-	-	-	-	Unit 1A: Sandy GRAVEL, with silt
16	0.5-0.8	18	35	47	28	15	13	5.5	Unit 2: Clayey, sandy GRAVEL, low plasticity fines
25	0.2-0.4	4	22	74	NP	NP	NP	-	Unit 1A: Sandy GRAVEL, trace silt
30	0.3-0.5	37	53	10	-	-	-	-	Unit 1B: Sandy SILT, trace gravel

Notes: Fines are particles smaller than 75 µm.
Sand is particles larger than 75 µm and smaller than 2.36 mm.
Gravel is particles larger than 2.36 mm and smaller than 63 mm.
PL: plastic limit LL: liquid limit PI: plasticity Index LS: linear shrinkage
'-': not tested.

Table 4: Summary of Laboratory Testing Results for Effluent Disposal

Test Location	Depth (m)	pH	EC (dS/m)	CEC (meq/100g)	Emerson Class	Material
6	0.3-0.5	6.6	0.037	2	2	Unit 1B: Sandy GRAVEL, with silt
16	0.5-0.8	6.3	0.024	3	5	Unit 2: Clayey, sandy GRAVEL, low plasticity fines
25	0.2-0.4	-	-	-	5	Unit 1B: Sandy GRAVEL, trace silt
30	0.3-0.5	-	-	-	2	Unit 1A: Sandy SILT, trace gravel

Notes:
- pH and EC tests are carried out in 1:5 (soil:water) solution.
- CEC: Cation exchange capacity in meq/100g.
- EC: Electrical conductivity

6. Proposed Development

It is understood that it is proposed to rezone the land from agricultural use to industrial use. Development of the land following rezoning is anticipated to comprise road pavements and earthworks to shape the lots to finished surface levels.

7. Comments

7.1 Sub-surface Conditions and Likely Site Classification

Ground conditions across the site were observed to generally comprise gravelly soils to a depth of between 0.5 m and 1 m underlain by cemented soil comprising mixture of clay, sand and gravel. Siltstone was encountered at a depth of approximately 2 m (generally below uncontrolled fill) at a few locations within the eastern part of the site.

Based on the encountered soils, no significant geotechnical constraints or challenges for the intended industrial development were identified during this investigation across most of the site, other than possibly its eastern end where various thicknesses of fill were identified within and around the existing quarry. The shallow cemented clayey soils across the site are generally hard and the siltstone in the eastern part of the site was low to medium strength. Therefore, it is anticipated that the one geotechnical constraint could be ground excavatability, depending on proposed excavation depths. Uncontrolled fill was encountered within and near the exiting quarry in the eastern part of the site and will require suitable site preparation to be re-used as foundation material.

The clayey soils, generally encountered from depths of between 0.5 m and 1.0 m are slightly reactive and therefore, it is considered that the areas of the site with natural soils have a site classification of Class S, in accordance with AS 2870-2011.

In accordance with AS 2870-2011, locations that have fill (e.g. generally the north-eastern part of the site) should be considered Class P in the absence of any certification from those controlling the placement of the fill (understood to be an ongoing process at the time of this reporting). If no certification for the fill can be provided, the filled class P areas could be reclassified following further geotechnical investigation.

Achieving Class A, if targeted, would require at a thickness of least 1.8 m of non-reactive soils over any reactive clayey material, which at this site would generally require the placement of over 1 m of non-reactive, granular fill.

It should also be noted that the abovementioned site classification comments do not take into account the possible effect of trees increasing the seasonal surface movement. In accordance with AS 2870-2011, trees will impact the classification as follows:

- If one tree is located within a distance of approximately its mature height of a building envelope;
- If a group of trees are located within a distance of approximately twice their mature height of a building envelope; and
- If trees are removed and the development proceeds shortly after removal. Recovery from abnormal moisture conditions arising from tree removal can typically take 2 to 3 years, although this may also be affected by weather patterns. Wherever possible, sufficient time should be allowed for this recovery to take place.

The presence (either existing or proposed) or removal of trees (if the development proceeds within 2 to 3 years of removal of mature trees), may therefore impact the site. As described in Section 2, trees were present across the site during the investigation in September 2020. Thus, the possible impact of existing

trees on foundation design should be considered at the site in the event that any of the above detailed conditions are met.

7.2 Site Preparation

7.2.1 Stripping

All topsoil and vegetation should be stripped from building envelopes, earth-working areas and pavement areas, and either removed from site or stockpiled for possible re-use if applicable.

Tree roots remaining from any clearing operations should be completely removed, and the excavations backfilled with material of similar geotechnical properties to the surrounding ground, and compacted to achieve a dry density ratio of not less than 92% and 95% relative to modified compaction for a cohesive and granular subgrade, respectively.

It is recommended that following stripping and prior to filling, if any, the natural subgrade be assessed by a geotechnical engineer to assess the suitability of the stripping.

7.2.2 Proof Rolling and Compaction

Once the stripped subgrade has been assessed by a geotechnical engineer, it is recommended that the exposed subgrade beneath the building and pavement envelopes be proof rolled using a heavy roller. Any areas that show signs of excessive deformation during compaction should be continually compacted until deformation ceases or, alternatively, the poor quality material should be excavated and replaced with suitable structural fill compacted to achieve a dry density ratio of not less than 92% and 95% relative to modified compaction for cohesive and granular subgrades, respectively.

It is recommended that compaction control of clayey and gravelly materials, be carried out using a nuclear surface moisture-density gauge, in accordance with AS 1289.5.8.1. Compaction control in sandy materials, for instance possible sand fill, could be carried out using a Perth sand penetrometer (PSP) test in accordance with test method AS 1289.6.3.3. It is suggested that the sand fill be compacted to achieve a minimum blow count of 8 blows per 300 mm rod penetration to a depth of not less than 1 m below foundation level. It should be noted that this compaction level has not been directly correlated to a dry density of 95% relative to modified compaction. Lower blow counts than the above level may be acceptable provided that a correlation between Perth sand penetrometer (PSP) test and dry density ratio has been established by a NATA accredited laboratory and following review by a geotechnical engineer.

7.2.3 Preparation of Uncontrolled Fill

As detailed in Section 4.1, fill was encountered to depths up to 2.1 m at seven locations near and within the quarry. The fill is considered uncontrolled and therefore, to provide a site classification other than Class P, either:

1. Certification is provided by others on the composition, density and suitability the fill for structural foundations; or

2. Provided the fill comprised soil and material suitable for foundation support (e.g. no compressible, or notable organic content) fill is compacted to a suitable depth to produce conditions suitable for foundation support.

It is possible that certification can be provided for the fill placed within the central quarry pit (e.g. test location 8), however it is anticipated that certification for fill encountered on the periphery of the pit is unlikely.

Where certification is not available, proof compaction of the existing fill should be undertaken. For fill less than 1 m deep, it is considered likely that a heavy roller (say 17 tonne) would be suitable to compact the fill. For deeper fill and up to a depth of approximately 4 m, rapid impact compaction (RIC) could be considered as a method to avoid any excavation and replacement in a controlled manner.

Rapid impact compaction is a specialised ground improvement technique that involves the repetitive dropping of a weight (5 to 10 tonnes) from limited height (1 m to 2 m), 40 to 60 times per minute, using a specialised hydraulic unit attached to an excavator. Indicatively, one possible local specialist contractor includes Rapid Impact Compaction Australia (however further research might indicate other contractors servicing Western Australia). It should be noted that RIC generates vibrations.

Alternatively to RIC, impact rolling could also be considered for fill depths of approximately 1 m to 2 m. Impact rolling is a specialised ground improvement technique that involves towing of a non-circular compaction module at a speed of about 12 km/hr. The module impact the ground, resulting in a greater depth of compaction than under a conventional circular drum roller. However, suitable expertise for such technique might be required to be sourced from interstate specialist contractors (e.g. Brooms, Landpac) who service Western Australia.

In the absence of additional information from the land owner of Lots 202 and 203, it is suggested that further investigation to provide more information on the depth and composition of the fill is undertaken to assist in the assessment of suitable site preparation methods for areas of uncontrolled fill. To optimise any further investigation for uncontrolled fill, it is also suggested that the investigation occurs once finished surface levels for future development are available.

7.3 Excavation Conditions and Groundwater

Based on the ground conditions described in Section 4.1, excavations associated with bulk earthworks, service trenches and foundations are anticipated to be undertaken through gravelly surficial soils and hard or cemented gravelly clayey soils.

Given the slow excavation rates and refusal experienced using an 8 tonne backhoe during the investigation, owing to the presence of cemented soils, the use of a powerful excavator (i.e. 20 tonne or heavier) fitted with tynes of hydraulic hammer is recommended for excavations during earthworks.

Siltstone was encountered a depths of approximately 2 m (generally below fill), however it cannot be preluded at shallower depths and therefore it is considered prudent to allow provision for hydraulic breakers or tynes during site works. Heavy ripping using D9 dozer or heavier using a single ripper tyne should be considered if large excavations in siltstone are proposed.

Slow groundwater seepage was encountered at four locations at the time of field work in September 2020 (near the typical highest groundwater levels of the year). As such, for relatively shallow excavations, say less than 2.5 m, no significant challenges with groundwater management are anticipated for shallow excavations. It is considered likely that some management of seepage water, e.g. through sump pumping to remove ponding water at the base of excavations, would be required if field work is undertaken within the wetter period of the year.

7.4 Re-use of On-Site Materials

The encountered silty sandy topsoil could be considered for re-use as fill, provided that it is blended at a suitable ratio with 'clean' imported sand, in-situ sand (SP-SM) or sandy gravel (GP-GM). Following site stripping operations, the topsoil would need to be screened (say with a 25 mm screen aperture) in order to remove the bulk of the organics (to be disposed or re-used in non-structural areas), prior to blending with the aforementioned non-organic soils. Alternatively, following stripping operation to remove the bulk of the vegetation and root mass, the remaining silty sandy topsoil could be mixed in-situ with the underlying sand or sandy gravel by raking through both materials using a dozer or grader tynes and blades. Field trials under geotechnical supervision should be considered during earthworks to assess suitable blending ratio and methodology.

The sandy and gravelly soils overlying the cemented clayey soils should generally be suitable for reuse as structural filling. However if it considered possible that some of the surficial soils may contain too much reactive components which could preclude the use of the soil for Class A lots, if such classification is targeted (rather than Class S). If earthworks to achieve Class A lots are being undertaken at the site, it is recommended that any material proposed for reuse is inspected by a geotechnical engineer.

Reuse of the cemented clayey soils is possible but should be considered with caution. If such materials are proposed to be re-used, it is recommended that excavation, placement and compaction be carried out during the dry season, in order to make handling, conditioning and compaction easier to manage. Furthermore, in order to minimise the above-mentioned difficulties, it is suggested that contractors with experience in reactive soils are engaged to undertake the site preparation works.

It is recommended that verification of the compaction works be undertaken by an experienced geotechnical engineer.

It is recommended that the in situ clayey materials and cohesive fill is placed in loose lift thicknesses with each layer compacted to achieve a dry density ratio of not less than 92% relative to modified compaction.

Compaction control of the natural clayey materials could be carried out using a nuclear surface moisture-density gauge, in accordance with AS 1289.5.8.1.

7.5 Soil Permeability

The shallow soil conditions within the site generally comprise gravelly soils (Unit 1A) overlying cemented or hard, clayey, gravelly soils (Unit 2). In situ testing indicated a permeability of approximately 8 m/day for the shallow gravelly soils and the cemented clayey gravelly soils (Unit 2) had an average permeability

of approximately 1 m/day. The shallow sandy silt (Unit 1B) encountered at one location in the south-eastern corner of the site had a permeability of 1 m/day.

Unit 2 ground conditions were encountered at typical depths in which stormwater drainage systems would infiltrate water. These soils are not favourable for on-site stormwater infiltration, owing to their relatively low permeability. It is considered however, that on-site drainage systems suitably designed for the lower rate of infiltration, and possibly with overflows into a suitable outflows, could be considered for the site.

7.6 Site and Soil Effluent Disposal Preliminary Assessment

Site characteristics observed during the field work and soil properties determined during subsequent laboratory testing have been assessed in relation to the anticipated limitations that they pose to onsite disposal of domestic effluent.

For this assessment, reference has been made to AS1547-2012, the 2019 WA Government Sewerage Policy and the 2011 NSW Environment and Health Protection Guidelines. This later guideline evaluates various soil and site characteristics and assigns either a minor, moderate or major limitation depending on the restrictions to the disposal of domestic effluent. Minor limitations are regarded as not posing a constraint to the application of domestic effluent. Site and soil characteristics which are considered to be major limitations would require site or soil improvement measures to allow on-site effluent disposal at the site.

Site and soil characteristics, including, the moderate and major limitations for effluent disposal within the site, are discussed next pages.

7.6.1 Soil Permeability

Saturated hydraulic conductivity (permeability) is a measure of the ability of soil to transmit water based on soil properties such as structure, texture and porosity. The soil types noted within the test pits are predominantly gravelly, with increasing clay content with depth.

A soil permeability category Groups 1 (reference to AS 1547-2012 Tables 5.1 and E1) is considered suitable for the sandy and gravelly soils of Unit 1 (average permeability of approximately 8 m/day) and category 4 is considered suitable for the clayey soils (Unit 2) encountered below Unit 1 (average permeability of 1 m/day).

The soil category Group 1 (Unit 1) is considered to be a major limitation owing to excessive percolation that could easily transport pathogens and nutrients, and Group 4 (Unit 2) forms a minor limitation.

7.6.2 Depth to Hardpan

Material which could be considered as hardpan was encountered at locations 7, 8 and 19 at a depth of 2 m or more. Test pits refused prior to target depth at nine locations (locations 6, 9, 10, 17, 18, 20, 22, 24, and 29) which could also be considered as hardpan. The shallowest of which was 1.4 m (at location 20) which indicates that depth to hardpan may affect the selection of an appropriate effluent disposal method in some locations of the site. Based on the available information, depth to hardpan is considered to be a minor limitation.

7.6.3 Depth to Groundwater

Groundwater was encountered with four locations (locations 3, 4, 13 and 22) during the investigation in September 2020 is considered to be perched water. Based on the results of the investigation, in conjunction with desktop information, it is considered that average annual maximum groundwater levels are greater than 2.5 m below the surface levels at this site.

Therefore, the groundwater table is considered a minor limitation for on-site disposal of sewage.

7.6.4 Coarse Fragments

Coarse fragments are defined as particles greater than 2 mm in AS 1547-2012. The abundance of coarse fragments in the soils encountered underlying the site is considered to typically be between 50% and 75%, corresponding to “abundant”, in accordance with Table E2, AS 1547-2012. Coarse fragment percentages over 40% can be considered as a major limitation owing to the potential for the fragments to restrict plant growth.

7.6.5 Slope

The site generally slopes downwards from the east, with typical gradients between 1° and 3° (up to approximately 5% grade). Slopes of this gradient are considered to be a minor limitation due to the limited potential of rapid runoff of the effluent from surface and subsurface irrigation and absorption systems.

7.6.6 Dispersivity

Laboratory testing of soil samples taken from the site indicate an Emerson classes of 2 (slightly dispersive) and 5 (non-dispersive). The sample representing Unit 2 soil, was non-dispersive. Although the laboratory results indicate an Emerson Class 2 for a soil sample of Unit 1B, this unit predominately granular soils (sandy gravel) that are inherently non-dispersive (the dispersivity indicated by the laboratory testing is inferred to be associated with the minor silt component of the sandy gravel forming Unit 1B). Therefore soil dispersity is not considered to be a limitation for effluent systems infiltrating into Unit 2 and Unit 1B soils.

Surface based effluent disposal systems may encounter moderate limitations due to soil dispersity, indicated by an Emerson Class 2 on Unit 1A (shallow soils).

7.6.7 pH

Laboratory testing indicates pH values of above 6. Therefore, pH is considered a minor limitation for on-site sewage disposal at the site.

7.6.8 Electrical Conductivity

Laboratory testing indicates that the electrical conductivity of soils underlying the site is less than 4 dS/m and therefore electrical conductivity is not a limitation to on-site sewage disposal.

7.6.9 Cation Exchange Capacity

The cation exchange capacity (CEC) is the total number of cations a soil can retain on its absorbent complex at a given pH, and is therefore a good measure of a soil ability to retain specific pollutants. The laboratory tests carried out on the samples collected from test locations 6 and 16, indicate CEC values of 2 and 3 meq/100g, or cmol+/kg. A cation exchange capacity of less than 5 cmol+/kg is considered as a major limitation for on-site effluent disposal, indicating some soil inability to hold pollutants and plant nutrients for the irrigation systems.

7.7 On-site Wastewater Management Options

Owing to the occurrence of soils with the major limitations, (primarily the percentage of coarse fragments and cation exchange capacity, some high permeability soils), secondary treatment of the primary effluent will need to be undertaken to produce secondary quality effluent, prior to on-site disposal over the land surface.

Several treatment options are possible and include the following:

- Aerobic Treatment Unit (ATU);
- Closed cell (amended soil) evapo-transpiration systems.

The effluent treatment system selected for use should be approved by the WA Department of Health.

Once the effluent has been treated by an approved system, the resulting effluent would be sent to the disposal area.

The disposal area required will be dependent on number of factors, including the following:

- Treatment system adopted and quality of effluent produced;
- Soil characteristics (as assessed in previous sections)
- Climate conditions; and
- Effluent loading, as determined by the number of people within the proposed buildings and the water reduction fixtures present.

The above matters are typically addressed by the designers of the adopted effluent disposal system.

The performance of an effluent disposal system is dependent on proper maintenance which should incorporate the following:

- Regular maintenance of surface vegetation to encourage water and nitrogen uptake; and
- Maintenance of surface drains to prevent the ponding of water in the vicinity of the disposal area.

7.8 Conclusions on Site Suitability for Effluent Disposal

The ground conditions at this site are generally considered suitable for on-site disposal of effluent produced by secondary treatment systems.

As there are a variety of Department of Health WA approved proprietary systems available, the choice of system is ultimately made by the purchaser of the properties within the guidelines of AS 1547:2012, local government authorities, the WA Department of Health and the site characteristics described above.

8. References

1. Australian Standard AS 1289-2000, Methods of Testing Soils for Engineering Purposes.
2. Australian Standard AS 1289.6.3.2-1999, Soil Strength and Consolidation Tests-Determination of the Penetration Resistance of a Soil – Dynamic Cone Penetrometer Test.
3. Australian Standard AS 1289.6.3.3-1999, Soil Strength and Consolidation Tests-Determination of the Penetration Resistance of a Soil – Perth Sand Penetrometer Test.
4. Australian Standard AS 1726-2017, Geotechnical Site Investigation.
5. Australian Standard AS 2870-2011, Residential Slabs and Footings.
6. Australian Standard AS 1547-2012, On-site Domestic Waste Management.
7. Department of Environment, Perth Groundwater Atlas, Second Edition, December 2004.
8. Government of Western Australia, Government Sewerage Policy, September 2019
9. Code of Practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Unit (ATUs) - November 2001.
10. Environment & Health Protection Guidelines: On-site Sewage Management for Single Households - January 1998.
11. Government Sewerage Policy – Consultation Draft, Department of Health, December 2011.
12. Code of Practice for Onsite Sewage Management, Consultation Draft, November 2012.

9. Limitations

Douglas Partners (DP) has prepared this report for the proposed industrial development at Lots 202 and 203 Great Northern Highway and Lots 204 and 205 Wandena Road, Muchea, in accordance with DP's proposal referenced PER200244.Rev2 dated 30 July 2020 and acceptance received from James Wortley of Tomahawk Property on behalf of Focus Demolition & Asbestos Removal & David Weightman Smith dated 24 August 2020. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Focus Demolition & Asbestos Removal & David Weightman Smith and their agents for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Sampling Methods

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Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are generally based on Australian Standard AS1726:2017, Geotechnical Site Investigations. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	19 - 63
Medium gravel	6.7 - 19
Fine gravel	2.36 – 6.7
Coarse sand	0.6 - 2.36
Medium sand	0.21 - 0.6
Fine sand	0.075 - 0.21

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

The proportions of secondary constituents of soils are described as follows:

In fine grained soils (>35% fines)

Term	Proportion of sand or gravel	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	>30%	Sandy Clay
With	15 – 30%	Clay with sand
Trace	0 - 15%	Clay with trace sand

In coarse grained soils (>65% coarse)
- with clays or silts

Term	Proportion of fines	Example
And	Specify	Sand (70%) and Clay (30%)
Adjective	>12%	Clayey Sand
With	5 - 12%	Sand with clay
Trace	0 - 5%	Sand with trace clay

In coarse grained soils (>65% coarse)
- with coarser fraction

Term	Proportion of coarser fraction	Example
And	Specify	Sand (60%) and Gravel (40%)
Adjective	>30%	Gravelly Sand
With	15 - 30%	Sand with gravel
Trace	0 - 15%	Sand with trace gravel

The presence of cobbles and boulders shall be specifically noted by beginning the description with 'Mix of Soil and Cobbles/Boulders' with the word order indicating the dominant first and the proportion of cobbles and boulders described together.

Soil Descriptions

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	VS	<12
Soft	S	12 - 25
Firm	F	25 - 50
Stiff	St	50 - 100
Very stiff	VSt	100 - 200
Hard	H	>200
Friable	Fr	-

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	Density Index (%)
Very loose	VL	<15
Loose	L	15-35
Medium dense	MD	35-65
Dense	D	65-85
Very dense	VD	>85

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Extremely weathered material – formed from in-situ weathering of geological formations. Has soil strength but retains the structure or fabric of the parent rock;
- Alluvial soil – deposited by streams and rivers;
- Estuarine soil – deposited in coastal estuaries;
- Marine soil – deposited in a marine environment;
- Lacustrine soil – deposited in freshwater lakes;
- Aeolian soil – carried and deposited by wind;
- Colluvial soil – soil and rock debris transported down slopes by gravity;
- Topsoil – mantle of surface soil, often with high levels of organic material.
- Fill – any material which has been moved by man.

Moisture Condition – Coarse Grained Soils

For coarse grained soils the moisture condition should be described by appearance and feel using the following terms:

- Dry (D) Non-cohesive and free-running.
- Moist (M) Soil feels cool, darkened in colour.
  Soil tends to stick together.
  Sand forms weak ball but breaks easily.
- Wet (W) Soil feels cool, darkened in colour.
  Soil tends to stick together, free water forms when handling.

