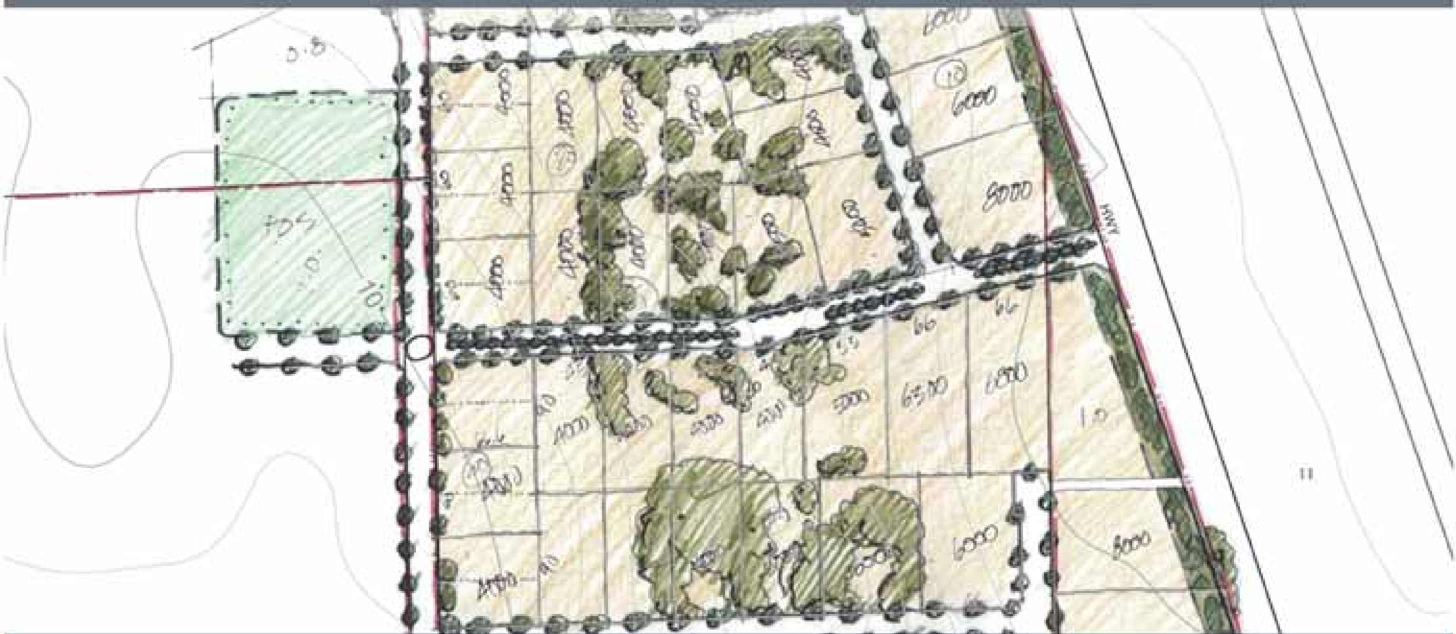
# LOCAL STRUCTURE PLAN



Lots 4, 5 and 10 Brand Highway, Bonniefield
Dongara

March 2015

CLE
TOWN PLANNING + DESIGN

# LOTS 4, 5 AND 10 BRAND HIGHWAY,

# BONNIEFIELD, DONGARA

## LOCAL STRUCTURE PLAN

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2172Rep87H

March 2015

(inc WAPC Modifications)

**ENDORSEMENT PAGE**

This structure plan is prepared under the provisions of the Shire of Irwin Local Planning Scheme No. 3.

IT IS CERTIFIED THAT THIS STRUCTURE PLAN WAS APPROVED BY RESOLUTION OF THE WESTERN AUSTRALIAN PLANNING COMMISSION ON:

**20 February 2015**

In accordance with Schedule 2, Part 4, Clause 28 (2) and refer to Part 1, 2. (b) of the *Planning and Development (Local Planning Schemes) Regulations 2015.*

Date of Expiry: **19 October 2035**

## TABLE OF MODIFICATIONS TO PART 1 AND STRUCTURE PLAN MAP

| Modification No. | Description of Modification | Date endorsed by Council | Date endorsed by WAPC |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

## EXECUTIVE SUMMARY

### Location of the Structure Plan Area

The structure plan area is approximately 3km north of the Dongara town centre within the suburb of Bonniefield. It is located immediately west of Brand Highway, and is approximately 1.5km from the ocean to the west.

### Land uses proposed by the Structure Plan

The structure plan proposes development of the site for residential purposes, supported by a public open space. It has been designed to fit into the larger development area identified within the Dongara District Structure Plan.

### Relationship to the Local Planning Scheme

The structure plan has been prepared under Clause 5.35 of the Shire of Irwin's Local Planning Scheme No. 5.

| Item | Data | Section Number Referenced within the Structure Plan Report |
|---|---|---|
| Total area covered by the structure plan | 59.2ha | 1.2 |
| Area of specific land uses | | 3.1 |
| Residential | 52.34ha | 3.4 |
| Commercial | - | |
| Industrial | - | |
| Public Open Space | 6.86ha (gross) | 3.3 |
| Estimated lot yield | 85 | 3.4 |
| Estimated number of dwellings | 85 | 3.4 |
| Estimated population (du x 2.6) | 221 people | |
| Number of high schools | - | 3.7 |
| Number of primary schools | - | 3.7 |
| Estimated commercial floorspace (NLA) | - | 3.8 |
| Estimated employment provided | - | 3.8 |
| Estimated number and % of public open space | | 3.3 |
| Regional Open Space | - | |
| District Open Space | - | |
| Estimated area and number | | 3.3 |
| Neighbourhood parks | 1.99ha (gross)<br>1 park (A) | |
| Local Parks | 4.87ha (gross)<br>3 parks B, C & D) | |

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## PART ONE

### 1. STRUCTURE PLAN AREA

This Structure Plan shall apply to Lots 4, 5 and 10 Brand Highway, Bonniefield being the land contained within the inner edge of the broken black line shown on the Structure Plan Map.

### 2. STRUCTURE PLAN CONTENT

This Structure Plan comprises the:

a) Statutory section (Part One);
b) Explanatory section (Part Two); and
c) Appendices to Part Two – Technical reports.

Part One includes the Structure Plan Map and provisions which require statutory effect.

Part Two (and its appendices) justifies and explains the provisions contained in Part 1, and should be used as a reference guide to interpret and implement Part 1. It does not hold statutory effect.

### 3. INTERPRETATIONS AND SCHEME RELATIONSHIP

This Structure Plan has been prepared under Clause 5.35.6 of the Shire of Irwin Local Planning Scheme No.5 ('the Scheme').

The words and expressions used in this part of the Structure Plan shall have the respective meanings given to them in the Scheme.

Land use permissibility for each zone within the Structure Plan shall be in accordance with the Scheme, except as specifically varied by this structure plan.

The provisions, standards and requirements specified under Part One of this Structure Plan shall have the same force and effect as if it were a provision, standard or requirement of the Scheme.

In accordance with sub-clause 5.35.12.2 of the Scheme, in the event of there being any inconsistencies or conflict between the provisions of the Scheme and the provisions of this Structure Plan, then the provisions of the Scheme shall prevail to the extent of the inconsistency.

Part Two of this Structure Plan and the Technical Appendices are to be used as a reference only to clarify and guide interpretation and implementation of Part One.

## 4. OPERATION

In accordance with the sub-clause 5.35.12.1 of the Scheme, this Structure Plan shall come into operation when it is endorsed by the Commission pursuant to sub-clause 5.35.12.1 (a).

## 5. LAND USE AND SUBDIVISION REQUIREMENTS

Subdivision and development shall be generally in accordance with the Structure Plan Map.

### 5.1 Public Open Space

Public open space will be provided in accordance with the WAPC's Liveable Neighbourhoods. Public open space is to be provided generally in accordance with the Structure Plan Map and Table 1.

| POS Site | Size (approximate) - Ha |
|---|---|
| A | 1.99 |
| B | 1.96 |
| C | 0.83 |
| D – Total (Restricted) | 2.07 |
| D - North | 0.91 |
| D - South | 1.16 |

### 5.2 Boulevard Entry Road

Prior to the creation of any lot in excess of 20 lots within the Structure Plan area, the Boulevard Entry Road access from Brand Highway shall be provided and / or upgraded by the developer to the specification of the WAPC, on the advice of Main Roads WA.

The Boulevard Entry Road shall be provided with a road reserve of 27m in order to accommodate a landscaped central median swale to capture stormwater and manage potential future traffic. The precise road layout and treatment of the verges and median shall be determined as a condition of subdivision in consultation with the Shire of Irwin.

### 5.3 Local Development Plans

At the time of subdivision, conditions may be recommended requiring the preparation of Local Development Plans which:

- Restrict access to the Boulevard Entry Road from abutting lots by limiting access points and requiring the placement and design of parking areas to allow vehicles to return to the street in forward gear; and
- Mitigate against noise received from Brand Highway through building placement and/or design controls on lots within, or with a portion within, 48m of Brand

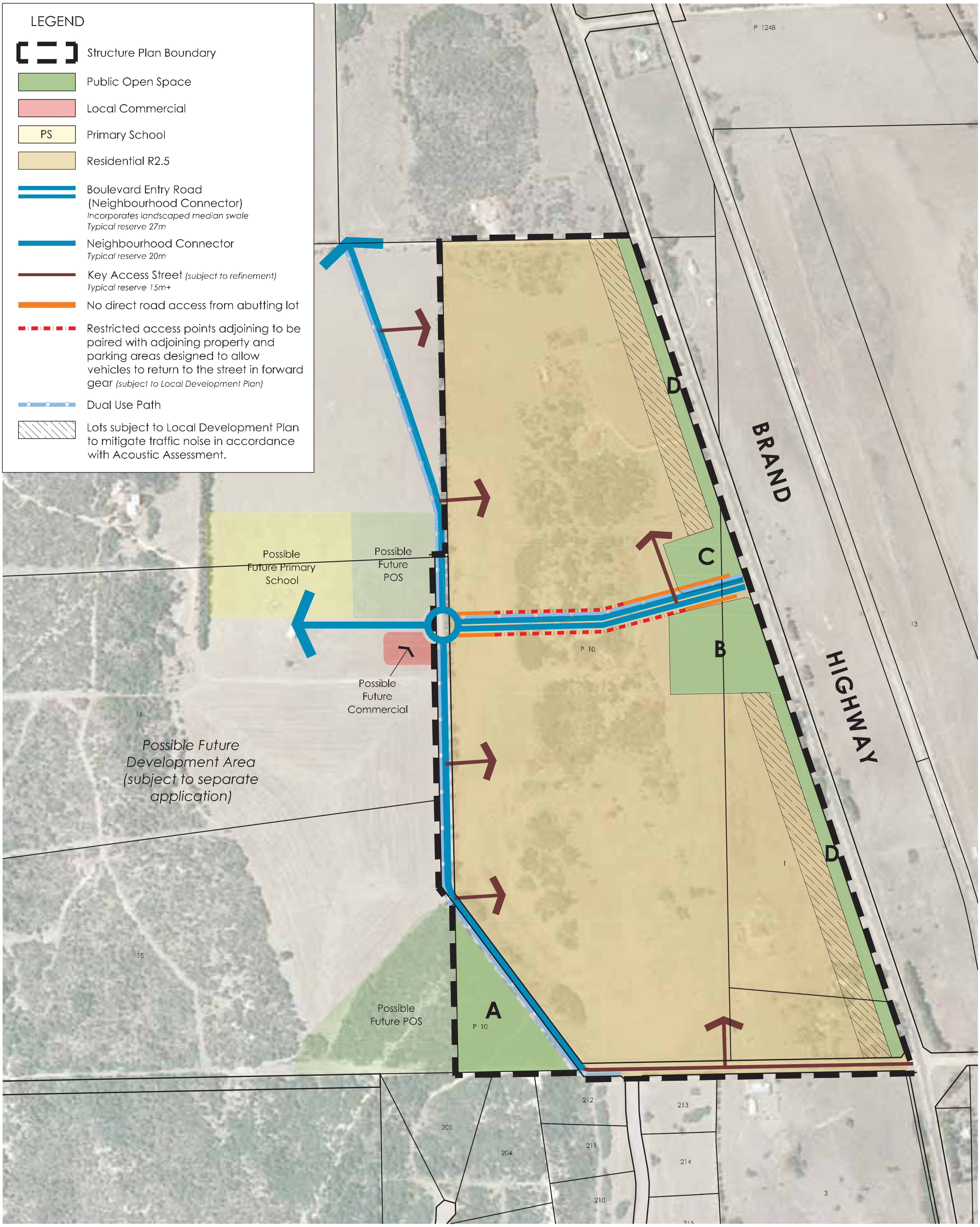
Highway in accordance with the Acoustic Assessment undertaken for the Structure Plan Area.

### 5.4 Pedestrian and Cyclist Infrastructure

As a condition of subdivision, the developer will provide dual use paths in accordance with the Structure Plan in addition to footpaths within the internal road network.

## 6. DEVELOPMENT REQUIREMENTS

Development of lots abutting or immediately opposite the triangular public open space ‘A’ in the south-west corner of the structure plan area are to be subject to Australian Standards ASA 3959-2009 ("Construction of Houses in Bushfire-prone Areas”) and all lots are to be provided with a 20m Bushfire Protection Zone to any habitable building.