Moisture Condition – Fine Grained Soils

For fine grained soils the assessment of moisture content is relative to their plastic limit or liquid limit, as follows:

- ‘Moist, dry of plastic limit’ or ‘w <PL’ (i.e. hard and friable or powdery).
- ‘Moist, near plastic limit’ or ‘w ≈ PL (i.e. soil can be moulded at moisture content approximately equal to the plastic limit).
- ‘Moist, wet of plastic limit’ or ‘w >PL’ (i.e. soils usually weakened and free water forms on the hands when handling).
- ‘Wet’ or ‘w ≈LL’ (i.e. near the liquid limit).
- ‘Wet’ or ‘w >LL’ (i.e. wet of the liquid limit).

Rock Strength

Rock strength is defined by the Unconfined Compressive Strength and it refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects.

The Point Load Strength Index $Is_{(50)}$ is commonly used to provide an estimate of the rock strength and site specific correlations should be developed to allow UCS values to be determined. The point load strength test procedure is described by Australian Standard AS4133.4.1-2007. The terms used to describe rock strength are as follows:

Strength Term	Abbreviation	Unconfined Compressive Strength MPa	Point Load Index * $Is_{(50)}$ MPa
Very low	VL	0.6 - 2	0.03 - 0.1
Low	L	2 - 6	0.1 - 0.3
Medium	M	6 - 20	0.3 - 1.0
High	H	20 - 60	1 - 3
Very high	VH	60 - 200	3 - 10
Extremely high	EH	>200	>10

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$. It should be noted that the UCS to $Is_{(50)}$ ratio varies significantly for different rock types and specific ratios should be determined for each site.

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Residual Soil	RS	Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely weathered	XW	Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are still visible
Highly weathered	HW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately weathered	MW	The whole of the rock material is discoloured , usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable, but shows little or no change of strength from fresh rock.
Slightly weathered	SW	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	FR	No signs of decomposition or staining.
Note: If HW and MW cannot be differentiated use DW (see below)		
Distinctly weathered	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching or may be decreased due to deposition of weathered products in pores.

Rock Descriptions

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with occasional fragments
Fractured	Core lengths of 30-100 mm with occasional shorter and longer sections
Slightly Fractured	Core lengths of 300 mm or longer with occasional sections of 100-300 mm
Unbroken	Core contains very few fractures

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq \text{100 mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or stronger. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	< 6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	> 2 m

Symbols & Abbreviations

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Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	Pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	Lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General


Asphalt


Road base


Concrete

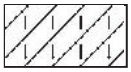

Filling

Soils


Topsoil


Peat


Clay

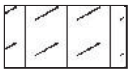

Silty clay

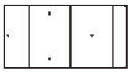

Sandy clay

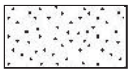

Gravelly clay


Shaly clay

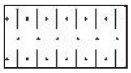

Silt


Clayey silt


Sandy silt

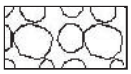

Sand

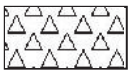

Clayey sand


Silty sand


Gravel


Sandy gravel


Cobbles, boulders

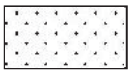

Talus

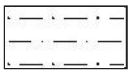
Sedimentary Rocks

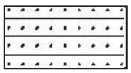

Boulder conglomerate

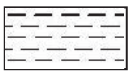

Conglomerate


Conglomeratic sandstone

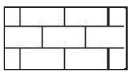

Sandstone


Siltstone

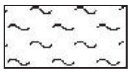

Laminite

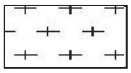

Mudstone, claystone, shale

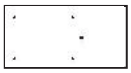

Coal


Limestone

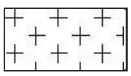
Metamorphic Rocks

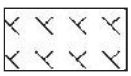

Slate, phyllite, schist

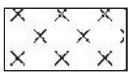

Gneiss

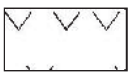

Quartzite

Igneous Rocks


Granite


Dolerite, basalt, andesite

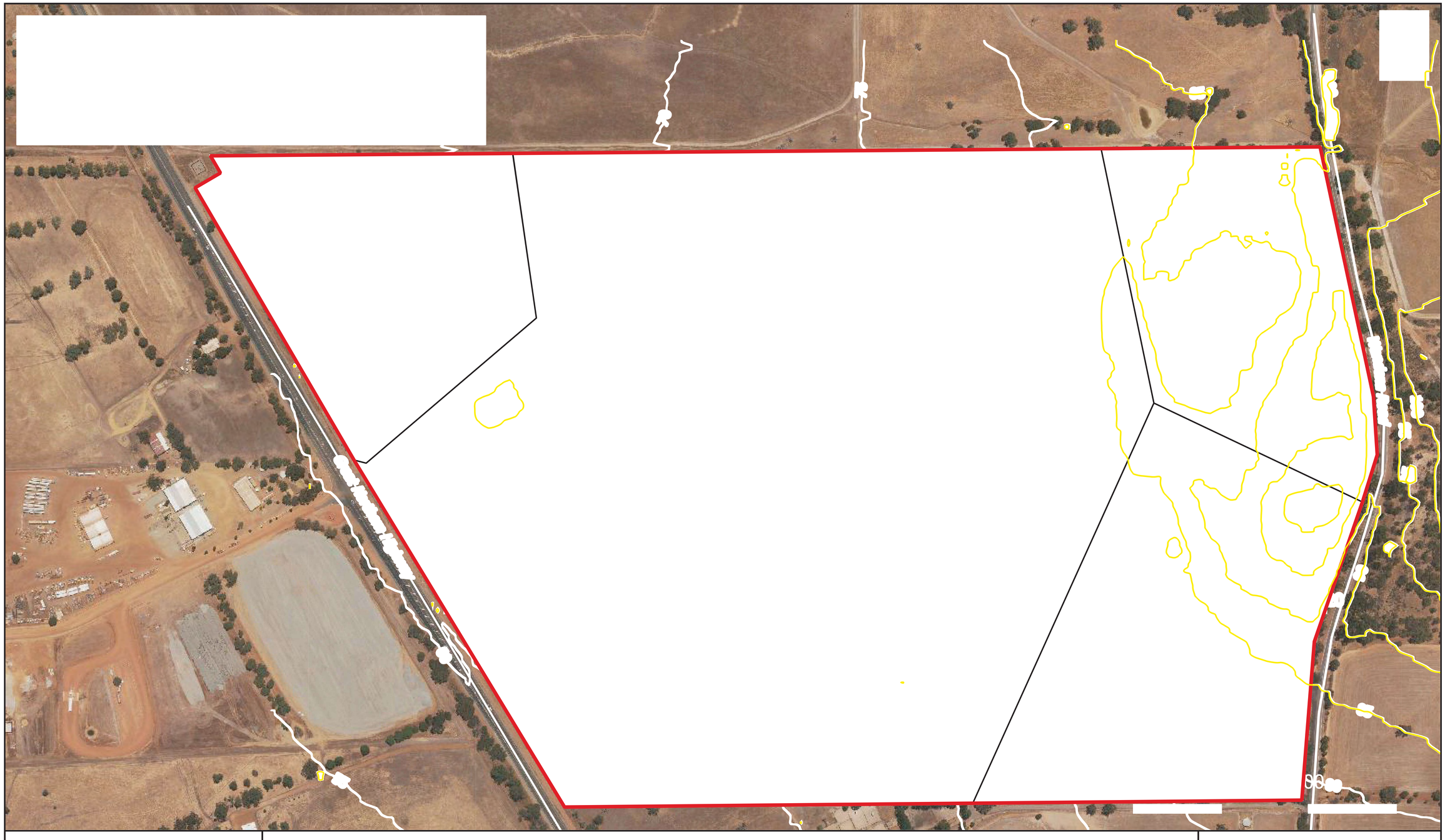

Dacite, epidote


Tuff, breccia


Porphyry

Appendix B

Test Location Plan
Test Pit Logs



Douglas Partners Geotechnics / Environment / Groundwater	**Test Location Plan** **Proposed Industrial Development** **Lots 202 and 203 Wandena Road & Lots 204 and 205 Great Northern Highway, Muchea, WA** CLIENT: Focus Demolition & Asbestos Removal & David Weightman Smith	PROJECT: 96712.00 Drawing No: 1 REV: 0 DATE: 8/10/2020

Appendix D

Groundwater Measurements

WANDENA RD / GT NORTHERN HWY BORES
STATIC DATA

Bore	Easting	Northing	Install Date	RLT (mAHD)	RLG (mAHD)	Total Depth (mbtoc)	Stickup (magl)	Total Depth (mbgl)
WB1	405843	6503819	24/03/2020	61.81	61.23	5.27	0.58	4.69
WB2	406206	6504189	24/03/2020	71.39	70.87	5.45	0.52	4.93
WB3	406365	6503799	24/03/2020	69.72	69.09	5.7	0.63	5.07
WB4	406393	6503460	24/03/2020	62.48	61.87	5.86	0.61	5.25
Ex Bore 1	405991	6504091	uk	66.03	65.73	uk	0.3	
Ex Bore 2	405991	6503948	uk	65.32	65.32	uk	0	
MW1	406899	6504175	6/04/2016	92.76	92.2	20.5	0.56	
MW2	406919	6504048	6/04/2016	94.96	94.32	25	0.64	
MW3	406684	6504119	6/04/2016	83.87	83.22	19.5	0.65	
MW4	406748	6503595	6/04/2016	79.43	78.78	19.7	0.65	
GD20	405300	6506021	uk	62.09	61.48	19.51	0.61	18.9
2-98	406399	6502795	uk	58.893	58.29	18.603	0.603	18

WANDENA RD / GT NORTHERN HWY BORES
DEPTHS TO WATER

	DEPTH TO WATER (mbgl)										
Bore	**12/07/2016**	**2/09/2016**	**28/09/2016**	**22/11/2016**	**17/08/2017**	**12/01/2018**	**18/10/2018**	**30/05/2019**	**21/08/2020**	**9/09/2020**	**2/10/2020**
WB1									>4.68		>4.69
WB2									>4.98		>4.93
WB3									1.58		2.64
WB4									2.34		1.73
Ex Bore 1									16.62		17.19
Ex Bore 2									9.92		9.74
MW1	18.54	15.67	15.38	15.32		15.39		15.64	>17.44		15.94
MW2	16.36	18.06	17.8	17.61		17.68		17.69	16.14		18
MW3	15.25	11.01	10.54	10.5		11.39		12.15	12.55		12.1
MW4	12.57	14.09	13.53	13.32		13.39		15.75	14.45		14.16
GD20					0.19				0.88		1.48
2-98					1.49				2.117		2.267

WANDENA RD / GT NORTHERN HWY BORES
WATER LEVELS

	WATER LEVEL (m AHD)										
Bore	**12/07/2016**	**2/09/2016**	**28/09/2016**	**22/11/2016**	**17/08/2017**	**12/01/2018**	**18/10/2018**	**30/05/2019**	**21/08/2020**	**9/09/2020**	**2/10/2020**
WB1									<56.55		<56.54
WB2									<65.89		<65.94
WB3									67.51		66.45
WB4									59.53		60.14
Ex Bore 1									49.11		48.54
Ex Bore 2									55.4		55.58
MW1	73.66	76.53	76.82	76.88		76.81		76.56	<74.76		76.26
MW2	77.96	76.26	76.52	76.71		76.64		76.63	78.26		76.32
MW3	67.97	72.21	72.68	72.72		71.83		71.07	70.67		71.12
MW4	66.21	64.69	65.25	65.46		65.39		63.03	64.33		64.62
GD20					61.29		60.91		60.6		60
2-98					56.793		56.623		56.173		56.023

WANDENA RD / GT NORTHERN HWY BORES
AAMGL and MGL
from 21/8/20 measurements

Bore	AAMGL (mAHD)	MGL (mAHD)	DTAAMGL (m)	DTMGL (m)
WB1				
WB2				
WB3	67.937	68.517	1.153	0.573
WB4	59.957	60.537	1.913	1.333
Ex Bore 1	49.537	50.117	16.193	15.613
Ex Bore 2	55.827	56.407	9.493	8.913
MW1				
MW2	78.687	79.267	15.633	15.053
MW3	71.097	71.677	12.123	11.543
MW4	64.757	65.337	14.023	13.443
GD20	59.85	61.35	1.63	0.13
2-98	56.6	57.18	1.69	1.11

Appendix E

Letter from Aqua Ferre Pty Ltd

AQUA FERRE PTY LTD
ACN 121 146 772
PO Box 1982 West Perth WA 6872
Level 1, 5 Ord Street West Perth WA 6005
Tel: 08 9282 5400
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29 January 2018

Tom Carmody
Director and Licensee
Tomahawk Property on behalf of the Muchea Employment Node Precinct 3 Landowner Group
8/355 Stirling Highway
Claremont WA 6010

Dear Mr Carmody

Muchea Employment Node Precinct 3 Landowner Group

I refer to your enquiries to Aqua Ferre Pty Ltd (Aqua Ferre) regarding the availability of water and the potential future supply of water, within the Muchea region.

You have advised that you represent a number of landowners with properties on Great Northern Highway and Brand Highway in Muchea (collectively described as the Muchea Employment Node Precinct 3 Landowner Group or more generally the landowner group).

On behalf of the landowner group you have requested information from Aqua Ferre in support of two planning documents:

- Shire of Chittering Town Planning Scheme No 6 Amendment No.67 - Rezoning Lots M1601, 800-804, 192, 194 and 35 Great Northern Highway, Muchea from 'Agricultural Resource' zone to 'Industrial Development' zone, and amending the Scheme Maps accordingly; and
- Precinct 3 Muchea Industrial Park Structure Plan.

In particular you have sought information regarding Aqua Ferre's water entitlements, the prospect that some of Aqua Ferre's water entitlement may be allocated to the landowner group properties, and whether the water can be practically supplied from Aqua Ferre's operations to the landowner group properties.

1 MEN & Precinct 3

The Muchea Employment Node Structure Plan (MENSP) was adopted by the WAPC in August 2011, and provides a 20-year planning framework for industrial development within the Shire of Chittering. We understand that the MENSP is currently under review and a revised document is expected to be released during 2019.

You have advised that the subject land is located within Precinct 3, which forms the eastern portion of the MENSP, to the west of Great Northern Highway (GNH).

Precinct 3 of the Muchea Employment Node (more recently referred to as the Muchea Industrial Park (MIP)) ('the Structure Plan area') is approximately 185ha in area and located to the south east of the

townsite of Muchea. Precinct 3 is triangular in shape and extends in a lineal pattern from Brand Highway in the north, along Great Northern Highway (GNH) in the east, to the southern boundary of the Shire of Chittering, and along the Perth-Darwin Highway (PDNH) to the west, which is currently under construction.

Figure 1 below shows the proposed Precinct 3 development boundaries (Urbis 2019, LPS Amendment, Muchea Employment Node, DWG-11).

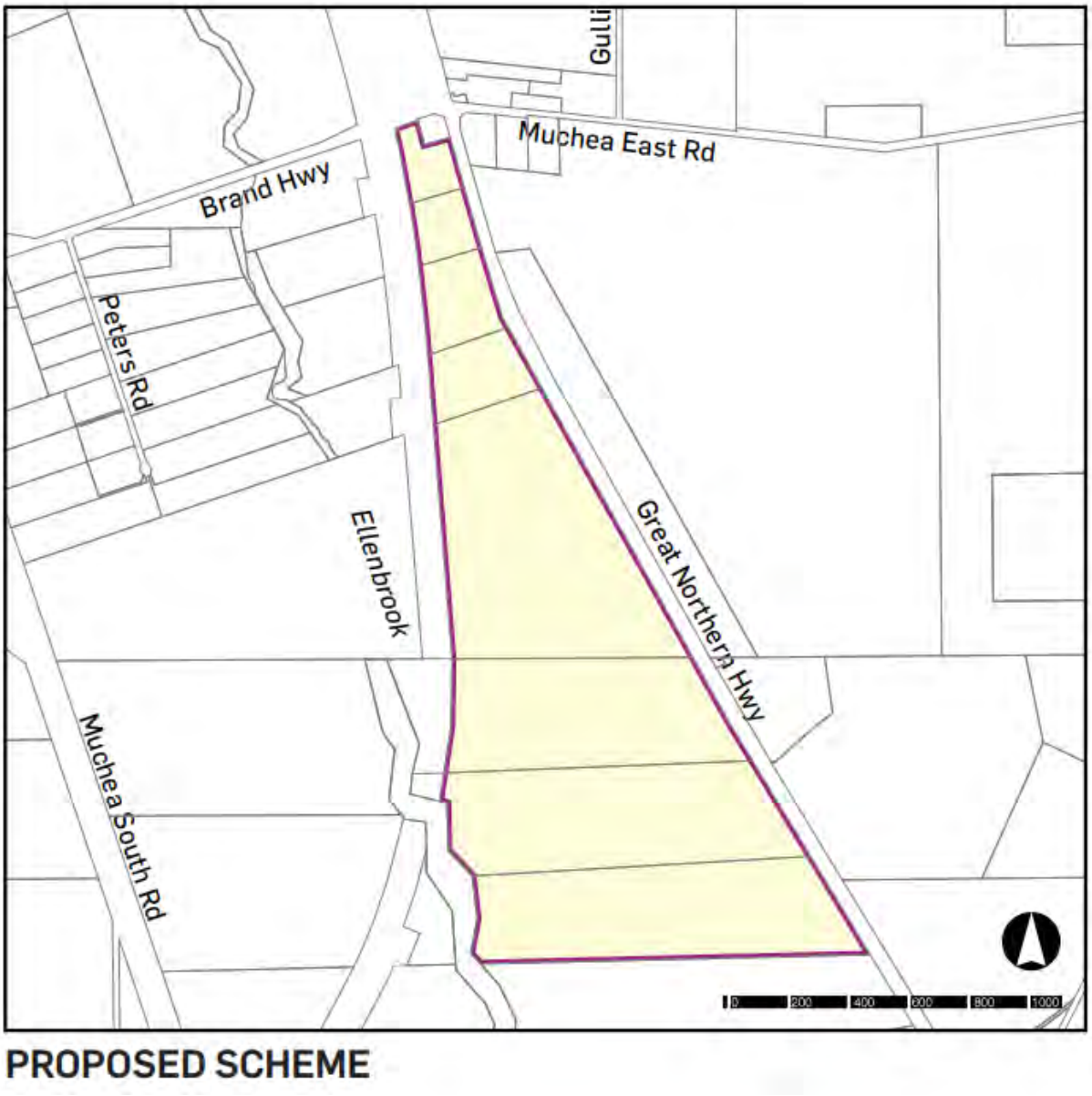


Figure 1 Proposed Precinct 3 development

Urbis[1] have indicated that the land has largely been historically cleared for agricultural purposes and contains stands of large, mature trees with degraded understorey, and a number of rural drainage lines.

[1] Urbis Pty Ltd 2019, Precinct 3, Muchea Industrial Park, Structure Plan, Draft January 2019

You have advised that the Structure Plan[2] will provide approximately 51 lots of approximately 1.3ha to 7.6ha providing flexibility for a range of industrial uses, expected to be primarily transport logistics related.

We understand that the Structure Plan is being progressed concurrently with Amendment No.67 to LPS6 which proposes to rezone the land from 'Agricultural Resource Zone' to the 'Industrial Development' zone, to introduce land use permissibility for Precinct 3; clarify requirements for the preparation of Management Plans, and introduce provisions relating to provision of reticulated water and construction of the loop road.

2 Aqua Ferre

Aqua Ferre was established to be an independent water service provider following approaches by property development groups seeking water services in the Chittering/Muchea region. Aqua Ferre is proposing to build and operate a potable water supply system at Reserve Road, Chittering (as shown in Figure 2).

The proposed water treatment plant (WTP) would be operated as a constant flow rate to promote a stable process with the intention of producing reliable potable water that meets the Australian Drinking Water Guidelines.

Figure 2 below broadly shows the Precinct 3 development (outlined in red) to the south of Harvis' proposed MEN (Phase 1) development (outlined in yellow) and Aqua Ferre's proposed water facility to the north.

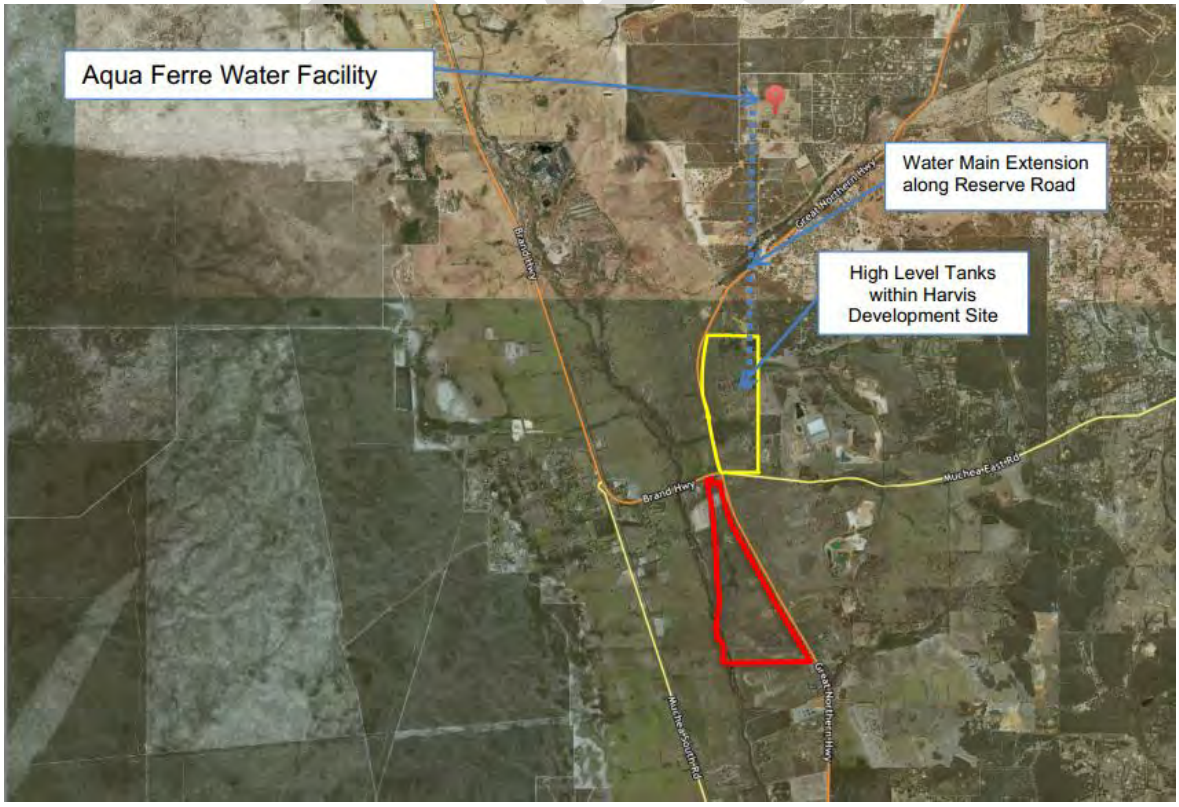


Figure 2 Development boundaries

[2] Urbis Pty Ltd 2019, Precinct 3, Muchea Industrial Park, Structure Plan, Draft January 2019

2.1 Water Entitlement

The Reserve Road (Chittering) property currently has a total water entitlement or allocation (licence to abstract water from an artesian aquifer) of 288,800 kL per annum. The developer of the Reserve Road residential development, Riverside, has transferred the Water Licence GWL 59907(3) to the Water Corporation to enable the licence to be changed from an agricultural extraction to public water supply. It is intended that this water entitlement will be transferred to Aqua Ferre when a water service licence has been granted.

Aqua Ferre has similar entitlement rights to a further 362,900 kL per annum licence, originally GWL 102502(4) which is now part of GWL 65011.

In total, it is intended that Aqua Ferre will have access to 651,700 kL of water per annum.

There is an existing production bore located within the proposed Reserve Road development that was previously used for wildflower irrigation, where the proposed potable WTP would be located.

2.2 Existing water supply commitments

Aqua Ferre intends supplying approximately 153 ML of treated potable water to the residential development at Reserve Road, Chittering, and to a commercial/industrial development at the adjacent MEN (northern Precinct 1 only). It is intended that a further 75 ML will be set aside for future demand across these two developments.

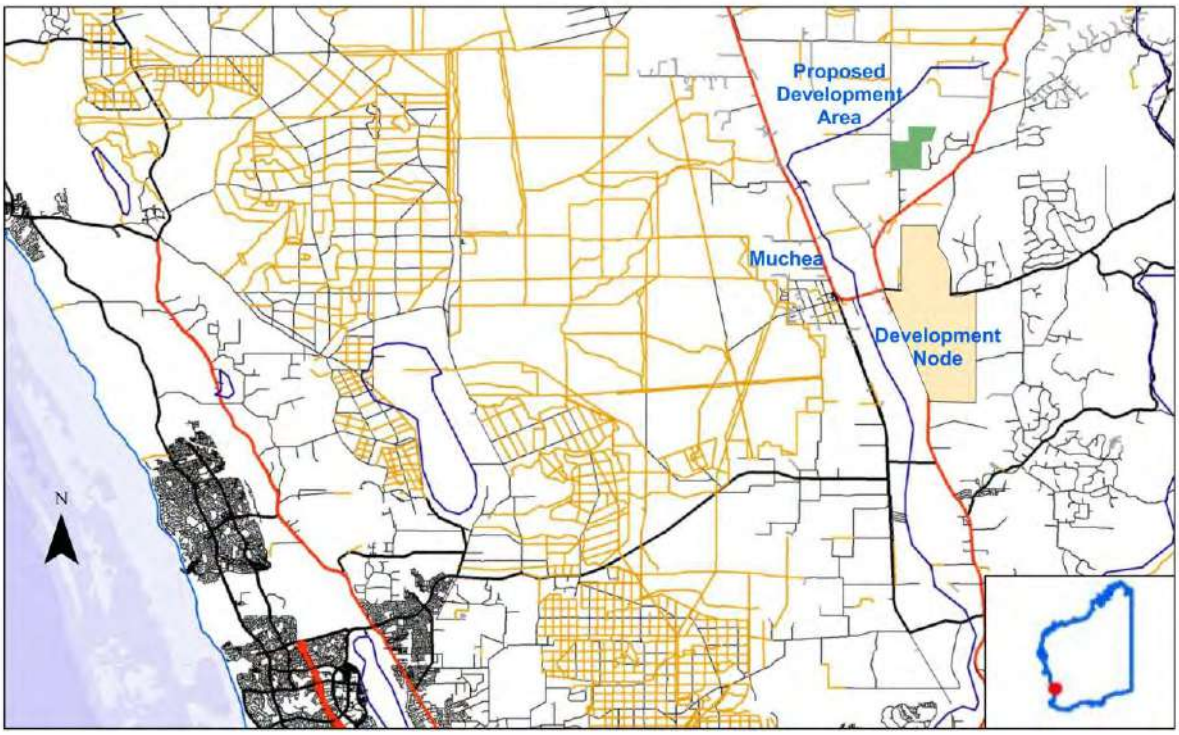


Figure 3 Location of Reserve Road residential development and MEN

The new Reserve Road rural living allotment development is located 8km north east of the Muchea town site and 80km north of the Perth central business district. It is also in close proximity (4km) to the

proposed MEN on the eastern side of Great Northern Highway. The development is in accordance with the Shire of Chittering's planning scheme (2004). The Reserve Road development covers an area of approximately 160 hectares and involves the creation of approximately 245 rural residential allotments in progressive stages. It is a requirement of the development approval that potable reticulated water is available.

Figure 4 Contour map (5m contour lines) of the Harvis MEN development showing ephemeral swale

Phase 1 of the MEN development is being undertaken by development group Harvis Capital Pty Ltd (Harvis). The Harvis development is located on the northern end of the proposed MEN. The site is slightly undulating with an ephemeral swale running through the development (Figure 4). The development is well placed and has been planned around the proposed Perth Darwin Highway.

It is the intention of the MEN development that these lots also have a reticulated water resource. Currently, the area does not have a public water supply scheme. Aqua Ferre is finalising documentation to allow the Economic Regulation Authority Western Australia to consider an application for a water services licence.

It is proposed that the water supply for the Harvis MEN development will have a standalone delivery and network system, to ensure that the demand of both systems can meet peak demand and firefighting requirements.

After treatment, it is intended that the water required for the Harvis MEN site will be delivered to a 500kL holding tank with aeration. Water would be reticulated to customers using a standard, continually pressurised water reticulation network. The piping would follow the general topography and alignment of the development streets and will have 600mm coverage.

3 Precinct 3 water requirement

You have advised that the intention is that the land the subject of the Structure Plan would be serviced with reticulated water provided by a licensed water provider.

The total area of supply is for an industrial development totalling approximately 185 hectares. No indication of staging of development has been provided at this point.

Estimated annual water usage has been provided (based on preliminary modelling by Cossill & Webley) as 203ML per annum on a net area of 139 hectares (after allowing for a 25% reduction in land area calculation to accommodate roads/drainage). The proposed system has been modelled at 4kL/day per hectare based on advice from Cossill & Webley of studies of similar industry types and uses. It is noted that this compares to the Water Corporation design standard for industrial land of approximately 17 kL/ha/day.

Based on your advice of estimated water usage, Aqua Ferre would have capacity under its entitlements to meet the demand of the subject land. This is not an undertaking to commit an allocation of water, or to supply water, to the Muchea Employment Node Precinct 3 Landowner Group. Any such arrangements would be the subject to future commercial negotiation, agreement on terms including pricing and remaining water availability under Aqua Ferre's entitlements.

4 Supply assessment

Aqua Ferre has conducted a preliminary desktop assessment of the potential supply route from its planned water treatment plant at Reserve Road to the proposed Precinct 3 development via Harvis' phase 1 MEN development. This represents a distance of approximately 3.5 kilometres.

The assessment did not highlight any major engineering impediments to the provision of water to the proposed development. (This is not to say, however, that any impediments would not become apparent on more detailed analysis.)

Any proposal for supply would be inclusive of the requirements of:

- Water Corporation Design Standard DS 63 – Water Reticulation Standard Design and Construction Requirements for Water Reticulation Systems or Water Reticulation Systems up to DN250
- DFES requirements for firefighting services
- Hydraulic modelling using EPANET 2 for system hydraulics.

Hydraulic modelling would require topographical mapping at 0.5m.

Additionally, there would be a requirement for a water reserve for tanks, pumps, sumps, generator and chlorination which would need to be met by the subject landowners' group.

5 Disclaimer

This report is dated 29 January 2019 and incorporates information available to Aqua Ferre up to that date only. It excludes consideration of any information arising, or event occurring, after that date which may impact opinions expressed or statements made by Aqua Ferre in this report.

Aqua Ferre has prepared this report on the instructions, and for the sole benefit, of Tomahawk Property (Instructing Party), for inclusion within a rezoning application and Structure Plan as described in paragraph 3 of this letter (Purpose) and not for any other purpose or use. To the extent permitted by applicable law, Aqua Ferre expressly disclaims all liability, whether direct or indirect:

- to the Instructing Party, which may arise in connection with any reliance or purported reliance on this report for any purpose other than the Purpose, and
- to any other person, which may arise in connection with any reliance or purported reliance on this report for any purpose whatsoever (including the Purpose).

All statements and opinions contained in or associated with this report are made on the basis of information supplied to Aqua Ferre as at the date of this report, and upon which Aqua Ferre has relied. To the extent permitted by applicable law, Aqua Ferre expressly disclaims any liability, whether direct or indirect, which may arise in connection with any errors or omissions in this report arising from information provided to Aqua Ferre by the Instructing Party or by any other person.

Achievement of any proposed or intended events or circumstances described in this report will depend, among other things, on the actions of others, over which Aqua Ferre has no control. To the extent permitted by applicable law, Aqua Ferre expressly disclaims any liability, whether direct or indirect, which may arise in connection with the delay in, or failure to occur of, any proposed or intended events or circumstances described in this report.

Yours sincerely

Peter Fogarty
Director

Appendix F

Flow Calculations

LOTS - 1 YEAR ARI 1 HOUR

Rainfall Intensity i (mm/h)	15.1	(1yr, 1hr Storm)
Runoff Coefficient Lots	0.8	
Permeability k (m/hr)	0.0417	

Segment	Lot(s)	Lot Area (m2)	Ai (m2)	Q (L/s)	Vinflow (m3)
A1					
	1	10900	8720	37	132
	2	10000	8000	34	121
	3	10000	8000	34	121
	5	11453	9162	38	138
A2					
	6	13372	10698	45	162
A3					
	13	10624	8499	36	128
A4					
	14	10017	8014	34	121
	15	10015	8012	34	121
	16	10013	8010	34	121
	17	10010	8008	34	121
	23N	4625	3700	16	56
A5					
	18	10649	8519	36	129
	24N	6205	4964	21	75
B1					
	7	10212	8170	34	123
	8	10000	8000	34	121
	9	10000	8000	34	121
	10	10000	8000	34	121
B2					
C1					
	4	24227	19382	81	293
D1					
	19	11032	8826	37	133
	20	10000	8000	34	121
	21	10000	8000	34	121
	22	10000	8000	34	121
	23S	5354	4283	18	65
	31	11160	8928	37	135
D2					
	11	20441	16353	69	
	12	22155	17724	74	
	32	10416	8333	35	126
D3					
	24S	7763	6210	26	94
	25	10221	8177	34	124
	26	10003	8002	34	121
	27	10265	8212	34	124
	28	21290	17032	71	257
	29	11383	9106	38	138
	30	10000	8000	34	121
D4					
	49	10003	8002	34	121
	50	11345	9076	38	137
D5			0		
	51	10139	8111	34	123
	52	11362	9090	38	137
D6					
	47	11988	9590	40	145
	48	11956	9565	40	145
D7					
D8					
	42	10314	8251	35	125
D9					
	33	13442	10754	45	163
	34	10000	8000	34	121

	35	10000	8000	34	121
	36	10000	8000	34	121
	37	10000	8000	34	121
	38	13726	10981	46	166
D10					
	41	10200	8160	34	123
	43	15438	12350	52	187
	44	12386	9909	42	150
	45	11475	9180	39	139
	46	12208	9766	41	148
D11					
	39	14627	11702	49	177
	40	16529	13223	56	200
E1					0
	53	11089	8871	37	134
	54	10086	8069	34	122
E2					
	55	10271	8217	34	124
	56	10041	8033	34	121
	57	10437	8350	35	126
	58	10559	8447	35	128
E3					

Swale Sizing		**Depth**	**Slope 1:x**	**Base Width**	**Base Length**	**Top Width (m)**	**Top Length (m)**	**Volume**	**Effective Volume**	**Surface Area (m2)**	**Volume check**
A1											
	1	**0.5**	**4**	**12**	**16**	16	20	127	137	320	ok
	2	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	3	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	5	**0.5**	**4**	**13**	**16**	17	20	136	147	340	ok
A2											
	6	**0.5**	**4**	**15**	**16**	19	20	154	166	380	ok
A3											
	13	**0.5**	**4**	**12**	**16**	16	20	127	137	320	ok
A4											
	14	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	15	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	16	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	17	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	23N	**0.5**	**4**	**7**	**10**	11	14	55	59	154	ok
A5											
	18	**0.5**	**4**	**12**	**16**	16	20	127	137	320	ok
	24N	**0.5**	**4**	**8**	**12**	12	16	71	77	192	ok
B1											
	7	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	8	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	9	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	10	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
B2											
C1											
	4	**0.5**	**4**	**19**	**24**	23	28	274	296	644	ok
D1											
	19	**0.5**	**4**	**12**	**16**	16	20	127	137	320	ok
	20	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	21	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	22	**0.5**	**4**	**13**	**22**	17	26	181	196	442	ok
	23S	**0.5**	**4**	**7**	**12**	11	16	64	69	176	ok
	31	**0.5**	**4**	**12**	**16**	16	20	127	137	320	ok
D2											
	11	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	12	**0.5**	**4**	**14**	**21**	18	25	185	200	450	ok
	32	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
D3											
	24S	**0.5**	**4**	**9**	**14**	13	18	89	96	234	ok
	25	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok
	26	**0.5**	**4**	**11**	**16**	15	20	118	127	300	ok

	27	0.5	4	11	16	15	20	118	127	300	ok
	28	0.5	4	17	24	21	28	248	268	588	ok
	29	0.5	4	13	16	17	20	136	147	340	ok
	30	0.5	4	12	16	16	20	127	137	320	ok
D4											
	49	0.5	4	11	16	15	20	118	127	300	ok
	50	0.5	4	12	16	16	20	127	137	320	ok
D5											
	51	0.5	4	11	16	15	20	118	127	300	ok
	52	0.5	4	13	16	17	20	136	147	340	ok
D6											
	47	0.5	4	13	16	17	20	136	147	340	ok
	48	0.5	4	13	16	17	20	136	147	340	ok
D7											
D8											
	42	0.5	4	11	16	15	20	118	127	300	ok
D9											
	33	0.5	4	13	18	17	22	151	163	374	ok
	34	0.5	4	11	16	15	20	118	127	300	ok
	35	0.5	4	11	16	15	20	118	127	300	ok
	36	0.5	4	11	16	15	20	118	127	300	ok
	37	0.5	4	11	16	15	20	118	127	300	ok
	38	0.5	4	14	18	18	22	161	174	396	ok
D10											
	41	0.5	4	11	16	15	20	118	127	300	ok
	43	0.5	4	14	20	18	24	177	191	432	ok
	44	0.5	4	13	17	17	21	143	155	357	ok
	45	0.5	4	13	16	17	20	136	147	340	ok
	46	0.5	4	14	16	18	20	145	157	360	ok
D11											
	39	0.5	4	14	19	18	23	169	183	414	ok
	40	0.5	4	15	20	19	24	188	203	456	ok
E1											
	53	0.5	4	12	16	16	20	127	137	320	ok
	54	0.5	4	11	16	15	20	118	127	300	ok
E2											
	55	0.5	4	11	16	15	20	118	127	300	ok
	56	0.5	4	11	16	15	20	118	127	300	ok
	57	0.5	4	11	16	15	20	118	127	300	ok
	58	0.5	4	12	16	16	20	127	137	320	ok
E3											

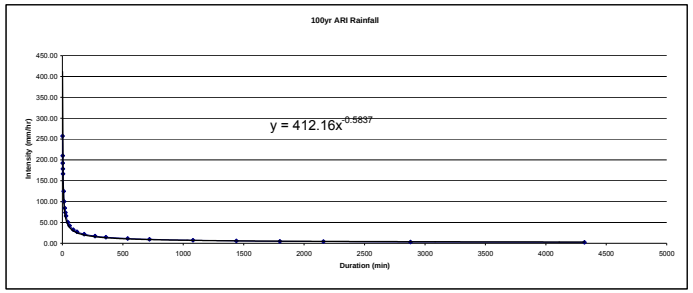
100 YEAR ARI DRAINAGE PROPERTIES - LOTS

Segment	Lot(s)	AREAS (m2)			TIME OF CONCENTRATION PRE-DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)		
		Area (m2)	Effective Area (m2)		Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (min)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (min)	Pre-Dev	Post-Dev	Time to Overflow (min)
			Pre	Post													
A1																	
	1	10900	3815	9265	126	62.7	60.2	19.84	7.0	126	62.7	60.2	19.84	6.4	132.2	139.2	5.89
	2	10000	3500	8500	134	62.9	60.7	16.42	7.8	134	62.9	60.7	16.42	7.2	124.1	130.7	6.35
	3	10000	3500	8500	122	63.4	60.8	21.31	6.8	122	63.4	60.8	21.31	6.2	135.1	142.3	5.83
	5	11453	4009	9735	124	65.5	63	20.16	6.8	124	65.5	63	20.16	6.3	134.1	141.2	5.92
A2																	
	6	13372	4680	11366	148	65.5	63	16.89	8.3	148	65.5	63	16.89	7.6	119.5	125.9	6.44
A3																	
	13	10624	3718	9030	116	72	69.6	20.69	6.4	116	72	69.6	20.69	5.9	139.2	146.6	5.74
A4																	
	14	10017	3506	8514	134	73.6	71.7	14.18	8.0	134	73.6	71.7	14.18	7.4	122.0	128.5	6.45
	15	10015	3505	8513	134	75.5	73.5	14.93	8.0	134	75.5	73.5	14.93	7.3	122.7	129.3	6.41
	16	10013	3505	8511	132	77.6	75.5	15.91	7.7	132	77.6	75.5	15.91	7.1	124.7	131.4	6.31
	17	10010	3504	8509	132	79.6	77.3	17.42	7.6	132	79.6	77.3	17.42	7.0	126.1	132.8	6.25
	23N	4625	1619	3931	84	79.5	77	29.76	4.7	84	79.5	77	29.76	4.3	167.0	175.9	4.74
A5																	
	18	10649	3727	9052	132	81.5	79.5	15.15	7.8	132	81.5	79.5	15.15	7.1	124.5	131.1	6.40
	24N	6205	2172	5274	115	86.7	80	58.26	5.5	115	86.7	80	58.26	5.0	153.0	161.1	4.99
B1																	
	7	10212	3574	8680	136	69	65.8	23.53	7.4	136	69	65.8	23.53	6.7	128.5	135.3	6.01
	8	10000	3500	8500	127	68.3	65.6	21.26	7.0	127	68.3	65.6	21.26	6.4	132.0	139.0	5.97
	9	10000	3500	8500	140	68.7	65.4	23.57	7.6	140	68.7	65.4	23.57	7.0	126.2	132.9	6.25
	10	10000	3500	8500	136	68	64.8	23.53	7.4	136	68	64.8	23.53	6.8	128.3	135.1	6.14
B2																	
C1																	
	4	24227	8479	20593	173	64.8	61.1	21.39	8.8	173	64.8	61.1	21.39	8.0	116.1	122.3	6.52
D1																	
	19	11032	3861	9377	131	71.5	69	19.08	7.3	131	71.5	69	19.08	6.7	128.7	135.6	5.98
	20	10000	3500	8500	129	73.2	70.5	20.93	7.2	129	73.2	70.5	20.93	6.6	130.5	137.5	6.04
	21	10000	3500	8500	129	75	72	23.26	7.0	129	75	72	23.26	6.4	132.2	139.2	5.97
	22	10000	3500	8500	129	76.9	73.7	24.81	6.9	129	76.9	73.7	24.81	6.3	133.2	140.2	9.09
	23S	5354	1874	4551	91	79.7	75.7	43.96	4.6	91	79.7	75.7	43.96	4.2	168.3	177.2	4.73
	31	11160	3906	9486	136	79.7	67	93.38	5.5	136	79.7	67	93.38	5.1	151.7	159.7	5.01
D2																	
	11	20441	7154	17375	152	79.7		524.34	4.1	152	79.7		524.34	3.8	180.1	189.7	2.14
	12	22155	7754	18832	153	63	60	19.61	8.0	153	63	60	19.61	7.3	122.8	129.4	4.55
	32	10416	3646	8854	154	67.4	64.2	20.78	8.5	154	67.4	64.2	20.78	7.8	117.9	124.2	6.42
D3																	
	24S	7763	2717	6599	116	86.5	79.5	60.34	5.3	116	86.5	79.5	60.34	4.9	154.9	163.1	4.94
	25	10221	3577	8688	132	87.0	78.0	68.18	5.8	132	87.0	78.0	68.18	5.3	148.0	155.9	5.21
	26	10003	3501	8503	123	83.0	74.1	72.36	5.3	123	83.0	74.1	72.36	4.9	155.1	163.4	5.08
	27	10265	3593	8725	122	77.5	70.8	54.92	5.6	122	77.5	70.8	54.92	5.1	151.2	159.2	5.08
	28	21290	7452	18097	216	78.7	69.5	42.59	9.7	216	78.7	69.5	42.59	8.8	109.7	115.5	7.11
	29	11383	3984	9676	139	73.0	68.9	29.50	7.1	139	73.0	68.9	29.50	6.5	131.1	138.0	6.09
	30	10000	3500	8500	133	71.4	68.2	24.06	7.2	133	71.4	68.2	24.06	6.6	130.3	137.3	6.51
D4																	
	49	10003	3501	8503	129	84.2	74.0	79.07	5.5	129	84.2	74.0	79.07	5.0	152.5	160.6	5.17
	50	11345	3971	9643	133	87.8	81.5	47.37	6.2	133	87.8	81.5	47.37	5.7	142.1	149.7	5.27
D5																	
	51	10139	3549	8618	137	100.0	87.8	89.05	5.7	137	100.0	87.8	89.05	5.2	149.4	157.3	5.21
	52	11362	3977	9658	129	98.0	94.5	27.13	6.7	129	98.0	94.5	27.13	6.1	135.6	142.8	5.90
D6																	
	47	11988	4196	10190	157	97.0	85.0	76.43	6.6	157	97.0	85.0	76.43	6.1	136.8	144.1	5.54
	48	11956	4185	10163	151	91.0	77.6	88.74	6.2	151	91.0	77.6	88.74	5.7	142.4	150.0	5.34
D7																	
D8																	
	42	10314	3610	8767	133	71.0	66.0	37.59	6.6	133	71.0	66.0	37.59	6.0	137.6	144.9	5.56
D9																	
	33	13442	4705	11426	160	68.0	63.8	26.25	8.3	160	68.0	63.8	26.25	7.5	120.3	126.7	6.25
	34	10000	3500	8500	133	68.4	64.8	27.07	7.0	133	68.4	64.8	27.07	6.4	132.1	139.2	5.97
	35	10000	3500	8500	131	69.4	64.6	36.64	6.5	131	69.4	64.6	36.64	6.0	138.1	145.5	5.71
	36	10000	3500	8500	133	65.0	61.2	28.57	6.9	133	65.0	61.2	28.57	6.4	133.0	140.0	5.93
	37	10000	3500	8500	126	64.7	61.3	26.98	6.7	126	64.7	61.3	26.98	6.1	136.3	143.6	5.78
	38	13726	4804	11667	166	64.0	61.8	13.25	9.8	166	64.0	61.8	13.25	9.0	108.8	114.6	7.21
D10																	
	41	10200	3570	8670	135	67.4	62.7	34.81	6.8	135	67.4	62.7	34.81	6.2	135.1	142.2	5.72
	43	15438	5403	13122	199	74.0	66.5	37.69	9.4	199	74.0	66.5	37.69	8.6	111.3	117.3	6.89
	44	12386	4335	10528	151	76.5	69.8	44.37	7.1	151	76.5	69.8	44.37	6.5	131.6	138.6	5.89
	45	11475	4016	9754	138	81.0	73.8	52.17	6.3	138	81.0	73.8	52.17	5.8	140.7	148.2	5.63
	46	12208	4273	10377	147	84.7	77.5	48.98	6.8	147	84.7	77.5	48.98	6.2	135.1	142.3	5.88
D11																	
	39	14627	5119	12433	140	61.2	58.2	21.43	7.5	140	61.2	58.2	21.43	6.8	127.6	134.4	6.06
	40	16529	5785	14050	277	61.3	58.7	9.39	17.2	277	61.3	58.7	9.39	15.7	78.4	82.5	9.71
E1																	
	53	11089	3881	9426	144	86.0	81.0	34.72	7.2	144	86.0	81.0	34.72	6.5	130.7	137.6	5.86
	54	10086	3530	8573	134	90.0	85.0	37.31	6.6	134	90.0	85.0	37.31	6.1	136.7	143.9	5.72
E2																	
	55	10271	3595	8730	140	85.0	82.6	17.14	8.1	140	85.0	82.6	17.14	7.4	121.8	128.2	6.30
	56	10041	3514	8535	130	94.0	87.0	53.85	6.0	130	94.0	87.0	53.85	5.5	145.1	152.9	5.41
	57	10437	3653	8871	129	95.0	81.5	104.65	5.2	129	95.0	81.5	104.65	4.7	157.9	166.3	4.78
	58	10559	3696	8975	138	95.0	84.0	79.71	5.8	138	95.0	84.0	79.71	5.3	147.2	155.0	5.46
E3																	