LOCAL STRUCTURE PLAN

Francisco Road, Dongara

**PART TWO**

# 1.0 PLANNING BACKGROUND

## 1.1 Introduction and Purpose

This Local Structure Plan (LSP) has been prepared on behalf of the owners of Lots 4, 5 and 10, Brand Highway, Bonniefield, and is lodged with the Shire of Irwin pursuant to clause 5.35.4 of the Scheme. The purpose of this LSP is to guide the subdivision and development of the subject area in a coordinated fashion. Development of the LSP area will assist in providing for the anticipated demand for residential lots within Dongara-Port Denison in an integrated and sustainable manner. The urban expansion that the LSP facilitates will support coordinated and ongoing growth as envisaged by the Shire of Irwin's *Strategic Community Plan 2012 – 2013.*

The LSP draws on the current strategic planning framework, and refines the level of detail in order to ensure that relevant environmental, social, economic and infrastructure issues are addressed, and that a clear and robust statutory framework is provided to enable subdivision and development of the structure plan area. The timeframe for the subdivision and development of the LSP area will be guided by land sales and market demand, anticipated to run over the course of the next 5 – 10 years.

Preparation of this LSP and the Development Concept from which it has been developed has involved consultation with the Shire of Irwin, Department of Planning, Main Roads WA, environmental agencies and relevant service authorities. The consultation early on in the process has ensured that the LSP addresses all matters raised by the various agencies prior to lodgement.

## 1.2 Land Description

### *1.2.1 Location*

The LSP area is located immediately north of the Dongara townsite, within the suburb of Bonniefield. It is bounded by Francisco Road to the south, Brand Highway to the east, existing farming land to the north, and existing farming land to the west, which abuts foreshore reserves and the Indian Ocean. The LSP area is approximately 3km north of the Dongara town centre and 1.5km from the ocean.

A location plan showing the LSP area within the broader district context is provided at Figure 1.

### *1.2.2 Area and Land Use*

The LSP area is approximately 59ha in total, and comprises 3 freehold lots. The majority of the land is used for farming, and a child care centre is understood to operate from the dwelling at Lot 4. A detailed site plan and orthophoto is Figure 2.

#### *1.2.3 Legal Description and Ownership*

The LSP area includes all of Lots 4, 5 and 10 Brand Highway. All three land parcels are privately owned, with the owners of Lot 10 the principal proponents of this plan. Table 1 provides the legal description and ownership of the subject land.

**Table 1 – Land Ownership and Legal Description**

| Lot No | Certificate of Title* | Owner | Area (ha) |
|---|---|---|---|
| 4 | 2046-796 | Paul Bender & Brenda Kretschmer-Bender | 2.4 |
| 5 | 2046-797 | Gary & Jose Norrish | 8.6 |
| 10 | 2072-286 | Lundy Pty Ltd & Texas Property Development Pty Ltd | 48.2 |
| **Total** | | | **59.2** |

* Refer Appendix 1

### 1.3 Planning Framework

#### *1.3.1 Zoning and Reservations*

The site was recently rezoned to 'Development' under the Shire of Irwin's Local Planning Scheme No 5 (LPS5) via Amendment 15, which was prepared by the proponents of this proposal.

The purpose of the 'Development' zone is to provide for the comprehensive planning and coordinated subdivision and development of land, in accordance with an approved structure plan.

Land to the north, east and west is zoned 'General Farming'. The Race Course estate to the south is zoned 'Rural Residential', and is largely developed for this purpose, with the areas immediately south and west of this being zoned 'Residential'.

Brand Highway, abutting the LSP area to the east, is reserved for 'Major Road or Highway'.

The coastal corridor to the west forms a Local Reserve, whilst Reserve 23600, a 50ha (approximately) block of land diagonally south-west of the site is reserved for conservation.

A plan depicting the current zonings under LSP5 is provided at Figure 3.

### *1.3.2 Regional and Sub-Regional Structure Plan*

The Shire commissioned a District Structure Plan (DSP) for the Dongara – Port Denison area which received final endorsement by the Western Australian Planning Commission in 2014 (refer Figure 4). This identifies the LSP land and the adjoining land to the west as '*Future Urban / Residential'* and more specifically, as the 'Francisco Road North Precinct'. This reflects the stated intentions of the landowners. In relation to this LSP area, the DSP acknowledges that it is likely to be developed in the short to mid-term for low density residential purposes with future development including a neighbourhood centre and public purpose reserve (a primary school) shown immediately to the west of the LSP area, within the heart of the development precinct. The proposed LSP is consistent with the provisions of the DSP and will serve as a catalyst for the future development of the land identified within the 'Francisco Road North Precinct' in accordance with the provisions of the plan.

Adjoining land to the south is also identified for future urban development, with land to the north of the LSP area indicated as future 'Rural Living'.

### *1.3.3 Planning Strategies*

A number of planning strategies apply to the region, though with limited direct implications for the site. The WAPC's draft Mid West Regional Planning and Infrastructure Framework 2011, for example, recognises Dongara's role as a regional centre, and acknowledges and responds to the high level of activity in the region which supports growth of such centres and hence their residential expansion.

More pertinently, the Shire's draft Local Planning Strategy identifies specific areas for urban expansion of the town, including a growth precinct running up to the boundary of this site (Policy Area B). The rezoning proposal for the site successfully demonstrated the rationale for incorporating the LSP area within area B and supporting its urban development as part of the town's growth strategy. This position is reinforced through its identification in the subsequently prepared District Structure Plan for the town.

As has been noted above, the Shire's Strategic Community Plan 2012-2022 identifies the need for future urban land to accommodated planned growth of the Dongara - Port Denison towns.

### *1.3.4 Policies*

A number of state planning policies and guidelines are relevant to the LSP, including the WAPC's:

- Liveable Neighbourhoods (Edition 3, 2007);

- State Planning Policy 5.4 – Road and Rail Transport Noise;
- Draft State Planning Policy 3.7 – Planning for Bushfire Risk Management;
- Development Control Policy 2.3 - Public Open Space in Residential Areas;
- Planning for Bush Fire Protection Guidelines (Edition 2, 2010);
- Better Urban Water Management Guidelines (2008) and the Department of Water's Best Practice Stormwater Management for WA document; and
- Structure Plan Preparation Guidelines (2012).

The structure plan and its supporting documents respond to and generally accord with the provisions and principles of these operational policies and guidelines, as discussed further in Part 3 of this report.

In particular, the design of the plan and associated Development Concept reflect the 'new urbanist' design principles underpinning Liveable Neighbourhoods through:

- Consolidating development in an accessible and amenable location, with good access to services, employment and amenities;
- Structuring development upon a 'modified grid' road layout which facilitates ease of movement, choice of routes, legibility and good access for all modes of transport;
- Planned provision of local services, within the next phase of the development, to supplement those already available within 3km, in the town;
- Provision of local open space, providing for both local amenity and environmental conservation; and
- Integration of storm water management within the design, allowing disposal at or close to source, utilisation of run-off to support green spaces, and sustainable water practices.

### *1.3.5 Other Approvals and Decisions*

In considering broader issues relating to Dongara, the WAPC in 2011 identified the subject site (and 145ha of adjoining land to the west) as suitable for urban development. This has been reflected in the Shire's draft DSP as the Francisco Road North Precinct.

The original rezoning proposal for the subject site incorporated this larger area, much of which is within the same ownership as the majority of the subject site. A consolidated urban residential development of up 1500-2000 lots was envisaged, as conceptually illustrated in Figure 5, to be progressively developed over the longer term. In considering this proposal at a number of briefing sessions in 2012, a number of Councillors present expressed concern at both the extent of the development site, and the residential density on the periphery of town. For this reason, the amendment area was modified to restrict it to the subject site, and the notional layout amended to accommodate larger lots which might eventually integrate into a more urban residential area to the west. This discussion process did not involve a formal decision by Council but very much affected the extent and form of the development concept which secured Council's support for the rezoning, and forms the basis of this proposal.

Future development of land to the west of the site cannot be assumed by the proposal, as it requires additional statutory decisions and processes, however it should be accommodated and planned for, to allow it to occur in an integrated fashion, if and when this land is rezoned.

## 2.0 SITE CONDITIONS AND CONSTRAINTS (SITE ANALYSIS)

A summary of opportunities and constraints presented by the site is shown graphically in Figure 6 – Site Analysis. Its attributes are further discussed below.

### 2.1 Biodiversity and Natural Area Assets

The majority of the site is cleared. Environmental investigations were undertaken as part of the LPS5 amendment process to rezone the land and prior investigations leading up to this incorporating the land to the west of the site. Based on this analysis, the Environmental Protection Authority (EPA) resolved to not formally assess the rezoning proposal, on the basis that development of the amendment area would not have any significant environmental implications. A copy of the EPA's formal advice is Appendix 2, and positively notes the proposed retention of remnant vegetation in the south-west corner of the site.

The findings of the environmental investigations are documented in Appendices 3 and 4 to this report. These apply to the broader area then under review, and are summarised as follows:

- The flora and vegetation represents a low species richness associated with the Quindalup dune, largely due to the poor condition of the site;
- No Threatened (Declared Rare) or Priority Listed flora species were found;
- Four separate Vegetation Associations were identified on the site, (refer Figure 7) as follows:
  - Ar *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub: main vegetation type on site, ranging from 2 – 5m tall, standing typically on the lee side of the dunes and in the valleys. Sparsely vegetated understorey with extensive weed, most Ar areas have been classed 'Good' or 'Degraded' with the exception of one 'Very Good' area in the south west corner of the site;
  - ArAh *Acacia rostellifera / Alyogne hueglii* Open Heath: A narrow strip of this vegetation type occurred on the top of the eastern ridge of the dunes on Lots 15 and 16 as well as a degraded part on the eastern side of Lot 1409. Overall, the vegetation type was dominated by weeds but was classified as being in Good condition;
  - MlAr *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland: This vegetation type occurs in two stands, one of around 5ha at the northern end of Lot 17 and a smaller one at the north-east corner of Lot 1409. Their conditions were assessed to be Very Good and Degraded, respectively. The larger area contained 13 specifies of which 10 were native;
  - EoAr *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub: A very small stand of EoAr occurred on the south east end of Lot 15 and was assessed to be in 'Good' condition although the quadrant contained only 2 of 7 species which were native.

- Overall, remnant vegetation condition is mainly 'Good' showing evidence of grazing and a dominance of weeds in the understorey, but with some pockets of vegetation in 'Very Good' condition;
- The dominant vegetation type *Acacia rostellifera* belongs to Beard's Vegetation Community 431 of which 73.76% of its original extent of 4,460ha remains (Ecoscape, 2011 and WAPC, 2010 quoted in PGV Environmental, 2011). The reserved proportion is far lower at less than 1% however includes the 50ha Conservation Reserve 23600 abutting the southern boundary of the site. Given the extent and better condition of the Ar in the adjoining Reserve 23600, the vegetation of the subject site is not considered to have regional significance;
- The vegetation types attributed to the site under the Dongara to Cape Burney Coastal Vegetation Survey similarly suggest that it holds no regional significance;
- The *Acacia rostellifera* community is not considered to hold local significance, but the limited extent of *Melaleuca lanceolata* (Lot 17) suggests it may have some local significance. A portion of the 5ha 'Very Good' condition area of this vegetation type in the north of the site is therefore recommended within the public open space network proposed;
- The *Eucalyptus obtusiflora* in Lot 15 could also be considered to hold local significance given its rarity in the area. This area is also suggested for retention within open space, recognising that it is a very small area and in poor condition.

In terms of Fauna:

- There are four habitats on the site;
- The vegetated areas of Lots 10 (south west corner), 15, 16 and 17 is considered to be Good Fauna Habitat. The remainder of the site is considered to be Disturbed or Highly Degraded Fauna Habitat;
  - Of the conservation significant species identified through a review of relevant government databases, only one, the carpet python, is known to occur on the site, with four others (Peregrine Falcon, Fork-tailed Swift, Cattle Egret and Rainbow Bee-eater identified as potentially visiting the site. Of these latter species, only the Rainbow Bee-eater is considered likely to utilise the habitat of the site (rather than temporarily visit);
- It is considered highly unlikely that development of the site will cause a significant impact on any fauna species of conservation significance "*due to the low usage potential of the site by a few species and the presence of similar habitat in adjoining reserves and the wider Dongara area*" (p15-16, PGV, 2012).

Whilst much of the (reduced) area the subject of this LSP was not included in the detailed surveys, it was included in the broader Dongara to Cape Burney Coastal Vegetation Survey prepared by Ecoscape for the Northern Agricultural Catchment Council in 2010. This mapped vegetation on the site is as follows:

- Vegetation condition: Degraded;

- Vegetation type: Unit 7 (as occurs on most of the remainder of the larger site area surveyed by PGV Environmental). Both Ecoscape and PGV concluded that this vegetation unit does not have any local or regional significance.

Given these conclusions and the fact that the majority of the site the subject of this Structure Plan is cleared, no environmental objection has been raised to its development, though retention of the vegetation in the south west corner of the site has been supported by all parties. This reflects a positive environmental outcome, reducing the need for land-clearing to accommodate urban growth of the town, and allowing for consolidation of residential areas within 3km of the town centre, and within walking / cycling distance of the beach.

## 2.2 Landform and Soils

A Land Capability and Geotechnical Assessment was undertaken by Landform in 2005 (refer Appendix 5). This assessment supports the suitability of the site for the form of development proposed. The assessment described soils on the site as follows:

- The western Quindalup Dune soils are relatively old and therefore contain a brown to cream brown sand with minor clay and calcareous materials;
- Eastern Tamala limestone soils (more prevalent in the rezoning area) are brown sands grading to earthy sands overlying limestone at variable depth;
- The coastal nature of the older Quindalup dunes makes them less susceptible to erosion than the younger phase Quindalup dunes. (Landform Research (2005) summarised in PGV Environmental, 2011)

The Landform report further notes that:

- The only areas of likely instability are the two high ridges in the south of the area;
- In general, the nature of the sands on the site is porous and permeability high;
- Some small amounts of clay may be present, but in general this gets washed down to lower levels of the soil profile; and
- A wind erosion risk exists if vegetation is removed and the soils are exposed to the wind.