Runoff Coefficients

Cleared Upland	0.35
Hardstand	0.85

Event	Duration (mins)	Intensity (mm/hr)
1 min	1	257.40
2 min	2	210.00
3 min	3	192.40
4 min	4	178.50
5 min	5	166.80
10 min	10	124.80
15 min	15	100.40
20 min	20	84.60
25 min	25	73.68
30 min	30	65.60
45 min	45	50.53
1 hr	60	42.10
1.5 hr	90	32.73
2 hr	120	27.55
3 hr	180	21.73
4.5 hr	270	17.24
6 hr	360	14.62
9 hr	540	11.44
12 hr	720	9.50
18 hr	1080	7.17
24 hr	1440	5.75
30 hr	1800	4.77
36 hr	2160	4.08
48 hr	2880	3.17
72 hr	4320	2.19



100 YEAR ARI FLOWS - LOTS

Storm Duration (mins)			A1														A2						A3	
	1				2				3				5				6				13			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	140.08	662.45	522.37	-11.21	120.66	607.75	487.09	-12.28	131.39	607.75	476.36	-9.62	149.27	696.06	546.78	-11.29	155.37	812.68	657.31	-18.10	143.77	645.67	501.90	-9.29
2	140.08	540.46	400.38	8.07	120.66	495.83	375.18	5.84	131.39	495.83	364.44	7.91	149.27	567.88	418.60	8.85	155.37	663.03	507.66	6.45	143.77	526.77	383.00	9.10
3	140.08	495.16	355.09	25.22	120.66	454.28	333.62	22.02	131.39	454.28	322.89	23.48	149.27	520.28	371.01	26.75	155.37	607.46	452.09	28.43	143.77	482.62	338.86	25.40
4	140.08	459.39	319.31	39.12	120.66	421.46	300.80	35.23	131.39	421.46	290.07	36.08	149.27	482.70	333.42	41.24	155.37	563.57	408.20	46.44	143.77	447.76	303.99	38.54
5	140.08	429.28	289.20	50.40	120.66	393.83	273.18	46.03	131.39	393.83	262.44	46.26	149.27	451.06	301.78	52.98	155.37	526.63	371.26	61.23	143.77	418.41	274.64	49.11
10	140.08	321.19	181.11	78.24	120.66	294.67	174.01	73.82	131.39	294.67	163.28	70.96	149.27	337.48	188.21	81.62	155.37	394.03	238.66	100.11	143.77	313.05	169.28	74.16
15	140.08	258.39	118.31	81.77	120.66	237.06	116.40	79.33	131.39	237.06	105.67	73.38	149.27	271.50	122.23	84.73	155.37	316.99	161.62	109.19	143.77	251.85	108.08	75.51
20	140.08	217.73	77.65	73.93	120.66	199.75	79.09	74.41	131.39	199.75	68.36	65.35	149.27	228.77	79.50	75.89	155.37	267.11	111.74	104.32	143.77	212.21	68.45	65.78
25	140.08	189.62	49.55	60.22	120.66	173.97	53.31	64.10	131.39	173.97	42.58	51.94	149.27	199.24	49.97	60.88	155.37	232.63	77.26	92.26	143.77	184.82	41.05	50.32
30	140.08	168.83	28.75	42.56	120.66	154.89	34.23	50.17	131.39	154.89	23.50	34.91	149.27	177.39	28.12	41.72	155.37	207.12	51.75	75.37	143.77	164.55	20.78	31.01
45	140.08	130.05	-10.02	-22.91	120.66	119.31	-1.34	-3.04	131.39	119.31	-12.07	-27.67	149.27	136.65	-12.62	-28.90	155.37	159.55	4.18	9.42	143.77	126.76	-17.01	-39.12
60	140.08	108.35	-31.73	-98.42	120.66	99.40	-21.25	-65.44	131.39	99.40	-31.99	-99.47	149.27	113.85	-35.43	-110.07	155.37	132.92	-22.45	-68.80	143.77	105.61	-38.16	-119.07
90	140.08	84.24	-55.83	-265.74	120.66	77.29	-43.37	-205.13	131.39	77.29	-54.10	-258.04	149.27	88.52	-60.76	-289.56	155.37	103.35	-52.02	-245.11	143.77	82.11	-61.66	-294.89
120	140.08	70.90	-69.17	-445.41	120.66	65.05	-55.61	-356.11	131.39	65.05	-66.34	-427.95	149.27	74.50	-74.77	-482.03	155.37	86.98	-68.39	-436.45	143.77	69.11	-74.66	-482.79
180	140.08	55.93	-84.14	-827.58	120.66	51.31	-69.34	-678.91	131.39	51.31	-80.07	-788.76	149.27	58.77	-90.50	-890.98	155.37	68.62	-86.75	-846.98	143.77	54.52	-89.25	-880.92
270	140.08	44.38	-95.70	-1433.93	120.66	40.72	-79.94	-1193.36	131.39	40.72	-90.67	-1360.38	149.27	46.63	-102.64	-1539.23	155.37	54.45	-100.92	-1503.10	143.77	43.26	-100.51	-1510.50
360	140.08	37.62	-102.46	-2066.15	120.66	34.51	-86.14	-1731.46	131.39	34.51	-96.88	-1955.76	149.27	39.53	-109.75	-2214.68	155.37	46.15	-109.22	-2190.80	143.77	36.67	-107.10	-2165.35
540	140.08	29.45	-110.62	-3381.53	120.66	27.02	-93.63	-2854.32	131.39	27.02	-104.37	-3193.28	149.27	30.95	-118.33	-3619.13	155.37	36.13	-119.24	-3628.50	143.77	28.71	-115.06	-3524.79
720	140.08	24.45	-115.63	-4739.92	120.66	22.43	-98.23	-4016.58	131.39	22.43	-108.96	-4470.28	149.27	25.69	-123.58	-5068.78	155.37	29.99	-125.38	-5118.85	143.77	23.83	-119.94	-4926.19
1080	140.08	18.44	-121.63	-7525.96	120.66	16.92	-103.74	-6404.56	131.39	16.92	-114.47	-7087.85	149.27	19.38	-129.89	-8040.86	155.37	22.63	-132.74	-8184.36	143.77	17.98	-125.79	-7796.57
1440	140.08	14.80	-125.28	-10367.27	120.66	13.58	-107.08	-8843.26	131.39	13.58	-117.81	-9756.13	149.27	15.55	-133.72	-11071.03	155.37	18.15	-137.22	-11317.69	143.77	14.42	-129.35	-10720.81
1800	140.08	12.27	-127.81	-13241.24	120.66	11.25	-109.40	-11311.99	131.39	11.25	-120.13	-12454.34	149.27	12.89	-136.38	-14135.49	155.37	15.05	-140.32	-14491.25	143.77	11.96	-131.81	-13676.82
2160	140.08	10.51	-129.57	-16126.74	120.66	9.64	-111.02	-13791.26	131.39	9.64	-121.75	-15163.14	149.27	11.04	-138.23	-17212.07	155.37	12.89	-142.48	-17678.86	143.77	10.24	-133.53	-16644.10
2880	140.08	8.15	-131.93	-21923.54	120.66	7.48	-113.18	-18773.52	131.39	7.48	-123.91	-20604.40	149.27	8.56	-140.71	-23392.34	155.37	10.00	-145.37	-24085.81	143.77	7.94	-135.83	-22603.78
4320	140.08	5.65	-134.43	-33559.71	120.66	5.18	-115.48	-28776.98	131.39	5.18	-126.21	-31526.01	149.27	5.93	-143.34	-35797.63	155.37	6.93	-148.44	-36951.75	143.77	5.50	-138.26	-34564.72
Volume check				ok				ok				ok				ok				ok				ok

Storm Duration (mins)									A4																A5			
	14				15				16				17				23N				18				24N			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	118.82	608.78	489.96	-12.86	119.51	608.66	489.15	-12.66	121.44	608.54	487.10	-12.13	122.70	608.36	485.66	-11.78	75.10	281.08	205.98	-1.84	128.88	647.19	518.31	-12.97	92.29	377.11	284.82	-3.82
2	118.82	496.68	377.85	5.40	119.51	496.58	377.07	5.55	121.44	496.48	375.04	5.98	122.70	496.33	373.63	6.25	75.10	229.32	154.22	5.47	128.88	528.01	399.13	6.30	92.29	307.66	215.37	6.47
3	118.82	455.05	336.23	21.72	119.51	454.96	335.45	21.84	121.44	454.87	333.43	22.15	122.70	454.73	332.03	22.34	75.10	210.10	135.00	11.85	128.88	483.76	354.88	23.51	92.29	281.88	189.59	15.51
4	118.82	422.17	303.35	35.07	119.51	422.09	302.58	35.14	121.44	422.01	300.57	35.34	122.70	421.88	299.18	35.45	75.10	194.92	119.82	16.84	128.88	448.81	319.93	37.56	92.29	261.51	169.22	22.70
5	118.82	394.50	275.68	46.01	119.51	394.42	274.91	46.04	121.44	394.35	272.90	46.12	122.70	394.23	271.53	46.15	75.10	182.15	107.04	20.72	128.88	419.39	290.51	49.04	92.29	244.37	152.08	28.40
10	118.82	295.17	176.35	74.44	119.51	295.11	175.60	74.25	121.44	295.05	173.61	73.77	122.70	294.96	172.26	73.42	75.10	136.28	61.18	28.01	128.88	313.79	184.91	78.52	92.29	182.84	90.55	40.62
15	118.82	237.46	118.64	80.54	119.51	237.41	117.90	80.15	121.44	237.36	115.92	79.10	122.70	237.29	114.59	78.38	75.10	109.64	34.53	24.98	128.88	252.44	123.56	84.27	92.29	147.09	54.80	39.01
20	118.82	200.09	81.27	76.19	119.51	200.05	80.54	75.60	121.44	200.01	78.57	73.99	122.70	199.95	77.25	72.90	75.10	92.38	17.28	17.11	128.88	212.71	83.83	78.91	92.29	123.94	31.65	30.91
25	118.82	174.26	55.44	66.45	119.51	174.23	54.72	65.66	121.44	174.19	52.75	63.48	122.70	174.14	51.44	62.02	75.10	80.46	5.36	6.74	128.88	185.26	56.37	67.82	92.29	107.95	15.65	19.47
30	118.82	155.15	36.33	53.10	119.51	155.12	35.61	52.10	121.44	155.09	33.65	49.36	122.70	155.04	32.35	47.53	75.10	71.64	-3.47	-5.30	128.88	164.94	36.06	52.87	92.29	96.11	3.82	5.77
45	118.82	119.52	0.70	1.57	119.51	119.49	-0.02	-0.04	121.44	119.47	-1.97	-4.47	122.70	119.43	-3.26	-7.41	75.10	55.18	-19.92	-46.79	128.88	127.06	-1.82	-4.14	92.29	74.03	-18.26	-42.47
60	118.82	99.57	-19.25	-59.15	119.51	99.55	-19.96	-61.37	121.44	99.53	-21.91	-67.50	122.70	99.50	-23.20	-71.56	75.10	45.97	-29.13	-92.59	128.88	105.85	-23.03	-70.93	92.29	61.68	-30.61	-96.47
90	118.82	77.42	-41.40	-195.50	119.51	77.40	-42.11	-198.94	121.44	77.39	-44.05	-208.48	122.70	77.36	-45.33	-214.77	75.10	35.75	-39.36	-191.20	128.88	82.30	-46.58	-220.39	92.29	47.96	-44.34	-213.83
120	118.82	65.16	-53.66	-343.13	119.51	65.15	-54.36	-347.80	121.44	65.13	-56.31	-360.75	122.70	65.11	-57.58	-369.28	75.10	30.08	-45.02	-295.14	128.88	69.27	-59.61	-381.86	92.29	40.36	-51.93	-338.29
180	118.82	51.40	-67.42	-659.27	119.51	51.39	-68.12	-666.40	121.44	51.38	-70.06	-686.19	122.70	51.37	-71.33	-699.20	75.10	23.73	-51.37	-512.86	128.88	54.65	-74.24	-727.01	92.29	31.84	-60.45	-600.34
270	118.82	40.79	-78.04	-1163.73	119.51	40.78	-78.73	-1174.55	121.44	40.77	-80.67	-1204.65	122.70	40.76	-81.94	-1224.39	75.10	18.83	-56.27	-853.71	128.88	43.36	-85.52	-1276.96	92.29	25.26	-67.03	-1012.43
360	118.82	34.57	-84.25	-1691.88	119.51	34.56	-84.95	-1706.39	121.44	34.56	-86.88	-1746.80	122.70	34.55	-88.15	-1773.29	75.10	15.96	-59.14	-1205.67	128.88	36.75	-92.13	-1852.10	92.29	21.41	-70.88	-1439.37
540	118.82	27.07	-91.76	-2794.86	119.51	27.06	-92.45	-2816.76	121.44	27.06	-94.38	-2877.81	122.70	27.05	-95.65	-2917.78	75.10	12.50	-62.61	-1931.37	128.88	28.78	-100.11	-3052.05	92.29	16.77	-75.53	-2322.38
720	118.82	22.47	-96.35	-3937.31	119.51	22.46	-97.05	-3966.58	121.44	22.46	-98.98	-4048.29	122.70	22.45	-100.25	-4101.74	75.10	10.37	-64.73	-2675.41	128.88	23.89	-105.00	-4293.98	92.29	13.92	-78.38	-3229.94
1080	118.82	16.95	-101.87	-6285.75	119.51	16.95	-102.56	-6329.78	121.44	16.94	-104.50	-6452.79	122.70	16.94	-105.76	-6533.19	75.10	7.83	-67.28	-4193.02	128.88	18.02	-110.86	-6845.41	92.29	10.50	-81.79	-5084.61
1440	118.82	13.60	-105.22	-8684.99	119.51	13.60	-105.91	-8743.77	121.44	13.59	-107.85	-8908.07	122.70	13.59	-109.11	-9015.41	75.10	6.28	-68.82	-5734.06	128.88	14.46	-114.43	-9450.85	92.29	8.42	-83.87	-6970.73
1800	118.82	11.27	-107.55	-11114.34	119.51	11.27	-108.24	-11187.86	121.44	11.27	-110.17	-11393.42	122.70	11.27	-111.43	-11527.68	75.10	5.21	-69.90	-7288.84	128.88	11.99	-116.90	-12088.26	92.29	6.98	-85.31	-8875.34
2160	118.82	9.66	-109.16	-13554.24	119.51	9.66	-109.86	-13642.49	121.44	9.65	-111.79	-13889.33	122.70	9.65	-113.05	-14050.50	75.10	4.46	-70.64	-8848.57	128.88	10.27	-118.62	-14736.90	92.29	5.98	-86.31	-10786.56
2880	118.82	7.49	-111.33	-18457.78	119.51	7.49	-112.02	-18575.50	121.44	7.49	-113.95	-18904.87	122.70	7.48	-115.21	-19119.88	75.10	3.46	-71.65	-11978.92	128.88	7.96	-120.92	-20059.43	92.29	4.64	-87.65	-14623.65
4320	118.82	5.19	-113.63	-28303.88	119.51	5.19	-114.32	-28480.53	121.44	5.19	-116.25	-28974.98	122.70	5.19	-117.51	-29297.65	75.10	2.40	-72.71	-18257.85	128.88	5.52	-123.37	-30745.99	92.29	3.22	-89.08	-22322.20
Volume check				ok				ok				ok				ok				ok				ok				ok

Storm Duration (mins)			B1														C1			
	7				8				9				10				4			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	127.55	620.63	493.08	-11.41	128.31	607.75	479.44	-10.34	122.68	607.75	485.07	-11.74	124.75	607.75	483.00	-11.21	273.48	1472.40	1198.91	-35.20
2	127.55	506.35	378.79	6.86	128.31	495.83	367.53	7.36	122.68	495.83	373.15	6.26	124.75	495.83	371.08	6.68	273.48	1201.26	927.77	9.72
3	127.55	463.91	336.36	23.13	128.31	454.28	325.97	23.11	122.68	454.28	331.60	22.33	124.75	454.28	329.53	22.63	273.48	1100.58	827.09	50.00
4	127.55	430.39	302.84	36.38	128.31	421.46	293.15	35.88	122.68	421.46	298.78	35.43	124.75	421.46	296.71	35.61	273.48	1021.07	747.58	83.09
5	127.55	402.18	274.63	47.16	128.31	393.83	265.53	46.24	122.68	393.83	271.15	46.11	124.75	393.83	269.08	46.17	273.48	954.14	680.66	110.34
10	127.55	300.91	173.36	74.29	128.31	294.67	166.36	71.83	122.68	294.67	171.98	73.32	124.75	294.67	169.92	72.79	273.48	713.89	440.41	183.08
15	127.55	242.08	114.53	78.67	128.31	237.06	108.75	75.13	122.68	237.06	114.37	78.24	124.75	237.06	112.31	77.12	273.48	574.31	300.83	201.83
20	127.55	203.98	76.43	72.39	128.31	199.75	71.44	68.00	122.68	199.75	77.07	72.74	124.75	199.75	75.00	71.01	273.48	483.93	210.45	195.32
25	127.55	177.65	50.10	60.60	128.31	173.97	45.66	55.48	122.68	173.97	51.28	61.84	124.75	173.97	49.22	59.52	273.48	421.47	147.99	175.78
30	127.55	158.17	30.62	45.13	128.31	154.89	26.58	39.34	122.68	154.89	32.21	47.33	124.75	154.89	30.14	44.41	273.48	375.25	101.77	147.50
45	127.55	121.84	-5.71	-12.99	128.31	119.31	-8.99	-20.55	122.68	119.31	-3.37	-7.65	124.75	119.31	-5.44	-12.37	273.48	289.06	15.58	34.97

60	127.55	101.51	-26.04	-80.51	128.31	99.40	-28.91	-89.65	122.68	99.40	-23.28	-71.82	124.75	99.40	-25.35	-78.36	273.48	240.82	-32.66	-99.74
90	127.55	78.93	-48.63	-230.79	128.31	77.29	-51.02	-242.79	122.68	77.29	-45.40	-215.08	124.75	77.29	-47.46	-225.24	273.48	187.24	-86.24	-405.10
120	127.55	66.43	-61.12	-392.61	128.31	65.05	-63.26	-407.27	122.68	65.05	-57.63	-369.62	124.75	65.05	-59.70	-383.44	273.48	157.59	-115.89	-737.66
180	127.55	52.40	-75.15	-737.61	128.31	51.31	-76.99	-757.16	122.68	51.31	-71.37	-699.60	124.75	51.31	-73.44	-720.73	273.48	124.32	-149.16	-1453.11
270	127.55	41.58	-85.97	-1286.06	128.31	40.72	-87.59	-1312.36	122.68	40.72	-81.97	-1224.83	124.75	40.72	-84.03	-1256.98	273.48	98.64	-174.84	-2599.22
360	127.55	35.24	-92.31	-1858.70	128.31	34.51	-93.80	-1891.30	122.68	34.51	-88.17	-1773.75	124.75	34.51	-90.24	-1816.92	273.48	83.61	-189.87	-3802.47
540	127.55	27.59	-99.96	-3051.69	128.31	27.02	-101.29	-3095.90	122.68	27.02	-95.66	-2918.24	124.75	27.02	-97.73	-2983.51	273.48	65.47	-208.02	-6321.74
720	127.55	22.91	-104.64	-4284.94	128.31	22.43	-105.88	-4339.96	122.68	22.43	-100.25	-4102.16	124.75	22.43	-102.32	-4189.52	273.48	54.34	-219.14	-8936.34
1080	127.55	17.28	-110.27	-6816.29	128.31	16.92	-111.39	-6891.60	122.68	16.92	-105.76	-6533.47	124.75	16.92	-107.83	-6665.05	273.48	41.00	-232.49	-14319.12
1440	127.55	13.86	-113.69	-9399.43	128.31	13.58	-114.73	-9493.96	122.68	13.58	-109.11	-9015.50	124.75	13.58	-111.17	-9191.30	273.48	32.89	-240.59	-19824.79
1800	127.55	11.49	-116.06	-12013.20	128.31	11.25	-117.05	-12126.29	122.68	11.25	-111.43	-11527.54	124.75	11.25	-113.50	-11747.54	273.48	27.27	-246.22	-25403.40
2160	127.55	9.85	-117.71	-14637.76	128.31	9.64	-118.67	-14769.18	122.68	9.64	-113.04	-14050.13	124.75	9.64	-115.11	-14314.34	273.48	23.36	-250.13	-31007.44
2880	127.55	7.64	-119.92	-19911.06	128.31	7.48	-120.83	-20078.66	122.68	7.48	-115.21	-19119.01	124.75	7.48	-117.27	-19471.63	273.48	18.11	-255.37	-42273.06
4320	127.55	5.29	-122.26	-30497.50	128.31	5.18	-123.13	-30736.65	122.68	5.18	-117.50	-29295.77	124.75	5.18	-119.57	-29825.23	273.48	12.55	-260.93	-64898.46
Volume check				ok				ok				ok				ok				ok

D1

Storm Duration (mins)	19				20				21				22				23S				31			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	138.06	670.47	532.41	-12.26	126.91	607.75	480.84	-10.67	128.48	607.75	479.27	-10.29	129.45	607.75	478.30	-10.06	87.58	325.39	237.81	-2.04	164.58	678.25	513.67	-7.11
2	138.06	547.00	408.94	7.46	126.91	495.83	368.92	7.10	128.48	495.83	367.35	7.40	51.04	495.83	444.79	35.95	87.58	265.47	177.89	6.39	164.58	553.35	388.77	11.46
3	138.06	501.16	363.10	25.03	126.91	454.28	327.37	22.93	128.48	454.28	325.80	23.13	51.04	454.28	403.24	55.35	87.58	243.22	155.64	13.73	164.58	506.97	342.40	27.80
4	138.06	464.95	326.89	39.32	126.91	421.46	294.55	35.78	128.48	421.46	292.98	35.89	51.04	421.46	370.42	71.83	87.58	225.65	138.07	19.48	164.58	470.35	305.77	40.82
5	138.06	434.48	296.42	50.95	126.91	393.83	266.92	46.22	128.48	393.83	265.35	46.24	51.04	393.83	342.79	85.94	87.58	210.86	123.28	23.94	164.58	439.52	274.94	51.15
10	138.06	325.08	187.02	80.19	126.91	294.67	167.75	72.21	128.48	294.67	166.18	71.78	51.04	294.67	243.63	130.12	87.58	157.76	70.18	32.18	164.58	328.85	164.27	73.54
15	138.06	261.52	123.46	84.84	126.91	237.06	110.14	75.92	128.48	237.06	108.57	75.04	51.04	237.06	186.01	152.18	87.58	126.92	39.34	28.49	164.58	264.55	99.98	71.05
20	138.06	220.36	82.31	77.98	126.91	199.75	72.84	69.19	128.48	199.75	71.27	67.85	51.04	199.75	148.71	163.99	87.58	106.95	19.36	19.20	164.58	222.92	58.34	56.90
25	138.06	191.92	53.86	65.17	126.91	173.97	47.05	57.07	128.48	173.97	45.48	55.28	51.04	173.97	122.93	170.67	87.58	93.14	5.56	7.01	164.58	194.15	29.57	36.72
30	138.06	170.87	32.81	48.38	126.91	154.89	27.98	41.34	128.48	154.89	26.41	39.09	51.04	154.89	103.85	173.91	87.58	82.93	-4.66	-7.13	164.58	172.86	8.28	12.50
45	138.06	131.63	-6.43	-14.64	126.91	119.31	-7.60	-17.33	128.48	119.31	-9.17	-20.95	51.04	119.31	68.27	173.23	87.58	63.88	-23.70	-55.72	164.58	133.16	-31.42	-73.02
60	138.06	109.66	-28.40	-87.82	126.91	99.40	-27.51	-85.21	128.48	99.40	-29.08	-90.20	51.04	99.40	48.36	164.65	87.58	53.22	-34.36	-109.30	164.58	110.93	-53.65	-168.90
90	138.06	85.26	-52.80	-250.63	126.91	77.29	-49.62	-235.90	128.48	77.29	-51.20	-243.65	51.04	77.29	26.25	135.13	87.58	41.38	-46.20	-224.58	164.58	86.25	-78.33	-377.48
120	138.06	71.76	-66.30	-425.91	126.91	65.05	-61.86	-397.91	128.48	65.05	-63.43	-408.43	51.04	65.05	14.01	96.67	87.58	34.83	-52.76	-346.04	164.58	72.59	-91.98	-598.82
180	138.06	56.61	-81.45	-799.55	126.91	51.31	-75.60	-742.85	128.48	51.31	-77.17	-758.94	51.04	51.31	0.27	2.85	87.58	27.47	-60.11	-600.35	164.58	57.27	-107.31	-1065.11
270	138.06	44.92	-93.14	-1393.46	126.91	40.72	-86.20	-1290.62	128.48	40.72	-87.77	-1315.07	51.04	40.72	-10.32	-162.34	87.58	21.80	-65.78	-998.35	164.58	45.44	-119.14	-1798.74
360	138.06	38.07	-99.99	-2013.51	126.91	34.51	-92.40	-1862.10	128.48	34.51	-93.97	-1894.94	51.04	34.51	-16.53	-347.73	87.58	18.48	-69.11	-1409.22	164.58	38.51	-126.06	-2559.04
540	138.06	29.81	-108.25	-3305.12	126.91	27.02	-99.89	-3051.77	128.48	27.02	-101.46	-3101.40	51.04	27.02	-24.02	-760.96	87.58	14.47	-73.12	-2256.17	164.58	30.16	-134.42	-4132.03
720	138.06	24.75	-113.31	-4640.24	126.91	22.43	-104.48	-4280.90	128.48	22.43	-106.05	-4347.31	51.04	22.43	-28.61	-1211.20	87.58	12.01	-75.57	-3124.35	164.58	25.03	-139.55	-5749.18
1080	138.06	18.67	-119.39	-7380.54	126.91	16.92	-109.99	-6802.67	128.48	16.92	-111.56	-6902.69	51.04	16.92	-34.12	-2171.79	87.58	9.06	-78.52	-4894.90	164.58	18.88	-145.69	-9054.58
1440	138.06	14.98	-123.08	-10176.78	126.91	13.58	-113.34	-9375.15	128.48	13.58	-114.91	-9508.77	51.04	13.58	-37.46	-3183.35	87.58	7.27	-80.31	-6692.58	164.58	15.15	-149.43	-12416.56
1800	138.06	12.42	-125.64	-13006.12	126.91	11.25	-115.66	-11977.61	128.48	11.25	-117.23	-12144.81	51.04	11.25	-39.79	-4228.27	87.58	6.03	-81.56	-8506.15	164.58	12.56	-152.02	-15811.80
2160	138.06	10.64	-127.42	-15847.10	126.91	9.64	-117.27	-14590.64	128.48	9.64	-118.84	-14791.43	51.04	9.64	-41.40	-5282.02	87.58	5.16	-82.42	-10325.46	164.58	10.76	-153.82	-19218.93
2880	138.06	8.25	-129.81	-21555.20	126.91	7.48	-119.43	-19840.37	128.48	7.48	-121.01	-20108.34	51.04	7.48	-43.56	-7414.72	87.58	4.00	-83.58	-13976.69	164.58	8.34	-156.23	-26059.53
4320	138.06	5.72	-132.34	-33014.43	126.91	5.18	-121.73	-30378.88	128.48	5.18	-123.30	-30781.23	51.04	5.18	-45.86	-11714.93	87.58	2.77	-84.81	-21300.25	164.58	5.78	-158.80	-39784.54
Volume check				ok				ok				ok				ok				ok				ok

D2

Storm Duration (mins)	11				12				32			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	357.96	1242.30	884.34	-4.71	264.59	1346.47	1081.88	-27.95	119.39	633.03	513.64	-14.58
2	357.96	1013.53	655.57	26.17	264.59	1098.52	833.93	12.33	119.39	516.46	397.07	4.63
3	357.96	928.59	570.63	52.84	264.59	1006.45	741.86	48.34	119.39	473.18	353.79	21.85
4	357.96	861.50	503.54	73.41	264.59	933.74	669.15	77.77	119.39	438.99	319.60	35.97
5	357.96	805.03	447.07	89.05	264.59	872.54	607.95	101.85	119.39	410.22	290.83	47.58
10	357.96	602.33	244.37	113.69	264.59	652.83	388.24	164.21	119.39	306.92	187.54	78.33
15	357.96	484.57	126.60	92.74	264.59	525.20	260.60	177.19	119.39	246.92	127.53	85.88
20	357.96	408.31	50.35	50.41	264.59	442.55	177.95	167.07	119.39	208.06	88.67	82.56
25	357.96	355.61	-2.36	-3.00	264.59	385.42	120.83	145.01	119.39	181.20	61.81	73.63
30	357.96	316.61	-41.35	-63.84	264.59	343.16	78.56	114.96	119.39	161.33	41.94	60.95
45	357.96	243.89	-114.07	-270.03	264.59	264.34	-0.25	-0.57	119.39	124.28	4.89	11.00
60	357.96	203.19	-154.77	-495.36	264.59	220.23	-44.37	-136.43	119.39	103.54	-15.85	-48.50
90	357.96	157.98	-199.98	-977.16	264.59	171.23	-93.36	-441.14	119.39	80.50	-38.89	-182.96
120	357.96	132.97	-225.00	-1482.64	264.59	144.12	-120.48	-770.81	119.39	67.75	-51.63	-329.13
180	357.96	104.89	-253.07	-2537.34	264.59	113.69	-150.90	-1476.35	119.39	53.45	-65.94	-643.12
270	357.96	83.23	-274.73	-4182.79	264.59	90.21	-174.39	-2601.61	119.39	42.41	-76.98	-1145.50
360	357.96	70.55	-287.42	-5877.55	264.59	76.46	-188.13	-3779.26	119.39	35.95	-83.44	-1672.46
540	357.96	55.23	-302.73	-9363.56	264.59	59.87	-204.73	-6237.87	119.39	28.15	-91.24	-2774.89
720	357.96	45.85	-312.11	-12930.77	264.59	49.69	-214.90	-8783.76	119.39	23.36	-96.03	-3918.32
1080	357.96	34.59	-323.37	-20195.84	264.59	37.49	-227.10	-14016.11	119.39	17.63	-101.76	-6271.23
1440	357.96	27.75	-330.21	-27564.52	264.59	30.08	-234.51	-19360.84	119.39	14.14	-105.25	-8676.97
1800	357.96	23.01	-334.96	-34993.67	264.59	24.93	-239.66	-24772.12	119.39	11.72	-107.67	-11114.05
2160	357.96	19.71	-338.25	-42444.83	264.59	21.36	-243.23	-30206.74	119.39	10.04	-109.35	-13562.07
2880	357.96	15.28	-342.68	-57395.20	264.59	16.56	-248.03	-41128.52	119.39	7.79	-111.60	-18482.85
4320	357.96	10.59	-347.37	-87376.74	264.59	11.48	-253.11	-63058.37	119.39	5.40	-113.99	-28364.90
Volume check				ok				ok				ok

D3

Storm Duration (mins)	24S				25				26				27				28				29				30			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	116.88	471.80	354.92	-4.53	147.09	621.18	474.09	-7.18	150.87	607.93	457.06	-5.79	150.86	623.86	473.00	-6.64	227.08	1293.90	1066.82	-35.25	145.05	691.80	546.75	-12.01	126.71	607.75	481.04	-10.72
2	116.88	384.92	268.04	8.26	147.09	506.79	359.70	10.03	150.87	495.98	345.11	10.67	150.86	508.97	358.11	10.48	227.08	1055.63	828.55	4.93	145.05	564.41	419.36	8.19	126.71	495.83	369.12	7.06
3	116.88	352.66	235.78	19.49	147.09	464.32	317.22	25.21	150.87	454.41	303.54	25.13	150.86	466.32	315.46	25.54	227.08	967.16	740.07	41.09	145.05	517.10	372.06	26.17	126.71	454.28	327.56	22.90
4	116.88	327.18	210.30	28.41	147.09	430.77	283.68	37.34	150.87	421.58	270.71	36.60	150.86	432.63	281.77	37.54	227.08	897.28	670.20	70.93	145.05	479.75	334.70	40.77	126.71	421.46	294.74	35.76
5	116.88	305.73	188.86	35.45	147.09	402.54	255.44	47.01	150.87	393.95	243.08	45.66	150.86	404.27	253.41	47.07	227.08	838.47	611.39	95.63	145.05	448.30	303.25	52.62	126.71	393.83	267.12	46.22
10	116.88	228.75	111.87	50.33	147.09	301.18	154.08	68.57	150.87	294.76	143.89	64.76	150.86	302.48	151.62	67.82	227.08	627.35	400.26	163.35	145.05	335.42	190.37	82.04	126.71	294.67	167.95	72.27
15	116.88	184.03	67.15	47.91	147.09	242.29	95.20	67.34	150.87	237.13	86.26	61.56	150.86	243.34	92.48	65.68	227.08	504.69	277.61	183.63	145.05	269.84	124.79	86.09	126.71	237.06	110.34	76.03
20	116.88	155.07	38.19	37.37	147.09	204.16	57.07	55.44	150.87	199.81	48.94	47.91	150.86	205.04	54.18	52.82	227.08	425.27	198.18	181.72	145.05	227.38	82.33	78.26	126.71	199.75	73.04	69.36
25	116.88	135.05	18.17	22.64	147.09	177.81	30.72	38.01	150.87	174.02	23.15	28.85	150.86	178.58	27.72	34.41	227.08	370.38	143.29	168.36	145.05	198.03	52.98	64.30	126.71	173.97	47.25	57.29
30	116.88	120.24	3.36	5.10	147.09	158.31	11.22	16.88	150.87	154.94	4.07	6.16	150.86	158.99	8.13	12.28	227.08	329.76	102.68	147.33	145.05	176.31	31.26	46.22	126.71	154.89	28.17	41.62
45	116.88	92.62	-24.25	-56.49	147.09	121.95	-25.14	-58.26	150.87	119.35	-31.52	-73.43	150.86	122.48	-28.38	-65.93	227.08	254.02	26.94	59.97	145.05	135.82	-9.23	-21.07	126.71	119.31	-7.40	-16.88
60	116.88	77.17	-39.71	-125.29	147.09	101.60	-45.50	-142.88	150.87	99.43	-51.44	-162.32	150.86	102.04	-48.82	-153.66	227.08	211.63	-15.45	-46.84	145.05	113.15	-31.90	-98.85	126.71	99.40	-27.31	-84.58
90	116.88	60.00	-56.88	-274.59	147.09	79.00	-68.10	-327.50	150.87	77.31	-73.56	-355.18	150.86	79.34	-71.52	-344.60	227.08	164.54	-62.54	-291.95	145.05	87.98	-57.07	-271.40	126.71	77.29	-49.43	-234.93
120	116.88	50.50	-66.38	-432.80	147.09	66.49	-80.61	-523.79	150.87	65.07	-85.80	-559.51	150.86	66.77	-84.09	-547.27	227.08	138.49	-88.59	-560.86	145.05	74.04	-71.00	-456.85	126.71	65.05	-61.67	-396.59
180	116.88	39.84	-77.04	-765.64	147.09	52.45	-94.65	-937.94	150.87	51.33	-99.54	-989.35	150.86	52.67	-98.19	-974.31	227.08	109.25	-117.83	-1142.76	145.05	58.41	-86.64	-851.57	126.71	51.31	-75.40	-740.83
270	116.88	31.61	-85.27	-1288.72	147.09	41.62	-105.48	-1590.44	150.87	40.73	-110.14	-1664.81	150.86	41.80	-109.06	-1646.33	227.08	86.68	-140.40	-2079.47	145.05	46.35	-98.70	-1478.19	126.71	40.72	-86.00	-1287.55
360	116.88	26.79	-90.08	-1830.39	147.09	35.27	-111.82	-2267.34	150.87	34.52	-116.35	-2364.21	150.86	35.43	-115.43	-2342.88	227.08	73.48	-153.61	-3066.24	145.05	39.28	-105.76	-2131.82	126.71	34.51	-92.20	-1857.97
540	116.88	20.98	-95.90	-2950.17	147.09	27.62	-119.48	-3669.09	150.87	27.03	-123.84	-3810.00	150.86	27.74	-123.12	-3784.16	227.08	57.53	-169.55	-5138.73	145.05	30.76	-114.29	-3492.27	126.71	27.02	-99.69	-3045.54
720	116.88	17.41	-99.46	-4100.69	147.09	22.93	-124.17	-5111.26	150.87	22.44	-128.43	-5295.39	150.86	23.02	-127.83	-5266.05	227.08	47.75	-179.33	-7294.90	145.05	25.53	-119.51	-4897.62	126.71	22.43	-104.28	-4272.56
1080	116.88	13.14	-103.74	-6451.21	147.09	17.30	-129.80	-8060.67	150.87	16.93	-133.94	-8329.92	150.86	17.37	-133.49	-8295.23	227.08	36.03	-191.06	-11742.06	145.05	19.26	-125.79	-7780.64	126.71	16.92	-109.79	-6790.11
1440	116.88	10.54	-106.34	-8841.08	147.09	13.88	-133.22	-11061.91	150.87	13.58	-137.29	-11415.16	150.86	13.94	-136.92	-11376.45	227.08	28.90	-198.18	-16297.22	145.05	15.45	-129.59	-10721.38	126.71	13.58	-113.14	-9358.38
1800	116.88	8.74	-108.14	-11254.06	147.09	11.50	-135.59	-14093.64	150.87	11.26	-139.61	-14530.18	150.86	11.55	-139.31	-14488.26	227.08	23.96	-203.12	-20916.61	145.05	12.81	-132.24	-13696.24	126.71	11.25	-115.46	-11956.62
2160	116.88	7.48	-109.39	-13675.32	147.09	9.85	-137.24	-17136.24	150.87	9.64	-141.23	-17655.87	150.86	9.90	-140.96	-17611.01	227.08	20.53	-206.56	-25558.28	145.05	10.97	-134.07	-16683.13	126.71	9.64	-117.07	-14565.43
2880	116.88	5.80	-111.07	-18536.17	147.09	7.64	-139.45	-23245.59	150.87	7.48	-143.39	-23930.86	150.86	7.67	-143.18	-23880.74	227.08	15.92	-211.16	-34892.24	145.05	8.51	-136.54	-22683.86	126.71	7.48	-119.24	-19806.73
4320	116.88	4.02	-112.85	-28288.37	147.09	5.30	-141.80	-35504.37	150.87	5.18	-145.69	-36520.15	150.86	5.32	-145.54	-36460.49	227.08	11.03	-216.05	-53642.75	145.05	5.90	-139.15	-34729.77	126.71	5.18	-121.53	-30328.37
Volume check				ok				ok				ok				ok				ok				ok				ok