This assessment supports the suitability of the site for the form of development proposed, and suggests excellent capacity for sustainable storm water management practices, including at-source disposal, and integration of stormwater swales for more severe events within public open space. More detailed geotechnical investigations will be required to support subdivision. Staged clearing and development, and its management during the development process, and the retention of the dune peak in the south should assist in addressing the erosion risk identified.

## 2.3 Groundwater and Surface Water

There are no surface water features such as creeklines, drainage lines or wetlands on the site.

PGV Environmental further noted that "*Groundwater occurs under the site at an average level of around 2m AHD (Landform Research, 2005) indicating a minimum depth to groundwater of around 10m*" (PGV Environmental, 2011). Ground water quality is noted in the Landform report as being suitable for stock, but not for horticulture. This conclusion was supported by the Local Water Management Strategy prepared for the site, discussed below.

## 2.4 Bushfire Hazard

A Bushfire Management Plan has been prepared for the site by York Gum Services (refer Appendix 6) which assesses the site and proposes a management framework for bushfire risk in accordance with draft State Planning Policy 3.7. This recognises that the cleared nature of much of the site and adjoining properties, and the management already in place moderates bushfire risk. It is generally supportive of the layout proposed in the Development Concept (provided at Figure 8) and applies a BAL rating of 19 to lots facing the proposed triangular public open space in the south (which has remnant vegetation) based on the type of vegetation within the open space, the separation provided by Francisco Road and the setback normally applied to dwellings on lots coded R2.5. It recommends that these lots be subject to Australian Standards ASA 3959-2009 ("Construction of Houses in Bushfire-prone Areas") and be provided with a 20m Bushfire Protection Zone defined as follows:

- width: 20 metres measured from any external wall of the building;
- location: within the boundaries of the lot on which the building is situated, unless this zone overlaps with a BPZ on an adjoining property or within a road reserve;
- fuel load: reduced to and maintained at 2 tonnes per hectare;
- any trees planted within the BPZ to be a minimum of 10 metres apart and trees low pruned at least to a height of 2 metres;
- no native scrub to be located within 2 metres of a building (including windows) and no tree crowns overhanging the building;
- fences and sheds within the BPZ constructed using non-combustible materials (e.g. Colorbond iron, brick, limestone);
- shrubs in the BPZ have no dead material within the plant and tall shrubs in the BPZ are not planted in clumps close to the building i.e. within 3 metres.

A standard requirement for installation of fire hydrants plus the provision of bushfire risk and management to lot purchasers represent other key recommendations.

## 2.5 Heritage

A search of the Department of Aboriginal Affairs website shows no registered sites within the LSP area.

The LSP area is not known to contain places of either state or local heritage significance, with no portion listed on either the State Register or the Shire's Municipal Inventory of Heritage Places.

## 2.6 Coast and Foreshores

The LSP area does not abut the coastal reserve, and is located approximately 1.5km from the shoreline of the Indian Ocean. As and when rezoning and development occur to the west of the site, formalisation of access to the beach and management of the foreshore (through development and implementation of an approved Foreshore Management Plan) would be required as part of the planning process for the abutting area.

## 2.7 Context Analysis

The contextual opportunities and constraints presented by the site have been reviewed with the key ones incorporated into Figure 9. The context analysis has concluded that:

- Development of the LSP area represents a northern extension to the townsite, extending the general form of the Racecourse Estate across Francisco Road, albeit at slightly higher density;
- The LSP area has good access to the regional road network, although access to Brand Highway will require consideration of sight lines and road safety;
- Francisco Road and Brennand Road to the south of the site provide secondary access points. It is understood that some concerns exist as to the operation of the existing Francisco Road – Brand Highway intersection, and that modification to this or its closure have been touted as possibilities. In the event that this occurs, the access available directly from Brand Highway, and through Brennand Road remain quite sufficient;
- The LSP area has good access to both the Dongara town centre (3km to the south) and Geraldton (65km to the north), providing for a range of retail, service, community, recreation and employment opportunities;
- Whilst the proposal works well in isolation, longer term development of the areas to the west and north of the site has been provided for, with a notional concept for this provided in Figure 5. In the interim, the land to the west and north contains small rural landholdings which are principally used for grazing. The limited interface to the north restricts impact, as do the larger lot sizes proposed and the road alignment along most of the western boundary;
- There are opportunities to recognise and integrate existing landform within key areas of open space – particularly in the south western corner of the LSP area;

- Where fire protection and civil engineering requirements allow, mature vegetation can be retained within road reserves and private lots, as well as within public open space;
- Soil types and depth to groundwater provide opportunities for on-site infiltration, minimising the requirement for overland or piped conveyance of stormwater and providing for more sustainable water management.

Additional, more localised provision for retail and commercial services is planned within a future small scale Neighbourhood / Local Centre immediately to the west of the LSP site, proposed as part of the broader area planning and reflected within the draft DSP for Dongara - Port Denison. Its notional location will place it within the centre of the estate, with good road connections to it, maximising its accessibility. Co-location with a future primary school should support its function and facilitate shared trips. This will provide local services and schools within about 800m of each lot within the LSP area. In the interim, the 3km distance into Dongara town centre is considered to provide very good accessibility to goods and services for future residents, particularly within the context of a regional town where critical mass and urban densities are developing. This is reflected within the DSP which acknowledges that the 'catchment radius' recommended by Liveable Neighbourhoods is not appropriate in subdivisions where large lots are proposed.

## 2.8 Noise

A transport noise assessment (Acoustic Assessment) of the structure plan area was undertaken in accordance with State Planning Policy 5.4 – Road and Rail Transport Noise (refer Appendix 7). This sought to define the noise impacts associated with Brand Highway on the development, and mitigation measures which might be required to achieve compliance with the Policy. The study concluded that in order to achieve compliance with the criteria stipulated by the Policy, a minimum 48m separation from Brand Highway (measured from the nearest kerb line) would be required. The eastern most line of dwellings parallel to Brand Highway (ie in closest proximity to the noise source) should also be made subject to Quiet House design guidelines (package A) and may warrant placement of Notifications on Title. Any dwellings within 48m of Brand Highway is likely to require application of more stringent Quiet House design guidelines (package B) unless otherwise demonstrated by a more detailed noise assessment. These recommendations are provided for within Part One of the Structure Plan through provision for a Local Development Plan/s to specify applicable design requirements for affected lots.

## 3.0 LAND USE AND SUBDIVISION REQUIREMENTS (INCLUDING DESIGN RATIONALE)

### 3.1 Land Use

The Structure Plan proposes residential development of the site at low (R2.5) densities, whilst maintaining the ability to increase densities (particularly along the western boundary) in the future, if and when sewer is extended to the site. This might occur in conjunction with future urban development anticipated west of the site, as envisaged by the Overall (Long Term Potential) Local Structure Plan Concept and reflected in the 'Francisco Road North Precinct' section of the draft DSP for Dongara – Port Denison.

This residential zoning facilitates expansion of the townsite and, based on the current Concept, provides for approximately 85 additional lots of between 1.5ha and 4000m$^2$. The precise number of lots and their sizes will be determined at subdivision stage, however the minimum lot sizes stipulated by the Residential Design Codes for R2.5 (4000m$^2$) will apply.

By designating the land as a 'Residential' zone, the limited non-residential uses permissible in this zone under the Scheme also apply, allowing the operation of home based businesses, subject to Council approval.

Development of a commercial facility within the LSP area is not viable given its scale and proximity to Dongara town centre, however a future facility is proposed abutting the LSP area within future stages of development, should these be supported.

### 3.2 Integration with Surrounding Land

The location of the site means that it will provide a logical extension to the existing townsite. Larger lots within the rezoning area have been proposed to provide a transition in density and built form from the existing Rural Residential to the south, and along Brand Highway (which is still largely rural in nature at this location currently) to the (potential) remainder of the estate area, which maintains long-term urban potential. Longer term, this will also provide a visual transition from future urban development to the south up to future rural living to the north (based on the draft District Structure Plan recommendations).

Some landscape screening between Brand Highway and the development is also proposed in the form of a vegetated open space strip of 20m. Fencing controls may be appropriate in some locations (eg along the northern boundary) to address the relationship between land uses, and manage visual impact.

Interconnection with the existing street network to the south is provided for, to accommodate connectivity of neighbourhoods and a secondary route into town. Future connections to the north and west are provided for to maintain the option for future longer term development of the neighbouring sites.

### 3.3 Open Space (Parkland Provision and Management)

The topography and visual prominence of the dune on the south-west corner of the site, and its covering of remnant vegetation have prompted its retention within the plan as a park, along with a proposed future adjoining area in the possible future urban area to the west (this area is outside the LSP area by virtue of its location on a separate lot). This site is proposed as POS 'A' on the Local Structure Plan map. It will provide more natural open space, though offers opportunities for pathways, some grassed areas and other such minor improvements.

A linear strip (20m wide) of open space is proposed along Brand Highway (POS 'D') to provide screening to the highway, reducing noise and visual impact to the residential areas, and supporting at-source disposal of stormwater. Integration of a pathway and retention of some remnant trees may be possible within this area, as part of the POS treatment to be undertaken in accordance with Liveable Neighbourhoods.

Two local parks on either side of the new Boulevard Entry Road totaling 2.79ha between them are proposed to provide more conventional local park land, as well as an attractive entry into the estate. These are shown as POS 'B' and 'C' on the Local Structure Plan map, and achieve the 10% creditable public open space policy requirement which is the default position of Liveable Neighbourhoods. A breakdown of POS allocation is provided in Table 1 below:

**Table 2 – Public Opens Space Schedule (Indicative)**

| Public Open Space Schedule (Indicative)<br>Lots 4, 5 and 10 Brand Hwy Dongara Local Structure Plan<br>(Plan 2172-88D-01)<br>January 2015 | | | | |
|---|---|---|---|---|
| | Area in Hectares (Ha.) | | | |
| | Items | Sub Total | Total | % of GSA |
| **Site Area** | | | | |
| **Less** | | | 59.20 | |
| Environmental Protection Area | 0.00 | | | |
| Regional Reservations | 0.00 | | | |
| Foreshore Reserves to be Ceded | 0.00 | | | |
| **Total** | | 0.00 | 0.00 | |
| **Net Site Area** | | | 59.20 | |
| | | | | |
| **Deductions** | | | | |
| Primary School | 0.00 | | | |
| Commercial | 0.00 | | | |
| Dedicated drainage reserve | 0.00 | | | |
| **Total** | | 0.00 | | |
| **Gross Subdivisible Area (GSA)** | | | 59.20 | |
| **Public Open Space @ 10%** | | | 5.92 | 10.00 |
| **Public Open Space Contribution** | | | | |
| May Comprise: | | | | |
| Minimum 80% unrestricted POS | | 4.74 | | |
| Maximum 20% restricted POS | | 1.18 | | |
| Unrestricted Public Open Space | | | | |
| Triangular POS | 1.99 | | | |
| Local POS south of Bvd Entry Road | 1.96 | | | |
| Local POS north of Bvd Entry Road | 0.83 | | | |
| Total Unrestricted POS | | 4.79 | | 8.10 |
| Restricted POS | | | | |
| Linear POS abutting Brand Hwy north | 0.91 | | | |
| Linear POS abutting Brand Hwy south | 1.16 | | | |
| Total Restricted POS | | 2.07 | | 3.50 |
| Total POS Gross | | | 6.86 | 11.59 |
| Credited Public Open Space | | | | |
| Unrestricted POS | 4.79 | | | |
| Restricted POS (max 20%) | 1.18 | | | |
| **Total Credited POS Provision** | | | **5.98** | **10.10** |
| Surplus Unrestricted POS | 0.06 | | | |
| Surplus Restricted POS | 0.89 | | | |

*NB areas approximate only. Detail to be determined at subdivision.*

These areas provide local open space within 400m of every lot proposed, and supplement the district recreation facilities available within the existing townsite, and the reserves along the coast and Irwin River which are the focus of much recreation for Dongara residents. A further active recreation oval is anticipated as part of a shared facility with the future primary school immediately west of the site, if and when future staged development occurs.

Additional 'greening' of the site and improvement of the amenity offered by local streets (as a component of the public realm, and potential recreational network for walkers and cyclists) may also be achieved through street tree planting and landscaping.

Treatment and management of the public open space areas and streetscapes would be expected to be addressed in standard conditions of subdivision requiring preparation and implementation of public open space plans and civil works plans, consistent with WAPC policy. Utilisation of water wise, predominantly native species would be anticipated as a standard requirement as would use of storm water run-off to provide an additional irrigation source.

Maintenance of public open space areas by the developer is required for a period of two summers following completion. Maintenance and management issues are also critical considerations in the development of landscape proposals, and will require the further, detailed input of the Shire at this stage of the process.

### 3.4 Residential

The plan proposes low density residential across the site. Densities have been kept low to reflect its location on the fringe of the town, and the preferences expressed by Councillors in briefing sessions undertaken in 2012, but are generally not of the traditional rural residential scale now discouraged by state planning policy. The preliminary Concept Plan (Figure 8) indicates approximately 85 lots ranging from 1.5ha in the south east corner, down to 4000m$^2$ internally. Lot sizes have been deliberately kept larger adjacent to Brand Highway to maintain a semi rural character at the entrance to the town, and to make efficient use of the land and infrastructure required to service it. Lot sizes then graduate down to the average 4000m$^2$ required at R2.5 along the western portions of the LSP area, providing a range of lot types and sizes. This interface allows for further potentially more diverse urban development to continue in future stages to the west, if and when rezoned.