D4 D5 D6 D8

Storm Duration (mins)	49				50				51				52				47				48				42			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	148.26	607.93	459.67	-6.24	156.74	689.49	532.75	-9.25	147.23	616.20	468.96	-6.88	149.74	690.53	540.78	-10.82	159.48	728.57	569.09	-11.09	165.55	726.63	561.07	-9.67	137.93	626.83	488.90	-9.38
2	148.26	495.98	347.72	10.36	156.74	562.52	405.79	10.21	147.23	502.73	355.49	10.13	149.74	563.37	413.62	9.07	159.48	594.41	434.92	9.82	165.55	592.82	427.27	10.82	137.93	511.40	373.47	8.57
3	148.26	454.41	306.15	24.97	156.74	515.38	358.64	27.43	147.23	460.59	313.36	25.10	149.74	516.15	366.41	26.73	159.48	544.59	385.10	28.37	165.55	543.13	377.58	28.95	137.93	468.54	330.61	24.49
4	148.26	421.58	273.32	36.60	156.74	478.14	321.41	41.28	147.23	427.32	280.08	37.06	149.74	478.86	329.12	41.01	159.48	505.24	345.76	43.36	165.55	503.90	338.34	43.52	137.93	434.69	296.76	37.34
5	148.26	393.95	245.69	45.81	156.74	446.80	290.07	52.39	147.23	399.31	252.07	46.58	149.74	447.47	297.73	52.56	159.48	472.13	312.64	55.45	165.55	470.87	305.31	55.20	137.93	406.20	268.27	47.70
10	148.26	294.76	146.49	65.66	156.74	334.30	177.56	78.20	147.23	298.76	151.53	67.58	149.74	334.80	185.06	80.49	159.48	353.25	193.76	84.50	165.55	352.30	186.75	82.30	137.93	303.92	165.99	72.48
15	148.26	237.13	88.87	63.21	156.74	268.94	112.20	78.73	147.23	240.35	93.12	65.98	149.74	269.34	119.60	83.11	159.48	284.18	124.70	86.82	165.55	283.42	117.87	82.74	137.93	244.50	106.57	74.28
20	148.26	199.81	51.55	50.32	156.74	226.62	69.88	67.41	147.23	202.53	55.29	53.79	149.74	226.96	77.21	73.86	159.48	239.46	79.98	76.63	165.55	238.82	73.27	70.70	137.93	206.02	68.09	65.30
25	148.26	174.02	25.76	32.02	156.74	197.37	40.63	49.96	147.23	176.38	29.15	36.12	149.74	197.66	47.92	58.48	159.48	208.55	49.07	59.98	165.55	207.99	42.44	52.21	137.93	179.43	41.50	50.77
30	148.26	154.94	6.67	10.09	156.74	175.72	18.98	28.41	147.23	157.04	9.81	14.78	149.74	175.98	26.24	38.99	159.48	185.68	26.20	38.98	165.55	185.19	19.63	29.39	137.93	159.75	21.82	32.50
45	148.26	119.35	-28.91	-67.22	156.74	135.36	-21.38	-49.29	147.23	120.97	-26.26	-60.92	149.74	135.57	-14.18	-32.50	159.48	143.03	-16.45	-37.75	165.55	142.65	-22.90	-52.82	137.93	123.06	-14.87	-34.15
60	148.26	99.43	-48.83	-153.81	156.74	112.77	-43.97	-137.48	147.23	100.78	-46.45	-146.01	149.74	112.94	-36.80	-114.49	159.48	119.16	-40.32	-125.56	165.55	118.85	-46.71	-146.09	137.93	102.52	-35.41	-110.33
90	148.26	77.31	-70.95	-342.08	156.74	87.68	-69.06	-330.89	147.23	78.36	-68.87	-331.47	149.74	87.81	-61.93	-295.46	159.48	92.65	-66.83	-319.12	165.55	92.40	-73.15	-350.57	137.93	79.71	-58.22	-278.13
120	148.26	65.07	-83.19	-541.79	156.74	73.80	-82.94	-537.22	147.23	65.95	-81.28	-528.52	149.74	73.91	-75.84	-489.33	159.48	77.98	-81.50	-526.30	165.55	77.77	-87.78	-568.67	137.93	67.09	-70.84	-457.64
180	148.26	51.33	-96.93	-962.38	156.74	58.22	-98.52	-973.75	147.23	52.03	-95.21	-944.03	149.74	58.30	-91.44	-900.91	159.48	61.52	-97.97	-965.83	165.55	61.35	-104.20	-1030.04	137.93	52.93	-85.01	-838.34
270	148.26	40.73	-107.53	-1623.92	156.74	46.19	-110.55	-1663.17	147.23	41.28	-105.95	-1598.34	149.74	46.26	-103.48	-1552.83	159.48	48.81	-110.67	-1661.61	165.55	48.68	-116.87	-1758.58	137.93	41.99	-95.94	-1440.79
360	148.26	34.52	-113.74	-2309.37	156.74	39.15	-117.58	-2379.62	147.23	34.99	-112.24	-2276.86	149.74	39.21	-110.53	-2231.76	159.48	41.37	-118.11	-2385.89	165.55	41.26	-124.29	-2515.61	137.93	35.60	-102.34	-2067.76
540	148.26	27.03	-121.23	-3727.25	156.74	30.66	-126.08	-3865.66	147.23	27.40	-119.84	-3681.47	149.74	30.70	-119.04	-3642.75	159.48	32.39	-127.09	-3890.54	165.55	32.31	-133.25	-4085.67	137.93	27.87	-110.06	-3369.98
720	148.26	22.44	-125.82	-5184.71	156.74	25.45	-131.29	-5396.52	147.23	22.74	-124.49	-5126.19	149.74	25.49	-124.26	-5098.60	159.48	26.89	-132.59	-5442.53	165.55	26.82	-138.73	-5702.98	137.93	23.13	-114.80	-4712.93
1080	148.26	16.93	-131.33	-8163.37	156.74	19.20	-137.54	-8530.44	147.23	17.16	-130.08	-8080.19	149.74	19.23	-130.52	-8082.51	159.48	20.29	-139.20	-8622.71	165.55	20.23	-145.32	-9013.67	137.93	17.45	-120.48	-7464.40
1440	148.26	13.58	-134.68	-11192.74	156.74	15.40	-141.34	-11721.88	147.23	13.77	-133.47	-11085.60	149.74	15.43	-134.32	-11124.05	159.48	16.28	-143.21	-11863.69	165.55	16.23	-149.32	-12384.99	137.93	14.00	-123.93	-10268.17
1800	148.26	11.26	-137.00	-14251.91	156.74	12.77	-143.97	-14947.21	147.23	11.41	-135.82	-14121.24	149.74	12.79	-136.96	-14199.59	159.48	13.49	-145.99	-15140.53	165.55	13.46	-152.10	-15792.02	137.93	11.61	-126.32	-13102.80
2160	148.26	9.64	-138.62	-17321.74	156.74	10.94	-145.80	-18184.59	147.23	9.78	-137.46	-17167.68	149.74	10.95	-138.79	-17287.17	159.48	11.56	-147.93	-18430.08	165.55	11.53	-154.03	-19211.74	137.93	9.94	-127.99	-15948.35
2880	148.26	7.48	-140.78	-23485.02	156.74	8.48	-148.26	-24686.17	147.23	7.58	-139.65	-23284.49	149.74	8.50	-141.25	-23489.21	159.48	8.96	-150.52	-25037.53	165.55	8.94	-156.61	-26079.46	137.93	7.71	-130.22	-21663.86
4320	148.26	5.18	-143.08	-35850.86	156.74	5.88	-150.86	-37733.76	147.23	5.25	-141.98	-35557.91	149.74	5.89	-143.86	-35937.70	159.48	6.21	-153.27	-38299.32	165.55	6.19	-159.36	-39861.72	137.93	5.34	-132.59	-33135.23
Volume check				ok				ok				ok				ok				ok				ok				ok

D9

Storm Duration (mins)	33				34				35				36				37				38			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	157.16	816.94	659.77	-57.50	128.47	607.75	479.28	-39.05	134.27	607.75	473.48	-37.38	129.28	607.75	478.47	-38.81	132.54	607.75	475.21	-9.36	145.20	834.20	688.99	-23.14
2	157.16	666.50	509.34	-23.85	128.47	495.83	367.36	-14.65	134.27	495.83	361.56	-13.30	129.28	495.83	366.55	-14.45	132.54	495.83	363.29	8.11	145.20	680.58	535.38	2.83
3	157.16	610.64	453.48	1.55	128.47	454.28	325.81	3.58	134.27	454.28	320.00	4.60	129.28	454.28	325.00	3.73	132.54	454.28	321.74	23.61	145.20	623.54	478.34	26.21
4	157.16	566.52	409.36	22.24	128.47	421.46	292.99	18.31	134.27	421.46	287.18	19.00	129.28	421.46	292.18	18.41	132.54	421.46	288.92	36.14	145.20	578.49	433.29	45.51
5	157.16	529.39	372.23	39.28	128.47	393.83	265.36	30.32	134.27	393.83	259.56	30.67	129.28	393.83	264.55	30.38	132.54	393.83	261.29	46.26	145.20	540.58	395.37	61.51
10	157.16	396.09	238.93	28.73	128.47	294.67	166.20	21.93	134.27	294.67	160.39	22.00	129.28	294.67	165.38	21.95	132.54	294.67	162.13	70.63	145.20	404.46	259.25	105.51
15	157.16	318.65	161.49	60.81	128.47	237.06	108.59	42.47	134.27	237.06	102.78	40.86	129.28	237.06	107.77	42.25	132.54	237.06	104.52	72.71	145.20	325.38	180.18	118.93
20	157.16	268.50	111.34	70.68	128.47	199.75	71.28	46.48	134.27	199.75	65.48	43.20	129.28	199.75	70.47	46.03	132.54	199.75	67.21	64.36	145.20	274.18	128.97	118.04
25	157.16	233.85	76.68	68.67	128.47	173.97	45.50	41.65	134.27	173.97	39.69	36.68	129.28	173.97	44.68	40.96	132.54	173.97	41.43	50.61	145.20	238.79	93.58	109.78
30	157.16	208.20	51.04	59.10	128.47	154.89	26.42	31.18	134.27	154.89	20.61	24.54	129.28	154.89	25.61	30.26	132.54	154.89	22.35	33.24	145.20	212.60	67.40	96.56
45	157.16	160.38	3.22	4.37	128.47	119.31	-9.15	-12.68	134.27	119.31	-14.96	-20.91	129.28	119.31	-9.97	-13.82	132.54	119.31	-13.23	-30.34	145.20	163.77	18.57	41.28
60	157.16	133.62	-23.55	-51.03	128.47	99.40	-29.07	-64.00	134.27	99.40	-34.87	-77.32	129.28	99.40	-29.88	-65.86	132.54	99.40	-33.14	-103.15	145.20	136.44	-8.76	-26.54
90	157.16	103.89	-53.27	-155.28	128.47	77.29	-51.18	-151.46	134.27	77.29	-56.99	-169.77	129.28	77.29	-52.00	-154.02	132.54	77.29	-55.25	-263.74	145.20	106.08	-39.12	-182.46

120	157.16	87.44	-69.73	-319.75	128.47	65.05	-63.42	-294.19	134.27	65.05	-69.23	-322.75	129.28	65.05	-64.23	-298.18	132.54	65.05	-67.49	-435.69	145.20	89.29	-55.92	-353.72
180	157.16	68.98	-88.19	-543.92	128.47	51.31	-77.15	-481.05	134.27	51.31	-82.96	-519.73	129.28	51.31	-77.97	-486.46	132.54	51.31	-81.23	-800.57	145.20	70.43	-74.77	-724.63
270	157.16	54.73	-102.43	-973.03	128.47	40.72	-87.75	-841.00	134.27	40.72	-93.56	-900.17	129.28	40.72	-88.57	-849.28	132.54	40.72	-91.82	-1378.32	145.20	55.89	-89.32	-1322.17
360	157.16	46.39	-110.77	-1624.53	128.47	34.51	-93.96	-1387.29	134.27	34.51	-99.76	-1477.44	129.28	34.51	-94.77	-1399.91	132.54	34.51	-98.03	-1979.85	145.20	47.37	-97.83	-1951.97
540	157.16	36.32	-120.84	-2373.32	128.47	27.02	-101.45	-2005.34	134.27	27.02	-107.25	-2126.19	129.28	27.02	-102.26	-2022.26	132.54	27.02	-105.52	-3229.67	145.20	37.09	-108.11	-3275.33
720	157.16	30.15	-127.01	-3815.31	128.47	22.43	-106.04	-3201.53	134.27	22.43	-111.84	-3384.47	129.28	22.43	-106.85	-3227.15	132.54	22.43	-110.11	-4518.98	145.20	30.79	-114.42	-4652.64
1080	157.16	22.75	-134.42	-5386.14	128.47	16.92	-111.55	-4492.40	134.27	16.92	-117.35	-4736.85	129.28	16.92	-112.36	-4526.64	132.54	16.92	-115.62	-7161.17	145.20	23.23	-121.98	-7494.17
1440	157.16	18.25	-138.91	-8459.73	128.47	13.58	-114.89	-7025.94	134.27	13.58	-120.70	-7394.61	129.28	13.58	-115.71	-7077.58	132.54	13.58	-118.96	-9854.07	145.20	18.63	-126.57	-10405.32
1800	157.16	15.13	-142.04	-11603.44	128.47	11.25	-117.21	-9611.55	134.27	11.25	-123.02	-10104.38	129.28	11.25	-118.03	-9680.58	132.54	11.25	-121.29	-12576.89	145.20	15.45	-129.76	-13357.91
2160	157.16	12.96	-144.20	-14781.86	128.47	9.64	-118.83	-12223.03	134.27	9.64	-124.63	-12840.05	129.28	9.64	-119.64	-12309.46	132.54	9.64	-122.90	-15310.31	145.20	13.23	-131.97	-16324.84
2880	157.16	10.05	-147.11	-18023.80	128.47	7.48	-120.99	-14879.19	134.27	7.48	-126.80	-15619.16	129.28	7.48	-121.81	-14982.85	132.54	7.48	-125.06	-20800.81	145.20	10.26	-134.94	-22291.36
4320	157.16	6.96	-150.20	-24419.07	128.47	5.18	-123.29	-20125.73	134.27	5.18	-129.09	-21111.68	129.28	5.18	-124.10	-20263.85	132.54	5.18	-127.36	-31820.90	145.20	7.11	-138.09	-34277.62
Volume check				ok				ok				ok				ok				ok				ok

D10

Storm Duration (mins)	41				43				44				45				46			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	133.93	619.91	485.98	-9.83	167.12	938.24	771.12	-24.73	158.50	752.76	594.26	-12.90	157.02	697.39	540.37	-9.67	160.40	741.94	581.54	-11.74
2	133.93	505.75	371.82	8.06	167.12	765.47	598.35	4.28	158.50	614.14	455.64	9.04	157.02	568.97	411.95	10.10	160.40	605.31	444.92	9.66
3	133.93	463.36	329.43	23.94	167.12	701.31	534.19	30.36	158.50	562.67	404.17	28.57	157.02	521.28	364.26	27.61	160.40	554.58	394.19	28.67
4	133.93	429.89	295.96	36.79	167.12	650.65	483.53	51.85	158.50	522.02	363.52	44.41	157.02	483.62	326.60	41.70	160.40	514.52	354.12	44.04
5	133.93	401.71	267.78	47.18	167.12	608.00	440.88	69.63	158.50	487.80	329.30	57.27	157.02	451.92	294.90	53.02	160.40	480.79	320.39	56.47
10	133.93	300.56	166.63	72.41	167.12	454.91	287.79	118.02	158.50	364.97	206.47	89.09	157.02	338.13	181.11	79.57	160.40	359.73	199.33	86.63
15	133.93	241.80	107.87	74.89	167.12	365.97	198.85	132.03	158.50	293.62	135.12	93.30	157.02	272.02	115.00	80.53	160.40	289.40	129.00	89.58
20	133.93	203.75	69.82	66.74	167.12	308.37	141.25	129.94	158.50	247.41	88.91	84.59	157.02	229.21	72.19	69.52	160.40	243.85	83.46	79.79
25	133.93	177.45	43.52	53.08	167.12	268.57	101.45	119.54	158.50	215.48	56.97	69.20	157.02	199.63	42.61	52.32	160.40	212.38	51.98	63.41
30	133.93	157.99	24.06	35.73	167.12	239.12	72.00	103.58	158.50	191.85	33.34	49.33	157.02	177.74	20.72	30.96	160.40	189.09	28.69	42.62
45	133.93	121.70	-12.23	-28.02	167.12	184.20	17.08	38.10	158.50	147.78	-10.72	-24.48	157.02	136.91	-20.11	-46.31	160.40	145.66	-14.74	-33.77
60	133.93	101.39	-32.54	-101.18	167.12	153.46	-13.66	-41.50	158.50	123.12	-35.38	-109.70	157.02	114.06	-42.96	-134.18	160.40	121.35	-39.05	-121.42
90	133.93	78.83	-55.10	-262.77	167.12	119.32	-47.81	-223.54	158.50	95.73	-62.77	-298.65	157.02	88.69	-68.33	-327.14	160.40	94.35	-66.05	-315.00
120	133.93	66.35	-67.58	-435.92	167.12	100.42	-66.70	-422.86	158.50	80.57	-77.93	-501.62	157.02	74.64	-82.38	-533.16	160.40	79.41	-80.99	-522.42
180	133.93	52.34	-81.59	-803.64	167.12	79.22	-87.90	-853.48	158.50	63.56	-94.94	-933.51	157.02	58.88	-98.14	-969.33	160.40	62.65	-97.75	-962.89
270	133.93	41.53	-92.40	-1386.23	167.12	62.86	-104.26	-1545.78	158.50	50.43	-108.07	-1618.94	157.02	46.72	-110.30	-1658.58	160.40	49.71	-110.69	-1660.70
360	133.93	35.20	-98.73	-1993.05	167.12	53.28	-113.84	-2274.41	158.50	42.75	-115.76	-2333.76	157.02	39.60	-117.42	-2375.15	160.40	42.13	-118.27	-2387.53
540	133.93	27.56	-106.37	-3254.39	167.12	41.72	-125.40	-3803.44	158.50	33.47	-125.03	-3821.28	157.02	31.01	-126.01	-3862.03	160.40	32.99	-127.41	-3898.27
720	133.93	22.88	-111.05	-4556.00	167.12	34.63	-132.49	-5393.17	158.50	27.78	-130.72	-5357.68	157.02	25.74	-131.28	-5394.24	160.40	27.38	-133.01	-5457.21
1080	133.93	17.26	-116.67	-7224.06	167.12	26.12	-141.00	-8670.42	158.50	20.96	-137.54	-8509.14	157.02	19.42	-137.60	-8531.66	160.40	20.66	-139.74	-8652.67
1440	133.93	13.85	-120.08	-9943.83	167.12	20.96	-146.16	-12025.98	158.50	16.82	-141.69	-11723.43	157.02	15.58	-141.44	-11727.27	160.40	16.57	-143.82	-11910.05
1800	133.93	11.48	-122.45	-12694.15	167.12	17.37	-149.75	-15428.09	158.50	13.94	-144.56	-14974.83	157.02	12.91	-144.11	-14957.17	160.40	13.74	-146.66	-15203.96
2160	133.93	9.83	-124.10	-15455.26	167.12	14.88	-152.24	-18846.37	158.50	11.94	-146.56	-18239.32	157.02	11.06	-145.96	-18199.25	160.40	11.77	-148.63	-18510.81
2880	133.93	7.63	-126.30	-21001.62	167.12	11.54	-155.58	-25719.62	158.50	9.26	-149.24	-24797.63	157.02	8.58	-148.44	-24710.54	160.40	9.13	-151.27	-25153.38
4320	133.93	5.28	-128.64	-32134.21	167.12	8.00	-159.12	-39526.04	158.50	6.42	-152.08	-37962.62	157.02	5.95	-151.07	-37778.04	160.40	6.33	-154.07	-38486.25
Volume check				ok				ok				ok				ok				ok

D11

Storm Duration (mins)	39				40				53				54			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	181.45	888.96	707.51	-16.66	125.92	1004.55	878.63	-51.21	140.86	673.93	533.07	-11.80	134.00	612.98	478.97	-9.37
2	181.45	725.26	543.81	9.57	125.92	819.56	693.64	-17.33	140.86	549.83	408.97	7.90	134.00	500.10	366.10	8.23
3	181.45	664.47	483.03	32.96	125.92	750.88	624.95	13.60	140.86	503.75	362.89	25.44	134.00	458.18	324.18	23.85
4	181.45	616.47	435.02	52.00	125.92	696.63	570.71	39.63	140.86	467.36	326.49	39.69	134.00	425.08	291.08	36.47
5	181.45	576.06	394.61	67.51	125.92	650.97	525.04	61.68	140.86	436.72	295.86	51.26	134.00	397.22	263.22	46.65
10	181.45	431.01	249.56	106.74	125.92	487.05	361.13	128.58	140.86	326.76	185.89	80.04	134.00	297.20	163.20	71.14
15	181.45	346.74	165.30	113.36	125.92	391.83	265.91	158.68	140.86	262.87	122.01	84.11	134.00	239.09	105.09	73.15
20	181.45	292.17	110.73	104.73	125.92	330.17	204.24	171.59	140.86	221.50	80.64	76.62	134.00	201.47	67.47	64.63
25	181.45	254.46	73.02	88.21	125.92	287.55	161.63	175.65	140.86	192.91	52.05	63.14	134.00	175.46	41.46	50.67
30	181.45	226.56	45.11	66.41	125.92	256.02	130.09	173.79	140.86	171.76	30.89	45.65	134.00	156.22	22.22	33.06
45	181.45	174.52	-6.92	-15.75	125.92	197.22	71.29	149.54	140.86	132.31	-8.55	-19.52	134.00	120.34	-13.66	-31.35
60	181.45	145.40	-36.05	-111.36	125.92	164.30	38.38	110.41	140.86	110.23	-30.63	-94.90	134.00	100.26	-33.74	-105.07
90	181.45	113.05	-68.40	-324.41	125.92	127.75	1.82	8.16	140.86	85.70	-55.16	-262.23	134.00	77.95	-56.05	-267.61
120	181.45	95.15	-86.30	-553.99	125.92	107.52	-18.40	-112.17	140.86	72.13	-68.73	-442.10	134.00	65.61	-68.39	-441.60
180	181.45	75.06	-106.39	-1043.72	125.92	84.82	-41.10	-386.35	140.86	56.90	-83.96	-825.07	134.00	51.76	-82.25	-810.76
270	181.45	59.56	-121.89	-1822.62	125.92	67.30	-58.62	-846.19	140.86	45.15	-95.71	-1433.18	134.00	41.07	-92.94	-1395.20
360	181.45	50.48	-130.97	-2636.18	125.92	57.04	-68.88	-1344.31	140.86	38.27	-102.59	-2067.58	134.00	34.81	-99.19	-2003.61
540	181.45	39.52	-141.92	-4331.57	125.92	44.66	-81.26	-2416.61	140.86	29.96	-110.90	-3388.20	134.00	27.25	-106.75	-3267.62
720	181.45	32.81	-148.64	-6084.64	125.92	37.08	-88.85	-3553.46	140.86	24.87	-115.99	-4752.55	134.00	22.62	-111.38	-4571.46
1080	181.45	24.75	-156.69	-9683.64	125.92	27.97	-97.95	-5931.26	140.86	18.76	-122.10	-7551.71	134.00	17.07	-116.93	-7243.26
1440	181.45	19.86	-161.59	-13356.83	125.92	22.44	-103.48	-8392.95	140.86	15.05	-125.81	-10407.10	134.00	13.69	-120.31	-9966.21
1800	181.45	16.46	-164.98	-17073.90	125.92	18.60	-107.32	-10905.08	140.86	12.48	-128.38	-13295.74	134.00	11.35	-122.65	-12719.33
2160	181.45	14.10	-167.34	-20806.41	125.92	15.94	-109.99	-13434.22	140.86	10.69	-130.17	-16196.08	134.00	9.72	-124.28	-15483.14
2880	181.45	10.94	-170.51	-28306.08	125.92	12.36	-113.56	-18532.05	140.86	8.29	-132.57	-22023.04	134.00	7.54	-126.46	-21034.62
4320	181.45	7.58	-173.87	-43362.48	125.92	8.56	-117.36	-28791.11	140.86	5.75	-135.12	-33720.26	134.00	5.23	-128.78	-32177.02
Volume check				ok				ok				ok				ok

E1

E2

Storm Duration (mins)	55				56				57				58			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	121.60	624.22	502.62	-13.26	141.69	610.24	468.55	-7.59	160.24	634.31	474.07	-5.57	151.08	641.72	490.64	-7.58
2	121.60	509.27	387.67	5.48	141.69	497.87	356.18	9.47	160.24	517.50	357.27	11.45	151.08	523.55	372.47	10.25
3	121.60	466.59	344.99	22.23	141.69	456.14	314.45	24.54	160.24	474.13	313.89	26.37	151.08	479.67	328.59	25.98
4	121.60	432.88	311.28	35.94	141.69	423.19	281.50	36.62	160.24	439.88	279.64	38.18	151.08	445.02	293.94	38.56
5	121.60	404.51	282.91	47.16	141.69	395.45	253.76	46.29	160.24	411.04	250.81	47.47	151.08	415.85	264.77	48.60
10	121.60	302.65	181.05	76.38	141.69	295.87	154.19	68.28	160.24	307.54	147.31	66.58	151.08	311.14	160.06	71.13
15	121.60	243.48	121.88	82.70	141.69	238.03	96.34	67.88	160.24	247.41	87.18	62.42	151.08	250.31	99.23	70.11
20	121.60	205.16	83.56	78.32	141.69	200.57	58.88	57.00	160.24	208.48	48.24	47.36	151.08	210.92	59.84	58.07
25	121.60	178.68	57.08	68.40	141.69	174.68	32.99	40.70	160.24	181.57	21.33	26.65	151.08	183.69	32.61	40.32
30	121.60	159.09	37.49	54.77	141.69	155.52	13.84	20.77	160.24	161.66	1.42	2.16	151.08	163.55	12.47	18.75
45	121.60	122.55	0.95	2.15	141.69	119.80	-21.88	-50.59	160.24	124.53	-35.71	-83.36	151.08	125.98	-25.09	-58.11
60	121.60	102.10	-19.50	-59.91	141.69	99.81	-41.88	-131.25	160.24	103.75	-56.49	-178.58	151.08	104.96	-46.12	-144.75
90	121.60	79.38	-42.22	-199.30	141.69	77.60	-64.08	-307.65	160.24	80.66	-79.57	-384.78	151.08	81.61	-69.47	-333.92
120	121.60	66.81	-54.79	-350.25	141.69	65.32	-76.37	-495.50	160.24	67.89	-92.34	-602.97	151.08	68.68	-82.39	-535.15
180	121.60	52.71	-68.89	-673.57	141.69	51.53	-90.16	-892.38	160.24	53.56	-106.68	-1061.46	151.08	54.18	-96.90	-959.87
270	121.60	41.82	-79.78	-1189.57	141.69	40.88	-100.80	-1518.37	160.24	42.50	-117.74	-1781.28	151.08	42.99	-108.09	-1629.26
360	121.60	35.45	-86.15	-1729.84	141.69	34.65	-107.03	-2168.31	160.24	36.02	-124.22	-2526.10	151.08	36.44	-114.64	-2323.84
540	121.60	27.75	-93.84	-2858.26	141.69	27.13	-114.56	-3515.25	160.24	28.20	-132.03	-4064.78	151.08	28.53	-122.55	-3762.52
720	121.60	23.04	-98.56	-4027.14	141.69	22.52	-119.17	-4901.88	160.24	23.41	-136.82	-5644.81	151.08	23.68	-127.39	-5242.96
1080	121.60	17.38	-104.22	-6430.06	141.69	16.99	-124.70	-7739.07	160.24	17.66	-142.57	-8871.40	151.08	17.87	-133.21	-8271.07
1440	121.60	13.94	-107.65	-8885.08	141.69	13.63	-128.06	-10627.16	160.24	14.17	-146.07	-12150.89	151.08	14.34	-136.74	-11352.71
1800	121.60	11.56	-110.04	-11370.96	141.69	11.30	-130.39	-13545.23	160.24	11.75	-148.49	-15461.44	151.08	11.88	-139.19	-14465.85
2160	121.60	9.90	-111.70	-13867.66	141.69	9.68	-132.01	-16473.97	160.24	10.06	-150.17	-18783.14	151.08	10.18	-140.90	-17590.22
2880	121.60	7.68	-113.92	-18885.41	141.69	7.51	-134.18	-22355.18	160.24	7.80	-152.43	-25451.15	151.08	7.89	-143.18	-23863.92
4320	121.60	5.32	-116.28	-28960.91	141.69	5.20	-136.49	-34156.95	160.24	5.41	-154.83	-38828.21	151.08	5.47	-145.61	-36452.71
Volume check				ok				ok				ok				ok

1 YEAR ARI 1 HOUR FLOWS - ROADS

Rainfall Intensity i (mm/h)	15.1	(1yr, 1hr Storm)
Runoff Coefficient Road Reserves	0.8	
Runoff Coefficient Swale	1	
Runoff Coefficient Lots	0	
Runoff Coefficient OS	0	
Permeability k (m/hr)	**0.0417**	
Swale Depth (m)	0.50	
Weir Height (m)	0.40	
Driveway Width (m)	10.0	
Swale Side Slope (1/x)	3.00	
Trapezoidal Swale Base Width (m)	1.00	
Swale top width (m)	4.00	

Segment	Road Reserve (m2)	Swale Length (m)	Swale Area (m2)	Lots (m2)	POS (m2)	Ai	Segment Peak Flow (L/s)	Segment 1 hr Flow (m3)
A1	5630					4504	19	68.1
A2	10573					8458	36	127.8
A3	7253					5802	24	87.7
A4	7494					5995	25	90.6
A5	2715					2172	9	32.8
B1	6454					5163	22	78.0
B2	6669					5335	22	80.6
C1	2968					2374	10	35.9
D1	11939					9551	40	144.3
D2	16225					12980	54	196.2
D3	11446					9157	38	138.4
D4	9025					7220	30	109.1
D5	4678					3742	16	56.6
D6	7843					6274	26	94.8
D7	3738					2990	13	45.2
D8	5120					4096	17	61.9
D9	6854					5483	23	82.9
E1	7788					6230	26	94.2
E2	5015					4012	17	60.6
E3	6372					5098	21	77.0

Trapezoidal Swales

Swale Segment	No. Driveways	No. Weirs	Length	Weir Spacing (m)	Long Slope	Max U/S Reach (m)	Upstream Ht (m)	1 hr Inflow per Weir (m3)	Storage per Weir (m3)	Total Storage (m3)	Effective Storage per Weir (m3)	Effective Total Storage (m3)	Volume Check
A1	0	4	227	57	0.0054	56.8	0.1	17.02	25.06	100.22	30.22	120.88	ok
A2	0	23	513	22	0.0202	19.8	0.0	5.56	5.81	133.60	7.10	163.36	ok
A3	1	7	118	17	0.0021	15.3	0.4	12.53	12.65	88.53	14.46	101.22	ok
A4	9	17	734	43	0.0221	18.1	0.0	5.33	5.31	90.26	6.49	110.36	ok
A5	2	14	233	17	0.0522	7.7	0.0	2.34	2.25	31.47	2.75	38.48	ok
B1	1	5	281	56	0.0063	54.2	0.1	15.61	21.59	107.94	26.03	130.17	ok
B2	0	14	281	20	0.0204	19.6	0.0	5.76	5.75	80.52	7.03	98.46	ok
C1	0	1	139	139	0.0033	121.2	0.0	35.88	35.56	35.56	43.48	43.48	ok
D1	0	14	452	32	0.0122	32.3	0.0	10.31	10.33	144.68	12.49	174.89	ok
D2	2	33	518	16	0.0223	15.1	0.1	5.94	6.10	201.43	7.37	243.11	ok
D3	4	10	335	34	0.0091	29.5	0.1	13.84	14.41	144.09	17.21	172.06	ok
D4	1	56	490	9	0.0631	6.3	0.0	1.95	1.86	104.13	2.27	127.33	ok
D5	2	15	659	44	0.0321	12.5	0.0	3.77	3.66	54.83	4.47	67.04	ok
D6	3	39	492	13	0.0504	7.9	0.0	2.43	2.33	90.79	2.85	111.02	ok
D7	2	8	143	18	0.0211	15.4	0.1	5.65	6.45	51.59	7.80	62.42	ok
D8	1	15	238	16	0.0294	13.6	0.0	4.13	3.99	59.86	4.88	73.20	ok
D9	2	1	314	314	0.0003	294.0	0.3	82.86	216.79	216.79	249.97	249.97	ok
E1	3	16	471	29	0.0205	19.5	0.0	5.88	5.72	91.58	7.00	111.98	ok
E2	0	14	260	19	0.0282	14.2	0.0	4.33	4.16	58.25	5.09	71.23	ok
E3	0	11	294	27	0.0162	24.7	0.0	7.00	7.24	79.67	8.86	97.42	ok

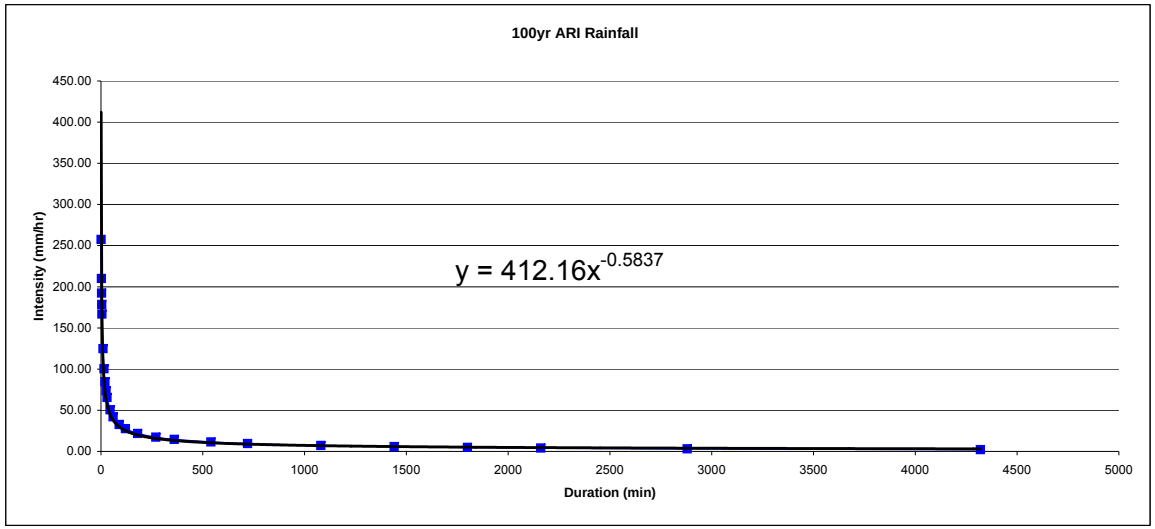
100 YEAR ARI DRAINAGE PROPERTIES - ROADS

CATCHMENT	AREAS (m2)					EFFECTIVE AREAS (m2)		TIME OF CONCENTRATION PRE DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Road Reserve (m2)	Swale	Lots (m2)	POS (m2)	Total	Pre	Post	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (mln)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mln)	Pre-Dev	Post-Dev
A1	5630		0	0	5630	1971	4786	225	60.5	59	6.67	16.6	225	60.5	59	6.67	15.2	79.8	84.1
A2	10573		0	0	10573	3701	8987	522	70.2	59.4	20.69	28.9	522	70.2	59.4	20.69	26.5	57.8	60.9
A3	7253		0	0	7253	2539	6165	144	69.8	69	5.56	10.8	144	69.8	69	5.56	9.9	102.9	108.4
A4	7494		0	0	7494	2623	6370	367	78	70	21.80	20.8	367	78	70	21.80	19.1	70.1	73.8
A5	2715		0	0	2715	950	2308	129	85	78	54.26	6.8	129	85	78	54.26	6.2	135.2	142.4
B1	6454		0	0	6454	2259	5486	303	66	65	3.30	25.5	303	66	65	3.30	23.3	62.3	65.6
B2	6669		0	0	6669	2334	5669	294	67	60.8	21.09	17.0	294	67	60.8	21.09	15.5	78.9	83.1
C1	2968		0	0	2968	1039	2523	148	61.3	60.2	7.43	11.4	148	61.3	60.2	7.43	10.5	99.5	104.7
D1	11939		0	0	11939	4179	10148	236	69.8	66	16.10	13.6	236	69.8	66	16.10	12.4	89.9	94.7
D2	16225		0	0	16225	5679	13791	319	66.8	59.3	23.51	16.5	319	66.8	59.3	23.51	15.1	80.2	84.5
D3	11446		0	1	11447	4006	9729	382	71.5	66.4	13.35	22.9	382	71.5	66.4	13.35	21.0	66.2	69.8
D4	9025		0	2	9027	3159	7671	286	86	73	45.45	13.8	286	86	73	45.45	12.6	89.3	94.0
D5	4678		0	0	4678	1637	3976	243	93	88	20.58	14.6	243	93	88	20.58	13.4	86.1	90.7
D6	7843		0	0	7843	2745	6667	263	87	72	57.03	12.3	263	87	72	57.03	11.2	95.5	100.5
D7	3738		0	0	3738	1308	3177	133	73	70.3	20.30	8.2	133	73	70.3	20.30	7.5	120.6	127.1
D8	5120		0	0	5120	1792	4352	251	70	62	31.87	13.7	251	70	62	31.87	12.5	89.4	94.2
D9	6854		0	0	6854	2399	5826	316	61.7	61.3	1.27	32.0	316	61.7	61.3	1.27	29.2	54.6	57.5
E1	7788		0	0	7788	2726	6620	273	86	81.5	16.48	16.3	273	86	81.5	16.48	14.9	80.8	85.1
E2	5015		0	0	5015	1755	4263	260	89	81.5	28.85	14.5	260	89	81.5	28.85	13.3	86.5	91.1
E3	6372		0	0	6372	2230	5416	319	93	89	12.54	20.5	319	93	89	12.54	18.8	70.6	74.4

Runoff Coefficients	Pre-Dev	Post-Dev
Roads	0.35	0.85
Swales/Basins	0.35	0
Lots	0.35	0
OS	0.35	0

Rainfall IFD

Event	Duration (mins)	Intensity (mm/hr)
1 min	1	257.40
2 min	2	210.00
3 min	3	192.40
4 min	4	178.50
5 min	5	166.80
10 min	10	124.80
15 min	15	100.40
20 min	20	84.60
25 min	25	73.68
30 min	30	65.60
45 min	45	50.53
1 hr	60	42.10
1.5 hr	90	32.73
2 hr	120	27.55
3 hr	180	21.73
4.5 hr	270	17.24
6 hr	360	14.62
9 hr	540	11.44
12 hr	720	9.50
18 hr	1080	7.17
24 hr	1440	5.75
30 hr	1800	4.77
36 hr	2160	4.08
48 hr	2880	3.17
72 hr	4320	2.19



100 YEAR ARI FLOWS - ROADS

Storm Duration (mins)	A1				A2				A3				A4				A5			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	43.69	342.16	298.47	-16.93	59.45	642.57	583.12	-50.67	72.57	440.80	368.23	-13.77	51.04	455.45	404.41	-27.55	35.69	165.00	129.32	-2.61
2	43.69	279.15	235.46	-5.43	59.45	524.24	464.79	-27.91	72.57	359.63	287.06	0.18	51.04	371.58	320.54	-11.87	35.69	134.62	98.93	2.15
3	43.69	255.76	212.06	5.05	59.45	480.31	420.85	-6.95	72.57	329.49	256.92	12.77	51.04	340.44	289.39	2.49	35.69	123.34	87.65	6.38
4	43.69	237.28	193.59	13.88	59.45	445.61	386.15	10.88	72.57	305.68	233.12	23.21	51.04	315.84	264.80	14.63	35.69	114.43	78.74	9.80
5	43.69	221.73	178.03	21.34	59.45	416.40	356.95	26.17	72.57	285.65	213.08	31.90	51.04	295.14	244.10	24.97	35.69	106.93	71.24	12.56
10	43.69	165.90	122.20	43.90	59.45	311.55	252.10	74.88	72.57	213.72	141.15	56.34	51.04	220.82	169.78	57.00	35.69	80.00	44.31	19.26
15	43.69	133.46	89.77	53.93	59.45	250.64	191.19	100.07	72.57	171.94	99.37	64.62	51.04	177.65	126.61	72.36	35.69	64.36	28.67	19.91
20	43.69	112.46	68.76	58.10	59.45	211.20	151.74	114.28	72.57	144.88	72.31	65.35	51.04	149.69	98.65	79.93	35.69	54.23	18.54	17.73
25	43.69	97.94	54.25	59.25	59.45	183.93	124.48	122.84	72.57	126.18	53.61	62.18	51.04	130.37	79.33	83.49	35.69	47.23	11.54	14.08
30	43.69	87.20	43.51	58.39	59.45	163.76	104.31	127.64	72.57	112.34	39.77	56.39	51.04	116.07	65.03	84.37	35.69	42.05	6.36	9.45
45	43.69	67.17	23.48	49.44	59.45	126.15	66.70	130.18	72.57	86.54	13.97	30.79	51.04	89.41	38.37	78.57	35.69	32.39	-3.29	-7.55
60	43.69	55.96	12.27	35.41	59.45	105.10	45.65	123.33	72.57	72.10	-0.47	-1.42	51.04	74.49	23.45	66.05	35.69	26.99	-8.70	-27.06
90	43.69	43.51	-0.18	-0.81	59.45	81.72	22.26	94.50	72.57	56.06	-16.51	-76.52	51.04	57.92	6.88	30.21	35.69	20.98	-14.70	-70.13
120	43.69	36.62	-7.07	-43.21	59.45	68.78	9.32	54.33	72.57	47.18	-25.39	-159.69	51.04	48.75	-2.29	-13.77	35.69	17.66	-18.03	-116.29
180	43.69	28.89	-14.80	-139.42	59.45	54.26	-5.20	-47.09	72.57	37.22	-35.35	-341.00	51.04	38.46	-12.59	-116.83	35.69	13.93	-21.76	-214.31
270	43.69	22.92	-20.77	-300.30	59.45	43.05	-16.40	-229.78	72.57	29.53	-43.04	-634.63	51.04	30.51	-20.53	-293.30	35.69	11.05	-24.63	-369.59
360	43.69	19.43	-24.26	-474.23	59.45	36.49	-22.96	-436.62	72.57	25.03	-47.54	-945.27	51.04	25.86	-25.18	-487.04	35.69	9.37	-26.32	-531.31
540	43.69	15.21	-28.48	-848.02	59.45	28.57	-30.88	-898.58	72.57	19.60	-52.97	-1600.18	51.04	20.25	-30.79	-908.90	35.69	7.34	-28.35	-867.47
720	43.69	12.63	-31.07	-1243.80	59.45	23.72	-35.74	-1401.61	72.57	16.27	-56.30	-2283.57	51.04	16.81	-34.23	-1359.97	35.69	6.09	-29.60	-1214.34
1080	43.69	9.53	-34.17	-2070.82	59.45	17.89	-41.56	-2473.95	72.57	12.27	-60.29	-3696.21	51.04	12.68	-38.36	-2309.21	35.69	4.59	-31.09	-1925.35
1440	43.69	7.64	-36.05	-2926.41	59.45	14.35	-45.10	-3599.97	72.57	9.85	-62.72	-5145.66	51.04	10.17	-40.87	-3296.50	35.69	3.69	-32.00	-2650.12
1800	43.69	6.34	-37.36	-3799.18	59.45	11.90	-47.55	-4758.57	72.57	8.16	-64.41	-6617.04	51.04	8.43	-42.61	-4306.74	35.69	3.06	-32.63	-3383.02
2160	43.69	5.43	-38.27	-4677.75	59.45	10.19	-49.26	-5927.89	72.57	6.99	-65.58	-8095.98	51.04	7.23	-43.82	-5324.65	35.69	2.62	-33.07	-4118.79
2880	43.69	4.21	-39.48	-6448.35	59.45	7.91	-51.55	-8291.97	72.57	5.42	-67.15	-11071.13	51.04	5.60	-45.44	-7378.44	35.69	2.03	-33.66	-5596.76
4320	43.69	2.92	-40.78	-10011.15	59.45	5.48	-53.97	-13060.29	72.57	3.76	-68.81	-17049.51	51.04	3.88	-47.16	-11514.65	35.69	1.41	-34.28	-8563.32
Volume check				ok				ok				ok				ok				ok

Storm Duration (mins)	B1				B2				C1			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	85.90	392.24	306.35	-75.38	51.15	405.31	354.16	-20.44	28.70	180.38	151.68	-6.04
2	39.09	320.01	280.92	-14.25	51.15	330.67	279.52	-6.79	28.70	147.16	118.47	-0.27
3	39.09	293.19	254.10	-1.62	51.15	302.96	251.81	5.67	28.70	134.83	106.13	4.93
4	39.09	272.01	232.91	9.11	51.15	281.07	229.92	16.15	28.70	125.09	96.39	9.26
5	39.09	254.18	215.09	18.29	51.15	262.65	211.50	25.03	28.70	116.89	88.19	12.88
10	39.09	190.18	151.08	47.24	51.15	196.51	145.36	51.93	28.70	87.46	58.76	23.16
15	39.09	153.00	113.90	61.83	51.15	158.09	106.94	63.97	28.70	70.36	41.66	26.84
20	39.09	128.92	89.82	69.72	51.15	133.21	82.06	69.08	28.70	59.29	30.59	27.42
25	39.09	112.28	73.18	74.16	51.15	116.02	64.87	70.63	28.70	51.63	22.94	26.41
30	39.09	99.97	60.87	76.30	51.15	103.30	52.14	69.78	28.70	45.97	17.27	24.33
45	39.09	77.01	37.91	75.46	51.15	79.57	28.42	59.69	28.70	35.41	6.71	14.72
60	39.09	64.15	25.06	68.87	51.15	66.29	15.14	43.61	28.70	29.50	0.80	2.41
90	39.09	49.88	10.79	46.43	51.15	51.54	0.39	1.75	28.70	22.94	-5.76	-26.58
120	39.09	41.98	2.89	17.04	51.15	43.38	-7.77	-47.40	28.70	19.31	-9.39	-58.86
180	39.09	33.12	-5.98	-54.68	51.15	34.22	-16.93	-159.23	28.70	15.23	-13.47	-129.53
270	39.09	26.28	-12.82	-180.97	51.15	27.15	-24.00	-346.59	28.70	12.08	-16.61	-244.39
360	39.09	22.27	-16.82	-322.06	51.15	23.02	-28.13	-549.39	28.70	10.24	-18.45	-366.20
540	39.09	17.44	-21.65	-633.76	51.15	18.02	-33.13	-985.70	28.70	8.02	-20.68	-623.56
720	39.09	14.48	-24.62	-970.57	51.15	14.96	-36.19	-1448.05	28.70	6.66	-22.04	-892.56
1080	39.09	10.92	-28.17	-1684.67	51.15	11.28	-39.87	-2414.76	28.70	5.02	-23.68	-1449.33
1440	39.09	8.76	-30.33	-2431.55	51.15	9.05	-42.10	-3415.31	28.70	4.03	-24.67	-2021.16
1800	39.09	7.26	-31.83	-3198.26	51.15	7.51	-43.64	-4436.22	28.70	3.34	-25.36	-2601.98
2160	39.09	6.22	-32.87	-3971.54	51.15	6.43	-44.72	-5463.99	28.70	2.86	-25.84	-3185.88