### 3.5 Movement Network (Traffic Management and Safety)

The traffic planning for the site is detailed in the attached assessment undertaken by Jonathan Riley Consulting (refer Appendix 8).

Primary access to the site is proposed from a new entrance point from Brand Highway, approximately midway up the site, supplemented by Francisco Road to the south (connecting into Brennand Road, which leads into town). The location of the new access point has been agreed in consultation with Main Roads WA to provide good visibility, and safe access onto the highway. Both the new entry road and Francisco Road extension are projected to carry low volumes of traffic associated with this structure plan, but are designated Neighbourhood Connectors by virtue of their function.

The new entry road has been designed to provide for access to a potentially larger area, with a reserve of 27m required to facilitate this and accommodate the boulevard style road and integrated water management.

The precise long-term treatment will in large part depend on the extent of development (and therefore traffic) which occurs to the west, with a conservative 'worst case scenario' adopted to ensure the robustness of the plan. Application of a requirement in the LSP for lots along the entry road to make provision for vehicles to return to the street in forward gear (either through circular driveways or turning areas) and collocation of driveways has been made to limit direct and reversing vehicle access to this road, in the event that its ultimate volumes require this. Any necessary changes to the entry road to accommodate any future development would be a cost attributable to that development and so would not fall upon the Shire.

The traffic assessment undertaken for the proposal indicates that the new Brand Highway connection will be required to be constructed prior to the creation of 24 lots to maintain safe and functional traffic access from the Highway. This figure has been reduced to 20 lots in Part 1 of the LSP to provide an additional safeguard. Construction of the intersection represents a substantial capital cost.

The road layout through the site reflects the modified grid advocated by the WAPC's design manual, Liveable Neighbourhoods, and provides direct and legible access to all lots. The planned north-south link on the western side of the site is notionally indicated to veer north-west across lot 17 as part of future development of this site, providing a more efficient layout for the northern part of Lot 10. The placement of the road also better provides for long term connection into Lot 1248 to the north, should this ever be required. This long term approach may require that development of some lots be held back at subdivision stage to coordinate in with this future stage, however this is considered appropriate, given the design benefits achieved. The precise details of local road alignment can be determined in consultation with approval agencies at subdivision, provided that the fundamental structure stipulated by the Structure Plan is maintained. Whilst minimum reserve widths required under policy are outlined in the traffic assessment, uniform widths of 18-20m are proposed for local roads to reflect local conditions, character and expectation. This more generous reserve width also provides for the integration of open drainage swales / channels within verges proposed by the Local Water Management Strategy, should this be approved.

A dual use / shared path (DUP) is proposed along the western boundary of the LSP land. The path will provide a pedestrian and bicycle connection to the Dongara townsite to the south and will extend to the northern border of the LSP land to connect with future developments to the north. A further DUP along the Boulevard Entry Road will provide an off-road cycling environment along this street. It is expected that development of the pathways will be required as a condition of subdivision approval. The location of the pathways allows them to integrate with the future activity centre and primary school site planned immediately west of the site, and to utilise the more amenable and lower traffic volume environments of Francisco and Brennand Road to provide access to Dongara townsite, in preference to Brand Highway.

Local pedestrian and cycle movement on lower order streets could be accommodated on-street, as it is throughout most of Dongara-Port Denison, given the generous road reserves and low traffic volumes of most streets however, a commitment is made to provide a footpath on internal roads at the request of the Shire to reflect Council Policy to facilitate more sustainable transport modes. Provision of an access easement from the disconnected road shown parallel to Brand Highway on the Development Concept (Figure 8) across Lot 5 to provide direct pedestrian connection to the Highway from the southern portion of the subject site has been requested to be Shire, to maximise pedestrian accessibility. This would be secured through a condition of subdivision of that lot.

### 3.6 Urban Water Management

A Local Water Management Strategy (LWMS) has been prepared for the site (refer Appendix 9) responding to the Department of Water's Stormwater Management Manual 2004-07, State Planning Policy 2.9 - Water Resources and the Commission's supplementary Better Urban Water Management Guidelines. The LWMS sets out a number of water management objectives and design criteria, a management strategy, preliminary catchment details and calculations and monitoring recommendations. It indicates provision of drainage swales within a central median on the Boulevard Entry Road and within verges in lower order road reserves, as part of a landscaped treatment, in accordance with state and local government guidelines. Additional runoff from the western portion of the land can continue to drain to the west based on natural land form, into temporary detention swales, pending development of this area (if approved) and integration of this within future swales. Runoff volumes are anticipated to be very low, with the majority permeating into the soil within the roadside swales before it reaches the site boundary.

The LWMS concludes that the site is capable of accommodating stormwater run-off through the application of integrated urban water management principles, and that swales and bubble-ups can permeate that water at or close to source, and 'harvest' it to support landscaping and the 'greening' of the site.

In providing comment on the LWMS, the Department of Water has requested that the following be included within the Urban Water Management Plan likely to be required as a condition of subdivision:

- Confirmation in writing from the Water Corporation of availability of potable water supply and / or demonstration that rainwater tanks and calculations can provide a sustainable ongoing supply;
- Demonstration that swale designs can be accommodated in road reserve widths;
- Details on stormwater drainage and bio filter proposals;
- Land Capability and Geotechnical reports;
- Site specific testing to support infiltration rates, and confirm that ATUs are appropriate; and
- Details of monitoring bore sites and permeability testing sites and a annual monitoring regime as outlined in email correspondence by DoW.

### 3.7 Education Facilities

The scale of the development does not warrant provision of an additional school or other education facilities, with the Department of Education verbally confirming that the existing Dongara District High School and Primary School have sufficient capacity to cater for the additional population generated by the LSP area. In the event that rezoning and development to the west is achieved in the future, provision for an additional primary school will be required, and is notionally shown in the conceptual structure plan for the larger area. This would provide a highly localised facility within walking and cycling distance of all lots proposed. Provision for good access to these facilities both by car, foot and cycle has been made in their location and the design of the surrounding road network.

### 3.8 Activity Centres and Employment

The LSP area is located within 3km of Dongara and 65km of Geraldton. These centres will provide for the commercial needs of the future population and, in conjunction with local agricultural, fishing and mining opportunities, are likely to provide for most of their employment.

A possible future Local Neighbourhood Centre is shown on the Long Term Potential Structure Plan Concept which would again provide a very localised and accessible resource to the site, should it be approved and developed. This would enhance the compliance of the proposal with the directions of Liveable Neighbourhoods, which strongly espouses provision of local facilities and reduced dependence on car travel, but cannot reasonably be expected to be provided within the limited area the subject of this structure plan.

### 3.9 Infrastructure Coordination, Servicing and Staging (Public Utilities)

A preliminary investigation of infrastructure and servicing requirements was undertaken in support of the rezoning proposal for the site. This investigation confirmed that provision of service infrastructure is not a constraint to residential development in this area, and concluded that:

- A desirable site grading for subdivision can be achieved with some earthworks. Site stabilisation will be a factor to be addressed in subdivision design and construction staging and management to avoid potential dust and ground erosion;
- The site's sandy soils provide opportunities to apply water sensitive stormwater design principles that encourage containment at source;
- A water main exists in Francisco Road which can provide a connection to the site;
- Under the LPS5, lots exceeding 4000m$^2$ in area (as proposed in the Development Concept) do not require connection to deep sewer. The preliminary findings of the investigation and prior Land Capability Assessment indicate the site's suitability for on-site disposal of waste water; and
- Power infrastructure will need to be upgraded and extended to accommodate development of the site. Planning for this in conjunction with Western Power will be undertaken parallel to structure planning and connections secured in accordance with standard conditions of subdivision.

The LSP provides for sufficient verge widths to accommodate services within standard alignments.

Given that the large majority of the LSP area is under single ownership, initial costs for the provision of infrastructure necessary to service the LSP area will be borne by the proponent, with opportunities to recover costs from service authorities as part of standard agreements.

The release of lots is likely to be staged, depending on market demand, and is proposed to commence in the south-east of the site and more progressively north and west over a 5 -10 year period, depending on sales.

The design and alignment of service corridors and infrastructure will accord with standard agency requirements, with potential for common trenching to be investigated.

### 3.10 Electricity Infrastructure Overview

A high level review of electricity infrastructure by the proponent has documented that the existing single phase aerial infrastructure continues west and will require relocation at the developer's cost to maintain supply to existing customers.

An existing 185mmHV cable on the south side of Franscisco Road at the intersection of Brennand Road is a potential source of three phase supply to accommodate the subdivision. The structure plan indicates a total of 74 residential lots and therefore it is considered that one set of switchgear supplied from the 185HV cable, seven 63kVA transformers supplied in two strings from this switchgear would supply the lots with an additional fuse to allow connection back into the single phase network.

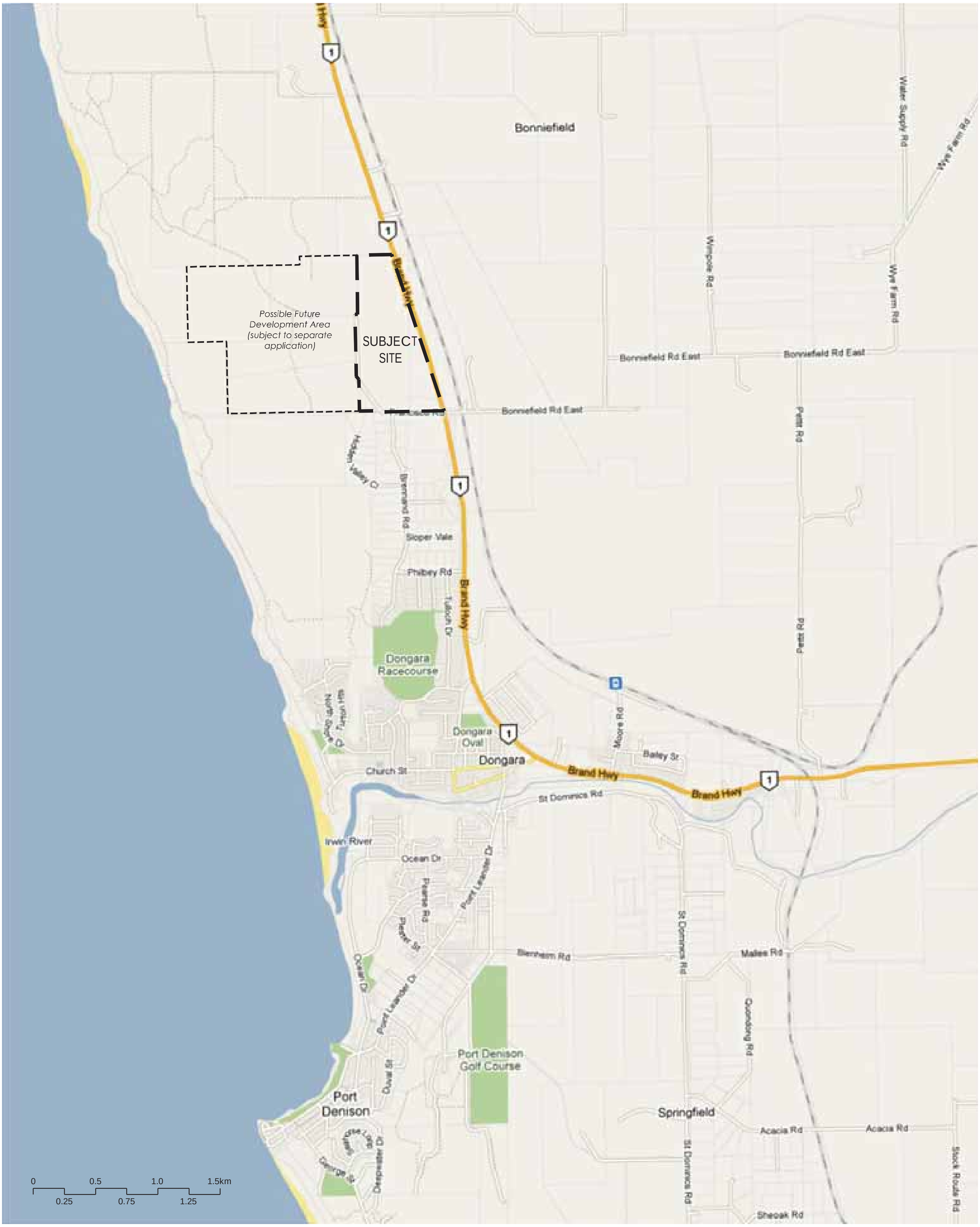
Further detailed design will be required at the subdivision stage to confirm the abovementioned assumptions, including any further works required as part of the proposal.

## 4.0 CONCLUSION & IMPLEMENTATION

In conclusion, this LSP outlines a subdivision and development proposal consistent with that negotiated with Council and incorporated in the rezoning documentation for the area, providing for the development of larger residential lots to provide for the continued growth of the town. The LSP provides the potential to link into future development of land to the west and north of the area, but does not depend on this. The LSP is supported by a range of technical studies which demonstrate its suitability for the development proposed, and outline how fire risk, traffic and water management, amongst other things, are most appropriately addressed.

Implementation of the LSP is likely to be driven by the majority landowner (Lot 10). The initial developer will be required to extend utilities to the site and develop the detail of road layouts, public open space and lot configuration under the direction of this plan, to facilitate subdivision. This will occur in consultation with the Shire, the WA Planning Commission and relevant other government agencies. The LSP layout allows for development of Lot 4 to occur independently, based on the street access available from Francisco Road. Development of Lot 5 is most likely to follow Lot 10, though the extension of additional internal road access however could occur separately under an access agreement. Progressive release of lots is likely to be led by the market, with an estimated timeframe of 5 to 10 years for completion of the estate.

# FIGURES




*Source: Google Maps 2010*

2172-89-01 (26.11.2013), nts

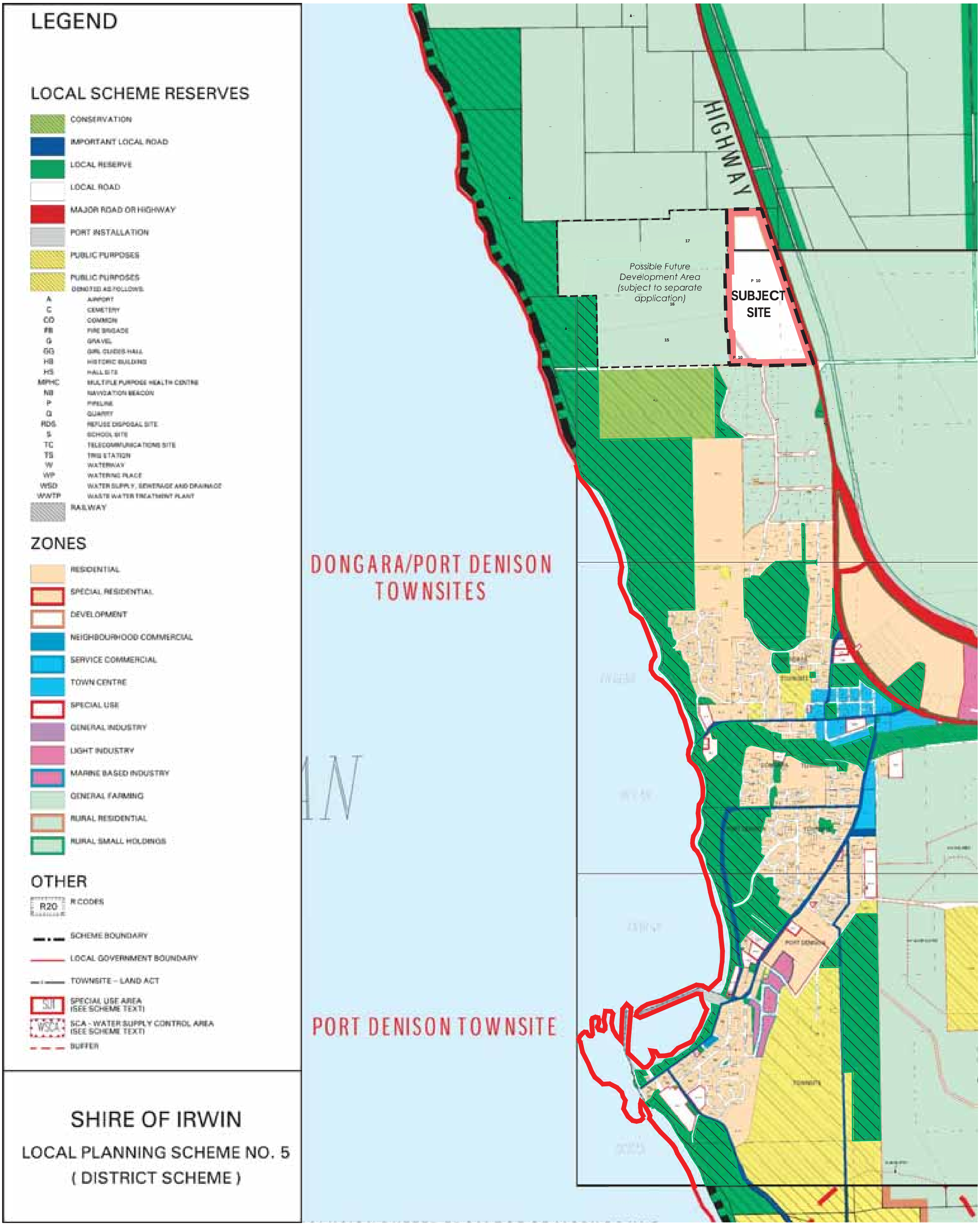
LOCATION PLAN

Francisco Road, Dongara: Figure 1

CLE
TOWN PLANNING + DESIGN


Source: Landgate 2009

# SITE PLAN

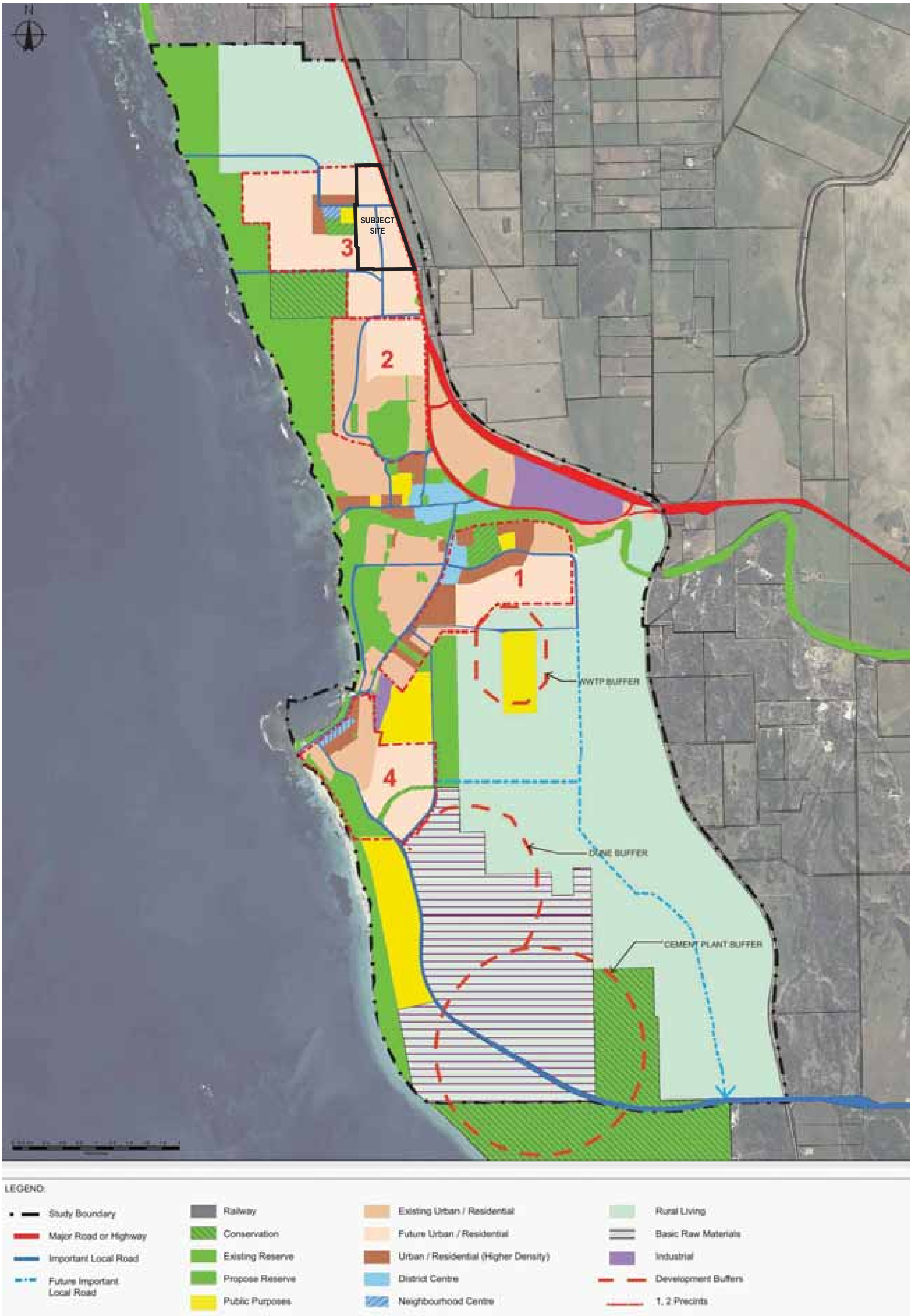



Source: WAPC

SHIRE OF IRWIN - TOWN PLANNING SCHEME No. 5

2172-91-01 (26.11.2013), nts

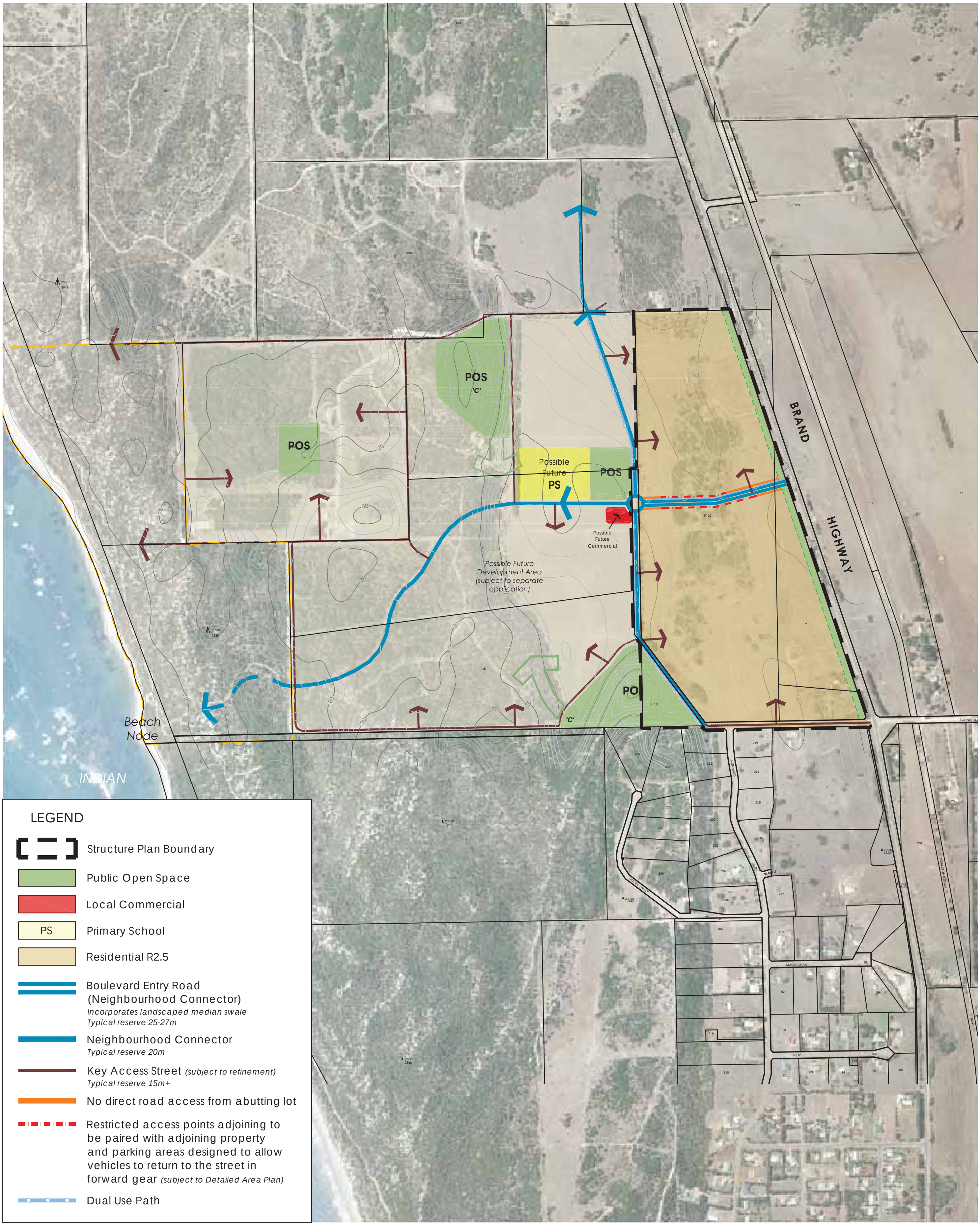
Francisco Road, Dongara : Figure 3




*Source: Shire of Irwin*

# DONGARA - PORT DENISON DISTRICT STRUCTURE PLAN

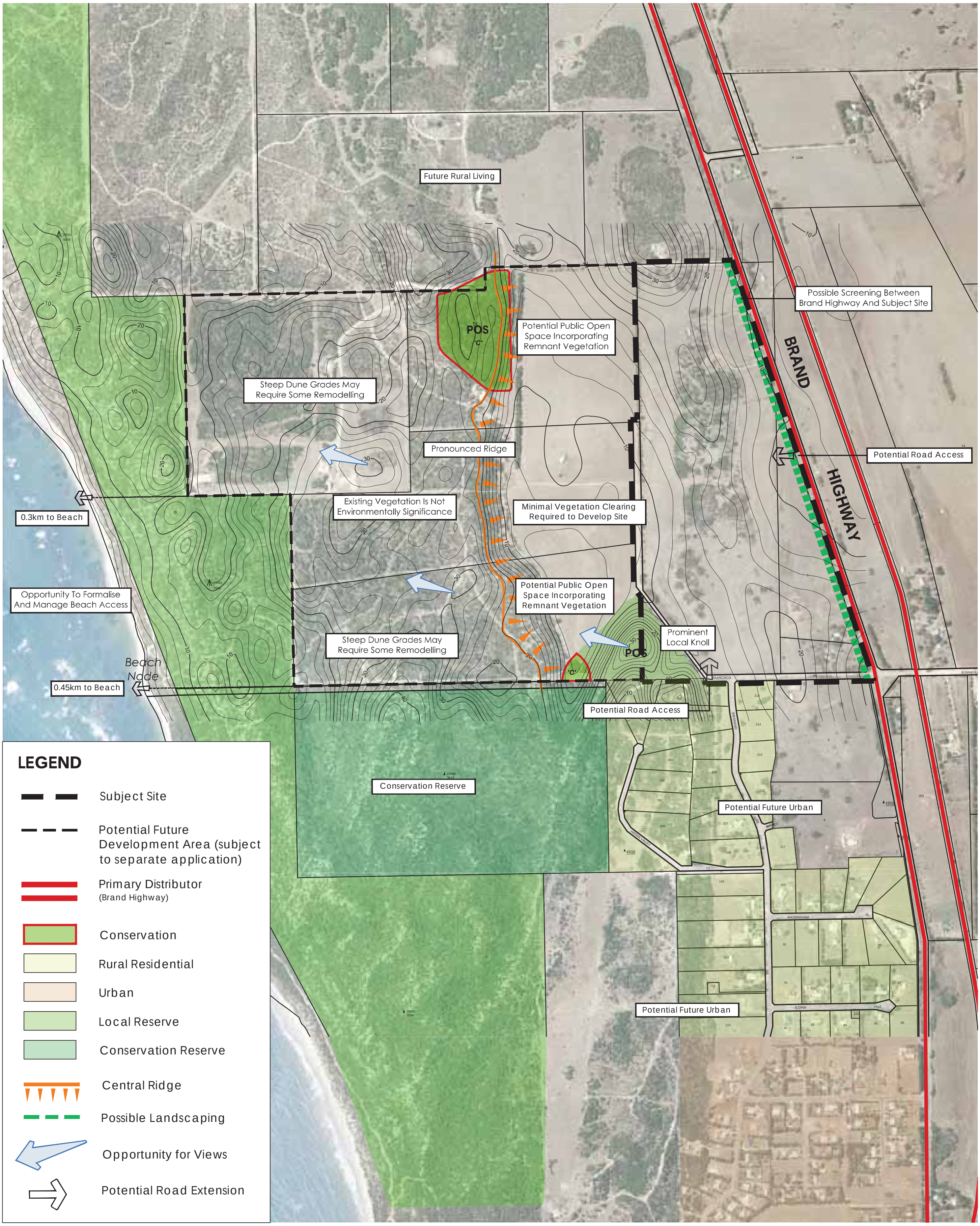
CLE TOWN PLANNING + DESIGN




# OVERALL STRUCTURE PLAN CONCEPT

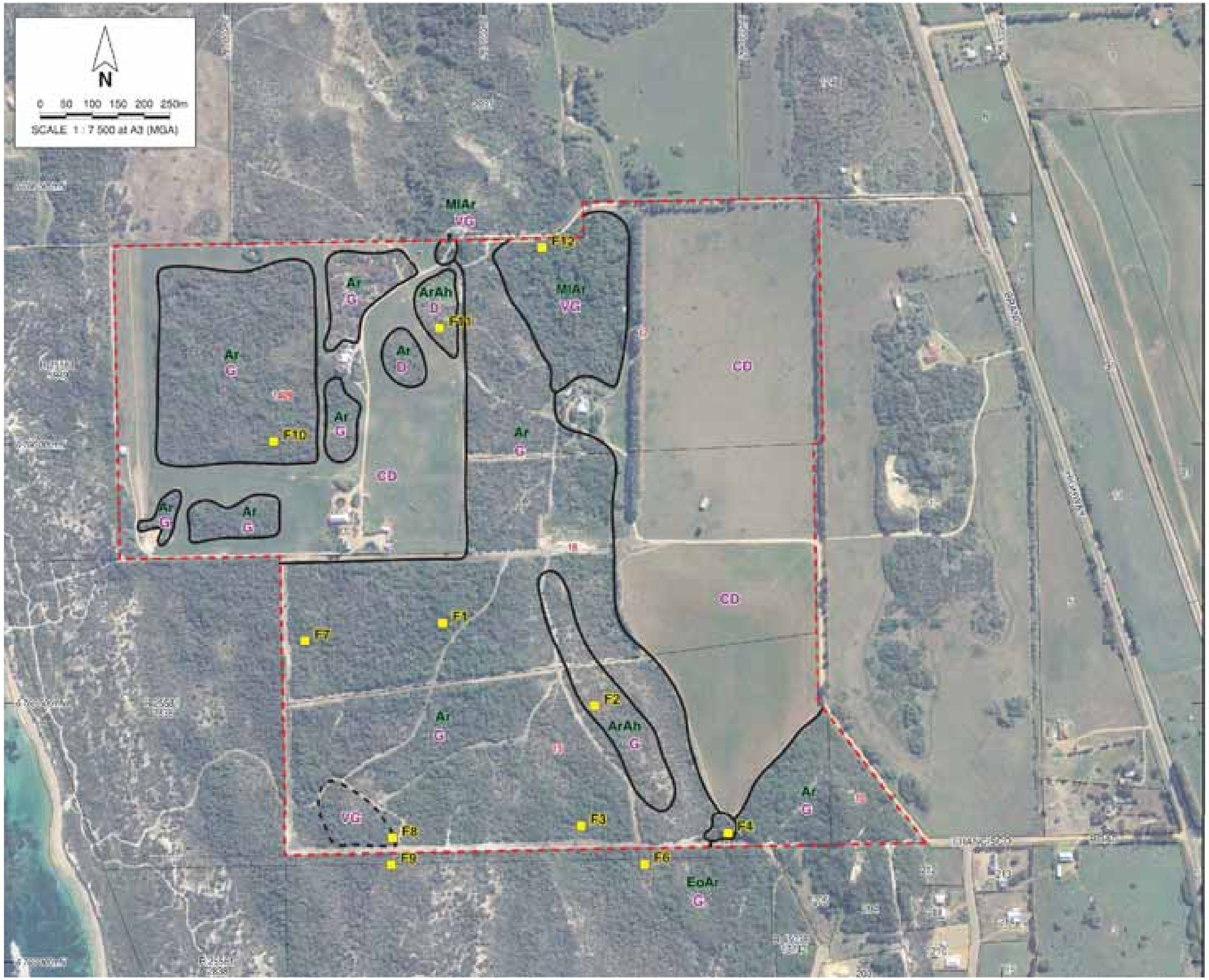
2172-92B-01 (07.05.2014), nts

Francisco Road, Dongara: Figure 5




# SITE ANALYSIS PLAN

Francisco Road, Dongara: Figure 6




**Legend**

- Site Boundary
- Cadastral Boundary
- Quadrat Location
- Vegetation Type Boundary
- Vegetation Condition Boundary
- **Ar** Vegetation Type
- G Vegetation Condition

**Vegetation Legend**

**Ar** *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub

**ArAh** *Acacia rostellifera/Alyogyne huegelii* Open Heath

**MlAr** *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland

**EoAr** *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub

**Vegetation Condition Legend**
(Source: BUSH FOREVER Govt. of W.A., 2000)

**P - Pristine**
Pristine or nearly so, no obvious signs of disturbance.

**Ex - Excellent**
Vegetation structure intact, disturbance affecting individual species and weeds are non aggressive species.