2880	39.09	4.83	-34.27	-5533.61	51.15	4.99	-46.16	-7535.48	28.70	2.22	-26.48	-4360.77
4320	39.09	3.34	-35.75	-8682.33	51.15	3.46	-47.70	-11704.05	28.70	1.54	-27.16	-6722.00
Volume check				ok				ok				ok

Storage Duration (mins)	D1				D2				D3			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	104.36	725.59	621.23	-29.34	126.57	986.07	859.50	-48.39	73.73	695.63	621.90	-45.61
2	104.36	591.98	487.61	-5.58	126.57	804.49	677.92	-15.29	73.73	567.53	493.80	-21.45
3	104.36	542.36	438.00	16.00	126.57	737.07	610.49	14.90	73.73	519.97	446.24	0.72
4	104.36	503.18	398.82	34.05	126.57	683.82	557.24	40.28	73.73	482.40	408.67	19.50
5	104.36	470.20	365.83	49.21	126.57	638.99	512.42	61.76	73.73	450.78	377.05	35.53
10	104.36	351.80	247.44	93.74	126.57	478.10	351.52	126.59	73.73	337.28	263.55	85.65
15	104.36	283.02	178.66	111.67	126.57	384.62	258.05	155.30	73.73	271.33	197.61	110.29
20	104.36	238.48	134.12	117.18	126.57	324.09	197.52	167.13	73.73	228.63	154.91	123.04
25	104.36	207.70	103.34	116.29	126.57	282.26	155.69	170.28	73.73	199.12	125.40	129.68
30	104.36	184.92	80.56	111.11	126.57	251.31	124.73	167.60	73.73	177.29	103.56	132.22
45	104.36	142.45	38.09	82.03	126.57	193.59	67.02	141.24	73.73	136.57	62.84	126.99
60	104.36	118.68	14.31	42.14	126.57	161.28	34.71	100.27	73.73	113.78	40.05	111.53
90	104.36	92.27	-12.09	-55.09	126.57	125.40	-1.17	-5.27	73.73	88.46	14.74	64.12
120	104.36	77.66	-26.70	-165.50	126.57	105.54	-21.03	-128.57	73.73	74.45	0.73	4.33
180	104.36	61.26	-43.10	-410.73	126.57	83.26	-43.31	-408.13	73.73	58.73	-14.99	-138.23
270	104.36	48.61	-55.75	-813.95	126.57	66.06	-60.51	-875.22	73.73	46.60	-27.12	-385.41
360	104.36	41.20	-63.16	-1244.98	126.57	56.00	-70.58	-1379.92	73.73	39.50	-34.22	-658.89
540	104.36	32.26	-72.10	-2162.21	126.57	43.84	-82.73	-2464.04	73.73	30.93	-42.80	-1258.29
720	104.36	26.78	-77.58	-3126.19	126.57	36.39	-90.18	-3611.55	73.73	25.67	-48.05	-1902.26
1080	104.36	20.20	-84.16	-5129.49	126.57	27.45	-99.12	-6008.78	73.73	19.37	-54.36	-3262.09
1440	104.36	16.21	-88.15	-7193.37	126.57	22.03	-104.54	-8488.36	73.73	15.54	-58.19	-4680.03
1800	104.36	13.44	-90.93	-9293.53	126.57	18.26	-108.31	-11017.43	73.73	12.88	-60.84	-6133.09
2160	104.36	11.51	-92.85	-11406.05	126.57	15.64	-110.93	-13563.20	73.73	11.04	-62.69	-7597.83
2880	104.36	8.93	-95.44	-15659.59	126.57	12.13	-114.44	-18693.55	73.73	8.56	-65.17	-10554.78
4320	104.36	6.19	-98.18	-24212.67	126.57	8.41	-118.17	-29016.53	73.73	5.93	-67.80	-16512.35
Volume check				ok				ok				ok

Storage Duration (mins)	D4				D5				D6			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	78.33	548.49	470.16	-22.48	39.17	284.31	245.14	-12.40	72.79	476.66	403.87	-17.27
2	78.33	447.49	369.16	-4.49	39.17	231.95	192.78	-3.00	72.79	388.88	316.09	-1.88
3	78.33	409.99	331.65	11.86	39.17	212.51	173.34	5.56	72.79	356.29	283.50	12.06
4	78.33	380.37	302.03	25.53	39.17	197.16	157.99	12.72	72.79	330.55	257.76	23.67
5	78.33	355.43	277.10	37.02	39.17	184.24	145.07	18.76	72.79	308.88	236.09	33.39
10	78.33	265.94	187.60	70.84	39.17	137.85	98.68	36.70	72.79	231.11	158.32	61.44
15	78.33	213.94	135.61	84.56	39.17	110.89	71.73	44.22	72.79	185.92	113.13	72.02
20	78.33	180.27	101.94	88.89	39.17	93.44	54.28	46.87	72.79	156.66	83.87	74.43
25	78.33	157.00	78.67	88.38	39.17	81.38	42.22	47.01	72.79	136.44	63.65	72.63
30	78.33	139.79	61.46	84.62	39.17	72.46	33.29	45.48	72.79	121.48	48.69	68.01
45	78.33	107.68	29.35	63.12	39.17	55.82	16.65	35.57	72.79	93.58	20.79	45.25
60	78.33	89.71	11.38	33.46	39.17	46.50	7.33	21.45	72.79	77.96	5.17	15.37
90	78.33	69.75	-8.58	-39.06	39.17	36.15	-3.01	-13.64	72.79	60.62	-12.17	-55.90
120	78.33	58.71	-19.63	-121.53	39.17	30.43	-8.74	-53.88	72.79	51.02	-21.77	-135.86
180	78.33	46.31	-32.02	-304.93	39.17	24.01	-15.16	-143.88	72.79	40.25	-32.54	-311.87
270	78.33	36.75	-41.59	-606.76	39.17	19.05	-20.12	-292.72	72.79	31.93	-40.86	-599.21
360	78.33	31.15	-47.19	-929.61	39.17	16.14	-23.02	-452.44	72.79	27.07	-45.72	-904.88
540	78.33	24.39	-53.94	-1617.00	39.17	12.64	-26.53	-793.45	72.79	21.19	-51.60	-1552.50
720	78.33	20.24	-58.09	-2339.72	39.17	10.49	-28.67	-1152.77	72.79	17.59	-55.20	-2230.87
1080	78.33	15.27	-63.06	-3842.11	39.17	7.92	-31.25	-1900.91	72.79	13.27	-59.52	-3637.16
1440	78.33	12.25	-66.08	-5390.30	39.17	6.35	-32.82	-2672.78	72.79	10.65	-62.14	-5083.24
1800	78.33	10.16	-68.17	-6965.92	39.17	5.26	-33.90	-3458.89	72.79	8.83	-63.96	-6553.11
2160	78.33	8.70	-69.63	-8550.88	39.17	4.51	-34.66	-4249.84	72.79	7.56	-65.23	-8031.12
2880	78.33	6.75	-71.58	-11742.35	39.17	3.50	-35.67	-5842.90	72.79	5.86	-66.93	-11005.84
4320	78.33	4.68	-73.66	-18160.05	39.17	2.42	-36.74	-9047.03	72.79	4.06	-68.73	-16985.56
Volume check				ok				ok				ok

D1

Storage Duration (mins)	D7				D8				D9			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	43.84	227.18	0.00	-4.94	44.50	311.17	266.67	-12.71	36.35	416.55	380.20	-35.41
2	43.84	185.34	0.00	1.90	44.50	253.87	209.36	-2.51	36.35	339.84	303.49	-20.55
3	43.84	169.81	0.00	8.02	44.50	232.59	188.09	6.76	36.35	311.36	275.01	-6.84
4	43.84	157.54	0.00	13.03	44.50	215.79	171.28	14.51	36.35	288.87	252.52	4.84
5	43.84	147.21	0.00	17.14	44.50	201.64	157.14	21.03	36.35	269.93	233.58	14.87
10	43.84	110.15	0.00	27.89	44.50	150.87	106.37	40.20	36.35	201.96	165.61	47.06
15	43.84	88.61	0.00	30.31	44.50	121.37	76.87	47.96	36.35	162.48	126.13	63.99
20	43.84	74.67	0.00	28.83	44.50	102.27	57.77	50.40	36.35	136.91	100.56	73.81
25	43.84	65.03	0.00	25.34	44.50	89.07	44.57	50.09	36.35	119.24	82.89	79.98
30	43.84	57.90	0.00	20.50	44.50	79.30	34.80	47.94	36.35	106.16	69.81	83.71
45	43.84	44.60	0.00	1.71	44.50	61.09	16.59	35.69	36.35	81.78	45.43	87.22
60	43.84	37.16	0.00	-20.52	44.50	50.89	6.39	18.80	36.35	68.13	31.78	84.65
90	43.84	28.89	0.00	-70.53	44.50	39.57	-4.93	-22.46	36.35	52.97	16.62	69.74
120	43.84	24.32	0.00	-124.74	44.50	33.30	-11.20	-69.36	36.35	44.58	8.23	47.50
180	43.84	19.18	0.00	-240.95	44.50	26.27	-18.23	-173.63	36.35	35.17	-1.18	-10.60
270	43.84	15.22	0.00	-426.56	44.50	20.85	-23.66	-345.21	36.35	27.91	-8.44	-117.49
360	43.84	12.90	0.00	-620.99	44.50	17.67	-26.83	-528.71	36.35	23.65	-12.70	-240.01
540	43.84	10.10	0.00	-1027.28	44.50	13.84	-30.67	-919.36	36.35	18.52	-17.83	-516.29
720	43.84	8.38	0.00	-1448.30	44.50	11.48	-33.02	-1330.06	36.35	15.37	-20.98	-819.17
1080	43.84	6.33	0.00	-2314.03	44.50	8.66	-35.84	-2183.77	36.35	11.60	-24.75	-1467.86

Storage Duration (mins)	E1				E2				E3			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
1	61.16	473.32	412.16	-22.98	42.16	304.79	262.63	-13.20	43.74	387.26	343.52	-23.16
2	61.16	386.16	325.00	-7.11	42.16	248.66	206.50	-3.13	43.74	315.95	272.21	-9.85
3	61.16	353.79	292.63	7.36	42.16	227.82	185.66	6.03	43.74	289.47	245.73	2.34
4	61.16	328.23	267.07	19.52	42.16	211.36	169.20	13.70	43.74	268.55	224.81	12.65
5	61.16	306.72	245.56	29.80	42.16	197.51	155.35	20.17	43.74	250.95	207.21	21.42
10	61.16	229.49	168.33	60.81	42.16	147.78	105.62	39.35	43.74	187.76	144.02	48.57
15	61.16	184.62	123.46	74.48	42.16	118.88	76.73	47.36	43.74	151.05	107.31	61.53
20	61.16	155.57	94.41	80.04	42.16	100.17	58.02	50.16	43.74	127.28	83.54	67.86
25	61.16	135.49	74.33	81.44	42.16	87.24	45.09	50.26	43.74	110.85	67.11	70.80
30	61.16	120.63	59.47	80.04	42.16	77.68	35.52	48.57	43.74	98.70	54.96	71.45
45	61.16	92.92	31.77	67.04	42.16	59.84	17.68	37.80	43.74	76.03	32.29	66.22
60	61.16	77.41	16.26	47.02	42.16	49.85	7.69	22.51	43.74	63.34	19.60	55.29
90	61.16	60.19	-0.97	-4.34	42.16	38.76	-3.40	-15.40	43.74	49.25	5.51	24.23
120	61.16	50.66	-10.50	-64.23	42.16	32.62	-9.54	-58.83	43.74	41.45	-2.29	-13.76
180	61.16	39.96	-21.19	-199.83	42.16	25.73	-16.42	-155.92	43.74	32.70	-11.04	-102.58
270	61.16	31.71	-29.45	-426.16	42.16	20.42	-21.74	-316.38	43.74	25.94	-17.79	-254.43
360	61.16	26.88	-34.28	-670.55	42.16	17.31	-24.85	-488.50	43.74	21.99	-21.75	-420.96
540	61.16	21.04	-40.11	-1195.21	42.16	13.55	-28.61	-855.89	43.74	17.22	-26.52	-783.27
720	61.16	17.47	-43.69	-1750.29	42.16	11.25	-30.91	-1242.90	43.74	14.29	-29.45	-1170.41
1080	61.16	13.18	-47.98	-2909.53	42.16	8.49	-33.67	-2048.54	43.74	10.78	-32.96	-1984.77

1440	43.84	5.07	0.00	-3198.72	44.50	6.95	-37.55	-3063.45	36.35	9.31	-27.05	-2151.35	61.16	10.57	-50.58	-4108.30	42.16	6.81	-35.35	-2879.64	43.74	8.65	-35.09	-2831.46
1800	43.84	4.21	0.00	-4094.66	44.50	5.76	-38.74	-3958.70	36.35	7.71	-28.64	-2855.99	61.16	8.77	-52.39	-5330.81	42.16	5.64	-36.51	-3726.00	43.74	7.17	-36.57	-3697.68
2160	43.84	3.60	0.00	-4994.52	44.50	4.94	-39.57	-4859.25	36.35	6.61	-29.74	-3567.56	61.16	7.51	-53.65	-6561.34	42.16	4.84	-37.32	-4577.53	43.74	6.14	-37.60	-4570.41
2880	43.84	2.79	0.00	-6803.12	44.50	3.83	-40.67	-6672.56	36.35	5.12	-31.23	-5007.22	61.16	5.82	-55.33	-9041.04	42.16	3.75	-38.41	-6292.59	43.74	4.76	-38.97	-6331.15
4320	43.84	1.94	0.00	-10434.86	44.50	2.65	-41.85	-10318.92	36.35	3.55	-32.80	-7912.52	61.16	4.04	-57.12	-14030.33	42.16	2.60	-39.56	-9742.00	43.74	3.30	-40.44	-9876.99
Volume check				ok				ok				ok				ok				ok				ok

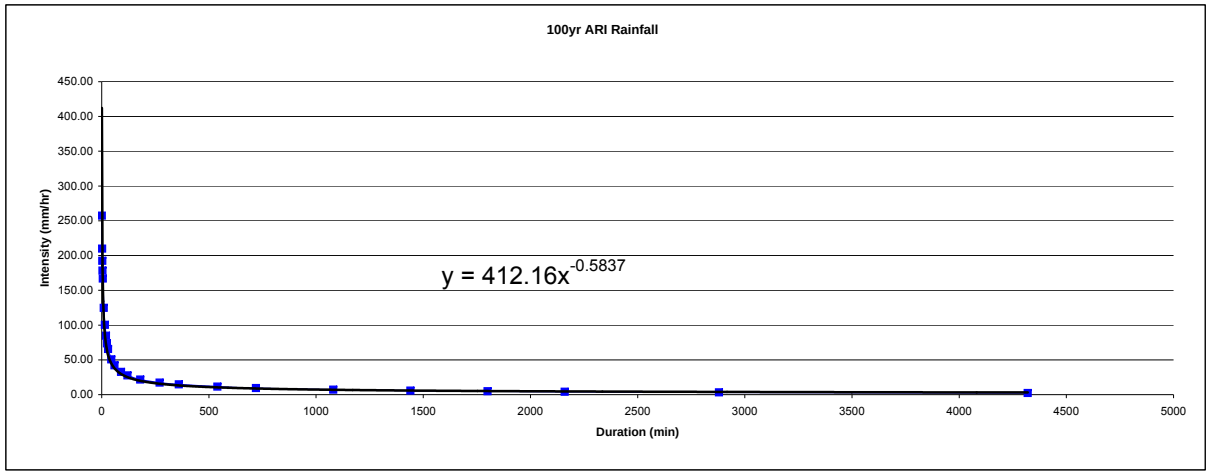
COMBINED 100 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT			CUMULATIVE EFFECTIVE AREAS (m2)		TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)
	Contibuting Segments	Contributing Lots	Road	Lots	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mIn)	Post-Dev
A1	A1,C1	2,3	7308	17000	378	61.3	59	6.08	25.0	63.0
A2	A2-A5	1,6,13-18,23N,24N	23830	69894	1162	85	59.4	22.03	52.8	40.7
A3	A3-A5	13-18,23N,24N	14843	61334	640	85	69	25.00	29.7	56.9
A4	A4,A5	14-18,23N,24N	8678	52304	496	85	70	30.24	23.4	65.5
A5	A5	18,24N	2308	14326	129	85	78	54.26	6.2	142.4
B1	B1	7-10	5486	34180	303	66	65	3.30	23.3	65.6
B2	B1,B2	7-10	11155	34180	458	66	60.8	11.35	25.6	62.1
C1	C1	4	2523	20593	148	61.3	60.2	7.43	10.5	104.7
D1	D1	19-22,23S,31	10148	18863	236	69.8	66	16.10	12.4	94.7
D2	D1-D7	11,12,19-22,23S,24S,25-32,47-52	55160	48914	1282	93	59.3	26.29	51.7	41.2
D3	D3-D7	24S,25-30,47-52	31221	125560	974	93	66.4	27.31	41.2	47.0
D4	D4,D5	49-52	11648	36422	483	93	73	41.41	20.8	70.2
D5	D5	51,52	3976	18276	243	93	88	20.58	13.4	90.7
D6	D6	47,48	6667	20352	263	87	72	57.03	11.2	100.5
D7	D4-D7	47,48	21491	20352	587	93	70.3	38.67	24.1	64.4
D8	D8	42	4352	8767	251	70	62	31.87	12.5	94.2
D9	D9	33-38	5826	57093	316	61.7	61.3	1.27	29.2	57.5
D10	D10	41,43-46	0	52451						
D11	D8,D9,D10,D11	33-46	0	109544						
E1	E1	53,54	6620	17999	273	86	81.5	16.48	14.9	85.1
E2	E2,E3	55-58	9679	35112	260	89	81.5	28.85	12.2	95.5
E3	E3		5416	0	319	93	89	12.54	18.8	74.4

Runoff Coefficients	Pre-Dev	Post-Dev
Roads	0.35	0.85
Swales/Basins	0.35	0
Lots	0.35	0
OS	0.35	0

Rainfall IFD

Event	Duration (mins)	Intensity (mm/hr)
1 min	1	257.40
2 min	2	210.00
3 min	3	192.40
4 min	4	178.50
5 min	5	166.80
10 min	10	124.80
15 min	15	100.40
20 min	20	84.60
25 min	25	73.68
30 min	30	65.60
45 min	45	50.53
1 hr	60	42.10
1.5 hr	90	32.73
2 hr	120	27.55
3 hr	180	21.73
4.5 hr	270	17.24
6 hr	360	14.62
9 hr	540	11.44
12 hr	720	9.50
18 hr	1080	7.17
24 hr	1440	5.75
30 hr	1800	4.77
36 hr	2160	4.08
48 hr	2880	3.17
72 hr	4320	2.19



COMBINED 100 YEAR ARI FLOWS

Segment	Contributing Segments	Contributing Lots	Segment Cum Peak Flow (L/s)	Lots Cum Peak Flow (L/s)	Total Cum Peak Flow (L/s)	Long Slope	Height in Channel (m) (Fang)	Height Over Weir (m)
A1	A1,C1	2,3	72.39	252.05	324.44	0.0054	0.48	0.21
A2	A2-A5	1,6,13-18,23N,24N	218.75	1217.97	1436.72	0.0202	0.70	0.33
A3	A3-A5	13-18,23N,24N	159.30	922.52	1081.82	0.0021	0.75	0.47
A4	A4,A5	14-18,23N,24N	86.73	778.75	865.48	0.0221	0.55	0.21
A5	A5	18,24N	35.69	221.18	256.86	0.0522	0.25	0.09
B1	B1	7-10	85.90	503.29	589.19	0.0063	0.61	0.24
B2	B1,B2	7-10	137.05	503.29	640.34	0.0204	0.49	0.18
C1	C1	4	28.70	273.48	302.18	0.0033	0.52	0.20
D1	D1	19-22,23S,31	104.36	775.07	879.43	0.0122	0.63	0.25
D2	D1-D7	11,12,19-22,23S,24S,25-32,47-52	538.79	3508.57	4047.36	0.0223	0.80	0.50
D3	D3-D7	24S,25-30,47-52	307.86	1991.56	2299.42	0.0091	1.02	0.47
D4	D4,D5	49-52	117.50	601.98	719.47	0.0631	0.39	0.14
D5	D5	51,52	39.17	296.98	336.14	0.0321	0.32	0.13
D6	D6	47,48	72.79	325.04	397.83	0.0504	0.31	0.12
D7	D4-D7	47-52	234.13	927.01	1161.14	0.0211	0.63	0.25
D8	D8	42	44.50	137.93	182.43	0.0294	0.24	0.09
D9	D9	33-38	36.35	826.93	863.28	0.0003	1.38	0.64
D10	D10	41, 43-46		776.97	776.97	0.0384	0.63	
D11	D8,D9,D10,D11	33-46		2049.20	2049.20	0.0093	0.57	
E1	E1	53,54	61.16	274.86	336.02	0.0205	0.36	0.13
E2	E2,E3	55-58	42.16	574.60	616.76	0.0282	0.44	0.17
E3	E3		43.74		43.74	0.0162	0.13	0.07