**VG - 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.

**G - Good**
Vegetation structure significantly altered by very obvious signs of multiple disturbance. 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.

**D - 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.

**CD - Completely Degraded**
The structure of the vegetation is no longer intact and the areas is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora composing weed or crop species with isolated native trees or shrubs.

**Cl - Cleared**
No native vegetation remaining.

# VEGETATION TYPES AND CONDITION

CLE TOWN PLANNING + DESIGN


DEVELOPMENT CONCEPT PLAN

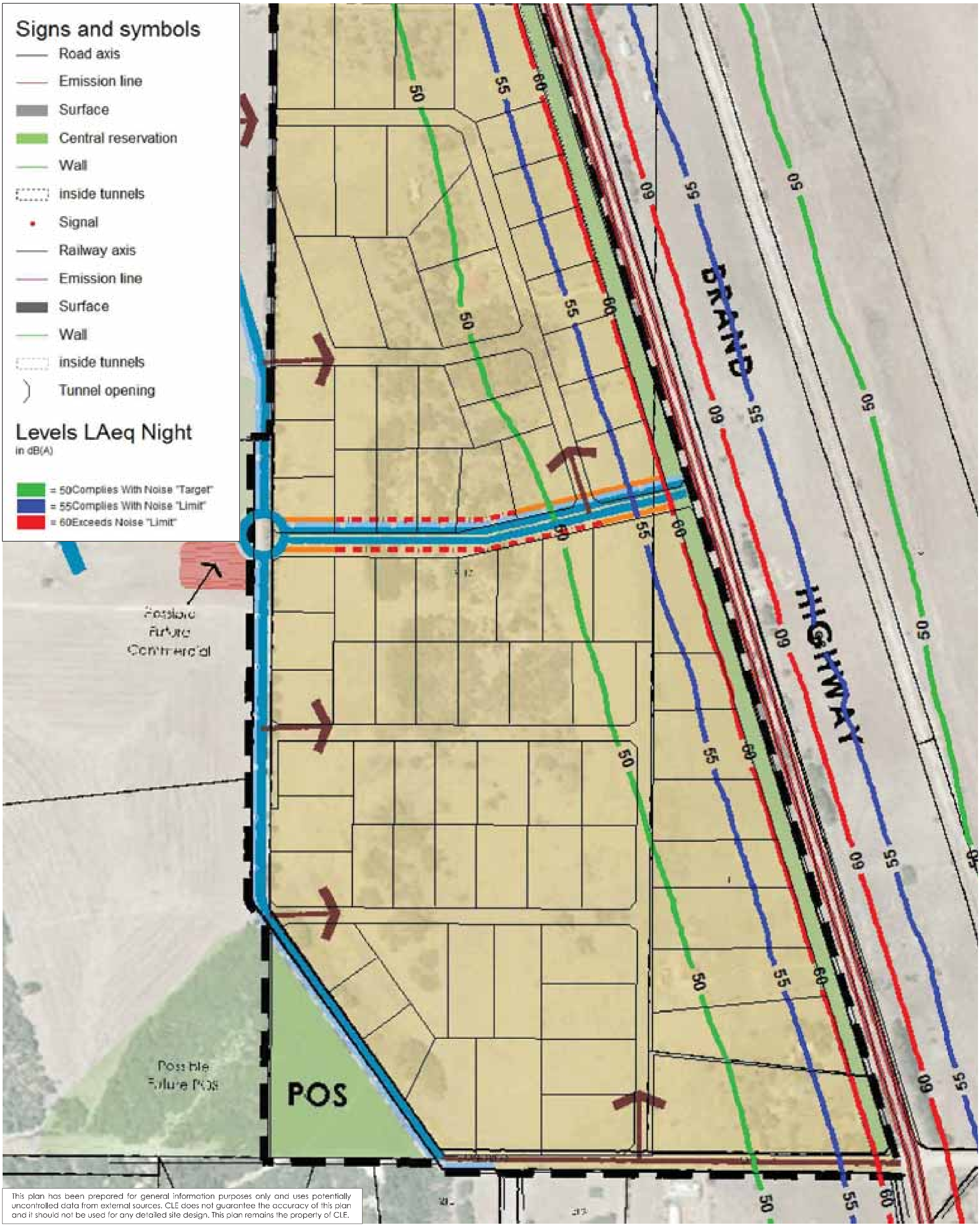
CLE TOWN PLANNING + DESIGN


*Source: Google Maps 2010*

# CONTEXT ANALYSIS PLAN

2172-104-01 (08.04.2014), nts

Francisco Road, Dongara: Figure 9




This plan has been prepared for general information purposes only and uses potentially uncontrolled data from external sources. CLE does not guarantee the accuracy of this plan and it should not be used for any detailed site design. This plan remains the property of CLE.

*Source: Herring Storer*

NOISE CONTOUR PLOT

2172-145-01 (03.03.2015), nts

Francisco Road, Dongara: Figure 10

# APPENDICES

# APPENDIX 1

## Certificates of Title

| REGISTER NUMBER | |
|---|---|
| **4/D88986** | |
| DUPLICATE EDITION | DATE DUPLICATE ISSUED |
| **2** | **10/12/2004** |

WESTERN AUSTRALIA

# RECORD OF CERTIFICATE OF TITLE

UNDER THE TRANSFER OF LAND ACT 1893

VOLUME **2046** FOLIO **796**

The person described in the first schedule is the registered proprietor of an estate in fee simple in the land described below subject to the reservations, conditions and depth limit contained in the original grant (if a grant issued) and to the limitations, interests, encumbrances and notifications shown in the second schedule.

BGRoberts

REGISTRAR OF TITLES

REGISTRAR OF TITLES WESTERN AUSTRALIA

**LAND DESCRIPTION:**

LOT 4 ON DIAGRAM 88986

**REGISTERED PROPRIETOR:**
(FIRST SCHEDULE)

PAUL REGINALD BENDER
BRENDA KRETSCHMER-BENDER
BOTH OF LOT 4 FRANCISCO ROAD, DONGARA
AS JOINT TENANTS

(T J859849 ) REGISTERED 3 AUGUST 2006

**LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:**
(SECOND SCHEDULE)

1. *J859850 MORTGAGE TO COMMONWEALTH BANK OF AUSTRALIA REGISTERED 3.8.2006.

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required.
* Any entries preceded by an asterisk may not appear on the current edition of the duplicate certificate of title.
Lot as described in the land description may be a lot or location.

--------------------------------------------------END OF CERTIFICATE OF TITLE--------------------------------------------------

**STATEMENTS:**

The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

| | |
|---|---|
| SKETCH OF LAND: | 2046-796 (4/D88986). |
| PREVIOUS TITLE: | 1530-936. |
| PROPERTY STREET ADDRESS: | 30701 BRAND HWY, BONNIEFIELD. |
| LOCAL GOVERNMENT AREA: | SHIRE OF IRWIN. |

| | | |
|---|---|---|
| NOTE 1: | G754302 | SECTION 138D TLA APPLIES TO CAVEAT G743704 |
| NOTE 2: | | DUPLICATE CERTIFICATE OF TITLE NOT ISSUED AS REQUESTED BY DEALING J859850 |

| REGISTER NUMBER | |
|---|---|
| 5/D88986 | |
| DUPLICATE EDITION | DATE DUPLICATE ISSUED |
| 1 | 2/8/2001 |

WESTERN AUSTRALIA

# RECORD OF CERTIFICATE OF TITLE

UNDER THE TRANSFER OF LAND ACT 1893

VOLUME 2046 FOLIO 797

The person described in the first schedule is the registered proprietor of an estate in fee simple in the land described below subject to the reservations, conditions and depth limit contained in the original grant (if a grant issued) and to the limitations, interests, encumbrances and notifications shown in the second schedule.

BGRoberts

REGISTRAR OF TITLES

REGISTRAR OF TITLES WESTERN AUSTRALIA

**LAND DESCRIPTION:**

LOT 5 ON DIAGRAM 88986

**REGISTERED PROPRIETOR:**
(FIRST SCHEDULE)

GARY ANTHONY NORRISH
JOSE NORRISH
BOTH OF POST OFFICE BOX 35, PERENJORI
AS JOINT TENANTS

(T H027153 ) REGISTERED 15 FEBRUARY 1999

**LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:**
(SECOND SCHEDULE)

1. EASEMENT BURDEN CREATED UNDER SECTION 27A OF T. P. & D. ACT - SEE DIAGRAM 88986.
2. H823814 MORTGAGE TO BANK OF WESTERN AUSTRALIA LTD REGISTERED 30.7.2001.

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required.
* Any entries preceded by an asterisk may not appear on the current edition of the duplicate certificate of title.
Lot as described in the land description may be a lot or location.

--------------------------------------------------END OF CERTIFICATE OF TITLE--------------------------------------------------

**STATEMENTS:**

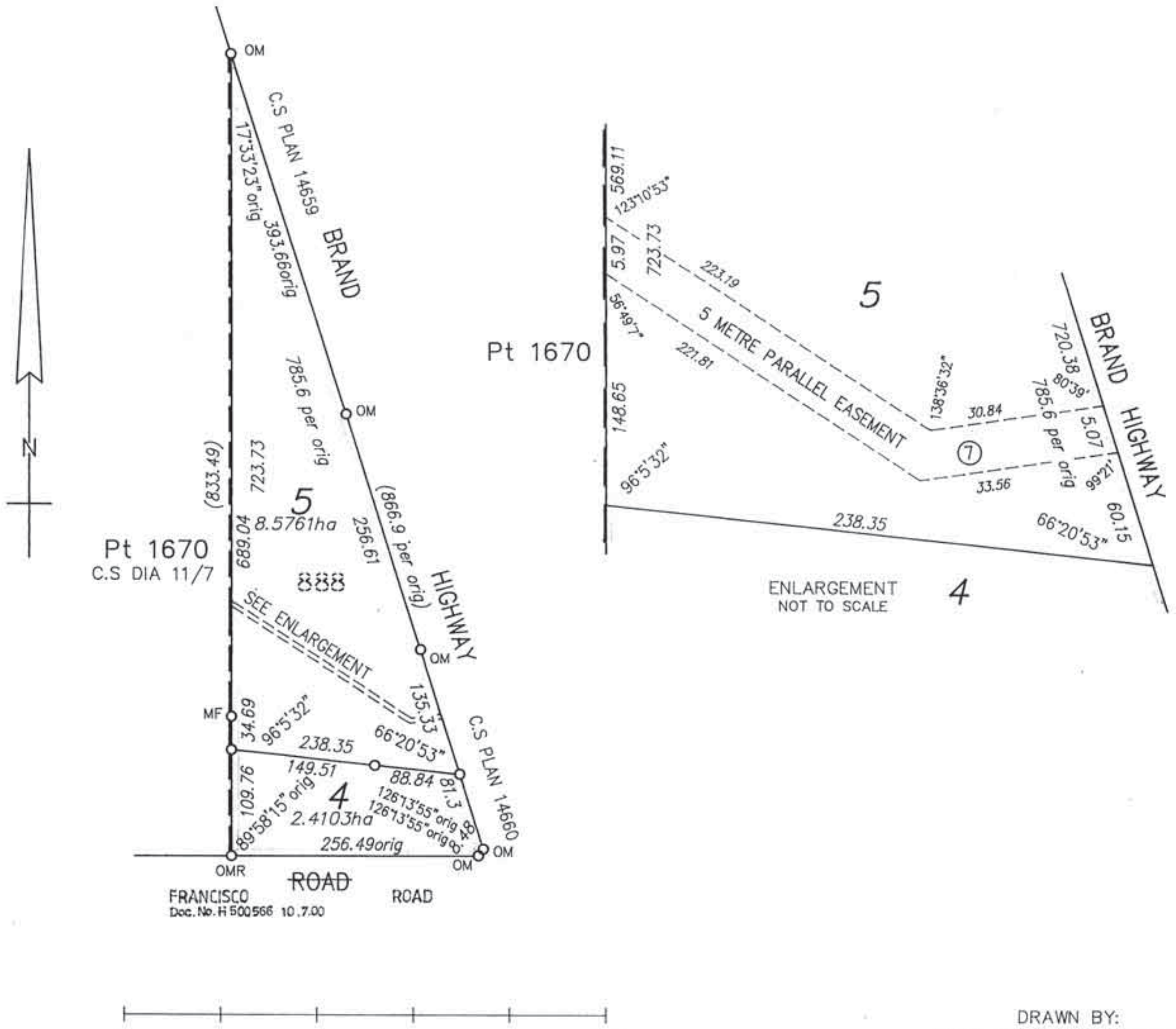
The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

| | |
|---|---|
| SKETCH OF LAND: | 2046-797 (5/D88986). |
| PREVIOUS TITLE: | 1530-936. |
| PROPERTY STREET ADDRESS: | 30721 BRAND HWY, BONNIEFIELD. |
| LOCAL GOVERNMENT AREA: | SHIRE OF IRWIN. |

| LAND DESCRIPTION | ON | CERTIFICATE OF TITLE | FIELD BOOK | DIA 88986 |
|---|---|---|---|---|
| PT LOT 1 OF PT VICTORIA LOCATION 888 | PLAN<br>DIAGRAM 55781<br>INDEX BOOKARA SE (25)<br>PUBLIC | VOLUME 1530<br>FOLIO 936 | 68631 | TOTAL AREA 10.9864ha |

LOCALITY: BONNIEFIELD
LOCAL AUTHORITY: SHIRE OF IRWIN

EASEMENT TO WESTERN POWER
⑦ UNDER SEC 27A OF THE T.P.& D. ACT REG 7 (POWER)




DRAWN BY:
HILLE, THOMPSON & DELFOS.
LICENSED SURVEYORS
48 MARINE TERRACE
GERALDTON
380/94/1303

## SURVEYOR'S CERTIFICATE

REG 54: I A.G.THOMPSON hereby certify that:
(a) this plan of survey is a correct and accurate representation of the survey carried out by me personally/under my own personal supervision, inspection and field check, and recorded in field books lodged for the purposes of this plan of survey;
(b) the measurements are in strict accordance with the Licensed Surveyors (Guidance of Surveyors) Regulations 1961 and in particular regulations 23 and 34 of those regulations; and
(c) this survey and this plan of survey are in strict accordance with the requirements of the Licensed Surveyors (Guidance of Surveyors) Regulations 1961 and the relevant law in relation to which it is lodged.

A.G.Thompson 18/4/95
Licensed Surveyor Date

REG 55D I ............ hereby certify that:
(a) this plan is correct and was prepared under my supervision and is the result of calculations from measurements made by me personally/under my own personal supervision, inspection and field check as recorded in the field books lodged for the purposes of this plan;
(b) the measurements are in strict accordance with the requirements of the Licensed Surveyors (Guidance of Surveyors) Regulations 1961 and in particular regulations 23 and 34 of those regulations; and
(c) this plan of survey conforms with the relevant law in relation to which it is lodged.

Licensed Surveyor Date

**APPROVED BY**
STATE PLANNING COMMISSION

FILE 96328

Eugene Ferraro
For Chairman

DATE 30.5.95

MINISTRY FOR PLANNING
25 MAY 1995
FILE 96328

**LODGED**
DATE 21.4.95
FEE PAID $253
ASSESSMENT NO 87910

EXAMINED (LEGALLY)
J. Chernouski 10/5/95

DOCKET ~~PLAN~~/DIAGRAM 87573

(LEGALLY) CERTIFIED CORRECT J. Chernouski 10/5/95

F.S.C. No.

DOLA
Department of LAND ADMINISTRATION

**SCALE** 1: 5000
ALL DISTANCES ARE IN METRES

**IN ORDER FOR DEALINGS**
SUBJECT TO
SEC.27A OF T.P. & D. ACT
G.J. Brinton 1.6.95
For Inspector of Plans and Surveys Date

APPROVED 10.7.95
APPROVED Date
Inspector of Plans and Surveys

**OFFICE OF TITLES DIAGRAM**
88986

| REGISTER NUMBER | |
|---|---|
| **10/D90656** | |
| DUPLICATE EDITION | DATE DUPLICATE ISSUED |
| **1** | **15/12/2003** |

WESTERN AUSTRALIA

# RECORD OF CERTIFICATE OF TITLE

UNDER THE TRANSFER OF LAND ACT 1893

VOLUME **2072** FOLIO **286**

The person described in the first schedule is the registered proprietor of an estate in fee simple in the land described below subject to the reservations, conditions and depth limit contained in the original grant (if a grant issued) and to the limitations, interests, encumbrances and notifications shown in the second schedule.

B G Roberts

REGISTRAR OF TITLES

**LAND DESCRIPTION:**

LOT 10 ON DIAGRAM 90656

**REGISTERED PROPRIETOR:**
(FIRST SCHEDULE)

LUNDY NOMINEES PTY LTD
TEXAS PROPERTY DEVELOPMENT PTY LTD
BOTH OF 21 MORETON TERRACE, DONGARA
AS TENANTS IN COMMON IN EQUAL SHARES

(T I711524 ) REGISTERED 28 NOVEMBER 2003

**LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:**
(SECOND SCHEDULE)

1. E852131 EASEMENT BURDEN SEE SKETCH ON VOL 2072 FOL 286. REGISTERED 7.4.1992.

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required.
* Any entries preceded by an asterisk may not appear on the current edition of the duplicate certificate of title.
Lot as described in the land description may be a lot or location.

-----END OF CERTIFICATE OF TITLE-----

**STATEMENTS:**

The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

| | |
|---|---|
| SKETCH OF LAND: | 2072-286 (10/D90656). |
| PREVIOUS TITLE: | 2006-40. |
| PROPERTY STREET ADDRESS: | 30799 BRAND HWY, BONNIEFIELD. |
| LOCAL GOVERNMENT AREA: | SHIRE OF IRWIN. |

LT. 37

ORIGINAL—NOT TO BE REMOVED FROM OFFICE OF TITLES

Application G155047
Volume 2006 Folio 40

WESTERN AUSTRALIA

REGISTER BOOK
VOL. FOL.
CT 2072 - 286

# CERTIFICATE OF TITLE

UNDER THE "TRANSFER OF LAND ACT, 1893" AS AMENDED

I certify that the person described in the First Schedule hereto is the registered proprietor of the undermentioned estate in the undermentioned land subject to the easements and encumbrances shown in the Second Schedule hereto.

Dated 18th April, 1996

G. Sach
REGISTRAR OF TITLES

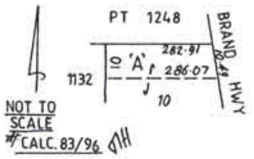
## ESTATE AND LAND REFERRED TO

Estate in fee simple in portion of Victoria Location 1670 and being Lot 10 on Diagram 90656, delineated on the map in the Third Schedule hereto.

## FIRST SCHEDULE (continued overleaf)

Rex David Tomsett and Pamela Mary Tomsett both of Post Office Box 10, Dongara.

## SECOND SCHEDULE (continued overleaf)

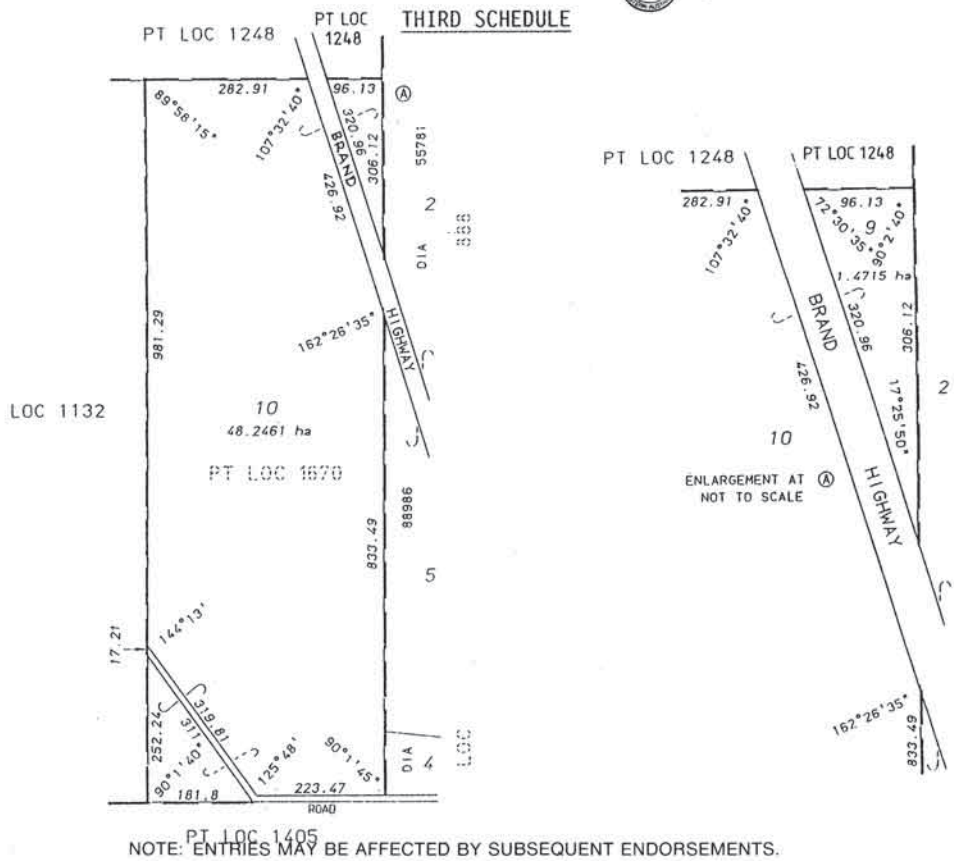



1. TRANSFER E852131. A right of carriageway over the portion of the within land marked 'A' on the map in the margin as set out in the said Transfer is granted to the proprietor or proprietors for the time being of Victoria Location 1409. Registered 7.4.92 at 9.04 hrs.

2. MORTGAGE F618037 to Westpac Banking Corporation. Registered 19.7.94 at 8.25 hrs.

3. ~~MORTGAGE F618038 to Westpac Banking Corporation. Registered 19.7.94 at 8.25 hrs.~~
Discharged G883426 24.8.98

## THIRD SCHEDULE




NOTE: ENTRIES MAY BE AFFECTED BY SUBSEQUENT ENDORSEMENTS.

PERSONS ARE CAUTIONED AGAINST ALTERING OR ADDING TO THIS CERTIFICATE OR ANY NOTIFICATION HEREON

LT. 37



**FIRST SCHEDULE (continued)** NOTE: ENTRIES MAY BE AFFECTED BY SUBSEQUENT ENDORSEMENTS

| REGISTERED PROPRIETOR | INSTRUMENT | | REGISTERED | TIME | SEAL | CERT. OFFICER |
|---|---|---|---|---|---|---|
| | NATURE | NUMBER | | | | |

**SECOND SCHEDULE (continued)** NOTE: ENTRIES MAY BE AFFECTED BY SUBSEQUENT ENDORSEMENTS

| INSTRUMENT | | PARTICULARS | REGISTERED | TIME | SEAL | CERT. OFFICER | CANCELLATION | NUMBER | REGISTERED OR LODGED | SEAL | CERT. OFFICER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NATURE | NUMBER | | | | | | | | | | |

CERTIFICATE OF TITLE VOL. 2072 FOL. 286

# APPENDIX 2

## EPA Advice on Site Rezoning

GOVERNMENT OF WESTERN AUSTRALIA

Environmental Protection Authority

The Atrium,
Level 8, 168 St Georges Terrace,
Perth, Western Australia 6000.
Telephone: (08) 6467 5000.
Facsimile: (08) 6467 5557.

Postal Address: Locked Bag 33,
Cloisters Square, Perth, Western Australia 6850.
Website: www.epa.wa.gov.au

Chief Executive Officer
Shire of Irwin
PMB 21
DONGARA WA 6525

*Our Ref* A569830
*Enquiries* Peta Hayward
*Phone* 6467 5304

ATTENTION:

Dear Sir/Madam

**DECISION UNDER SECTION 48A(1)(a)**
***Environmental Protection Act 1986***

| | |
|---|---|
| **SCHEME AMENDMENT TITLE:** | **Shire of Irwin Local Planning Scheme 5 Amendment 15 - Rezoning from General Farming to Development** |
| **LOCATION:** | **Lots 4, 5 and 10 Brand Highway** |
| **LOCALITY:** | **Bonniefield, Dongara** |
| **RESPONSIBLE AUTHORITY:** | **Shire of Irwin** |
| **DECISION:** | **Scheme Amendment Not Assessed – Advice Given (no appeals)** |

Thank you for referring the above scheme amendment to the Environmental Protection Authority (EPA).

After consideration of the information provided by you, the Environmental Protection Authority (EPA) considers that the proposed scheme amendment should not be assessed under Part IV Division 3 of the *Environmental Protection Act 1986* (EP Act) but nevertheless provides the following advice and recommendations.

**ADVICE AND RECOMMENDATIONS**

**1. Environmental Issues**

- Native Vegetation.

**2. Advice and recommendations regarding Environmental Issues**

The EPA considers that with the retention of the native vegetation in the south west corner of the amendment area as Public Open Space (outlined in the Draft Local Structure Plan) the amendment will not result in any significant environmental impacts.

The EPA notes the future proposal to develop properties to the west of the subject site. The EPA advises that the approval of this amendment does not preempt approval for future development which will require a separate referral under the EP Act.

### 3. General Advice

- For the purposes of Part IV of the EP Act, the scheme amendment is defined as an assessed scheme amendment. In relation to the implementation of the scheme amendment, please note the requirements of Part IV Division 4 of the EP Act.
- There is no appeal right in respect of the EPA's decision on the level of assessment of scheme amendments.
- A copy of this advice will be sent to relevant authorities and made available to the public on request.

Yours faithfully

A. Sutton

Anthony Sutton
Director
Assessment and Compliance Division

17 December 2012

# APPENDIX 3

## Flora and Vegetation Survey 2011 (PGV Environmental)

# LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

## FLORA AND VEGETATION SURVEY

| | |
|---|---|
| Prepared for: | BJ Clarke & Co Real Estate |
| Report Date: | 16 November 2011 |
| Version: | 2 |
| Report No. | 2011-27 |

PGV ENVIRONMENTAL

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**Tables**


Table 1: List of Flora Species Identified from DEC Database Searches

Table 2: Statement of Botanical Survey Conditions

Table 3: Vegetation Condition Rating Scale


**Figures**


Figure 1: Location

Figure 2: Vegetation Types and Condition


**Appendices**


Appendix 1: DEC Database Searches

Appendix 2: Quadrat Data

Appendix 3: Flora List

# 1 INTRODUCTION

## 1.1 Background

Lots 10, 15, 16, 17 and 1409 Francisco Road, Dongara (the site) are located adjacent to the coast approximately 3km north of the Dongara town centre. The site is currently being considered by the Department of Planning for its potential urban development to accommodate the future expansion of Dongara.

The owners of the lots are assisting the Department of Planning by undertaking planning and environmental work to investigate the opportunities and constraints to future urban development. This flora and vegetation survey has been commissioned by the landowners as part of those investigations.

## 1.2 Scope of Work

The flora and vegetation survey included the following tasks:

1. A Department of Environment and Conservation database search for potential Declared Rare Flora, Priority Flora and Threatened and Priority Ecological Communities that might occur on the site;
2. A review of any relevant flora and vegetation surveys undertaken in the vicinity of the site and the region in general;
3. A survey on the site to record the flora in permanent 10m x 10m quadrats;
4. A thorough site walkover of the site to record flora and vegetation outside of the sampled quadrats;
5. Compilation of a list of all flora species occurring at the time of survey;
6. A map of the vegetation types and condition; and
7. A description and GPS co-ordinates of any significant flora species or vegetation communities on the site.

# 2 EXISTING ENVIRONMENT

## 2.1 Land Use

Lot 10 west of Francisco Road currently consists of undeveloped native vegetation. The eastern portions of Lots 15, 16 and 17 have been cleared for agriculture while the western portions contain native vegetation. The native vegetation on these lots has been grazed in the past. A residential dwelling exists on Lot 17. Lot 1409 contains two residential dwellings, some cleared land for horse paddocks, and a central area of native vegetation.

The lots are zoned General Farming in the Shire of Irwin Town Planning Scheme No. 5.

Several tracks and firebreaks occur in the vegetated part of Lots 15, 16 and 17. Tracks lead down to the beach from Lot 15 and Lot 1409. The beach is located approximately 450m west of Lot 15 and 270m west of Lot 1409. The lots are separated from the coast by two Local Reserves (25581 5949 and 25581 2838) as well as a strip of Unallocated Crown Land.

Conservation Reserve 23600 abuts Lot 15 to the south and consists of native vegetation.

Private lots 205, 205 and 212 are located south of Lot 10 and a part of Lot 15 and contain native vegetation.

The balance of Lot 10 east of Francisco Rd abuts the eastern side of the site and has been predominantly cleared for agriculture.

Private Lots 2092, 2091 and 1248 occur to the north of the site and have been partially cleared for agriculture but retain native vegetation on the majority of the land.

## 2.2 Topography and Landform

The site is located close to the coast and includes undulating coastal Quindalup dunes on the western side and the flatter Tamala limestone landform on the eastern side. Generally the clearing for agriculture has occurred on the eastern Tamala limestone landform although some of the coastal soils on Lot 1409 have been cleared for horse paddocks.

The eastern cleared area is relatively flat from west to east but slopes generally from the north down to the south. Elevation on the eastern portion ranges from 32mAHD down to 9m AHD.

The western dunal area is undulating and ranges in elevation from 20m - 38m AHD on Lots 15-27 and 12m – 33m AHD on Lot 1409.

## 2.3 Geology and Soils

Soils on the site have been described by Landform Research (2005). The eastern Tamala limestone soils are brown sands grading to earthy sands overlying limestone at variable depth. The western Quindalup Dune soils are relatively old Quindalup dunes and therefore contain a brown to cream brown sand with minor clay and calcareous materials. The coarser nature of the older Quindalup

dunes makes them less susceptible to erosion than younger phase Quindalup dunes (Landform Research, 2005).

## 2.6 Hydrology

There are no surface water features such as creeklines, drainage lines or wetlands on the site.

Groundwater occurs under the site at an average level of around 2m AHD (Landform Research, 2005) indicating a minimum depth to groundwater of around 10m.

# 3 Vegetation and Flora

## 3.1 Methodology

A flora and vegetation survey of the site was conducted by Dr Paul van der Moezel on 20 and 21 September 2011. The survey was undertaken in accordance with the EPA's Guidance Statement No. 51 *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia*.

The survey included sampling from 10 permanent 10m x 10m quadrats on the site as well as a thorough walk over the area. Given the uniformity of the vegetation and overall low species diversity, the number of quadrats and site coverage during the field survey was considered high.

Each quadrat was marked with an aluminium dropper in the south-west and south-east corners of the quadrat. Hand-held GPS co-ordinates were taken from the position of the south-east dropper.

All plant species were either identified on site or collected for identification.

## 3.2 Department of Environment and Conservation Database Searches

A search of the DEC Threatened Flora Database and the WA Herbarium indicates that one Threatened (Declared Rare Flora) and 15Priority species are listed in the vicinity of the site but not on the site (Table 1).

**Table 1: List of Flora Species Identified from DEC Database Searches.**

| Species | Status under Wildlife Cons. Act | Status under EPBC Act | Flowering Period |
|---|---|---|---|
| *Acacia telmica* | P3 | | July - Sept |
| *Anthocercis intricata* | P3 | | June - Sept |
| *Banksia elegans* | P4 | | Oct - Nov |
| *Calytrix eneabbensis* | P4 | | July - Oct |
| *Comesperma rhadinocarpum* | P2 | | Oct - Nov |
| *Conostylis micrantha* | Threatened | Endangered | July - Aug |
| *Cryptandra pendula* | P1 | | July, Aug |
| *Dampiera tephrea* | P2 | | July |
| *Eucalyptus ebbanoensis* | P4 | | Jan - Mar |
| *Eucalyptus macrocarpa x pyriformis* | P3 | | - |
| *Eucalyptus zopherophloia* | P4 | | Nov - Jan |
| *Grevillea tenuiloba* | P3 | | Apr or July - Oct |
| *Haloragis foliosa* | P3 | | Oct |
| *Stylidium carnosum* subsp narrow leaves (JA Wege 490) | P1 | | Sept, Oct |
| *Stylidium pseudocaespitosum* | P2 | | Sept |

A search of the DEC's Threatened (TEC) and Priority Ecological Communities (PEC) database did not identify any known occurrences of TECs or PECs within 5km of the site.

## 3.3 Survey Conditions

The conditions that the survey was undertaken in are presented in Table 2 in order to assess the adequacy of the survey. In summary, there were no constraints to the survey.

**Table 2: Statement of Botanical Survey Conditions**

| **ISSUE** | **CONSTRAINTS (YES/NO); SIGNIFICANT, MODERATE OR NEGLIGIBLE** | **COMMENT** |
|---|---|---|
| Competency/experience of the consultant conducting the survey | No constraints | Dr Paul van der Moezel has extensive survey experience on the Swan Coastal Plain, including the Dongara and Geraldton areas. |
| Proportion of the flora identified | No constraints | The uniformity of the vegetation and timing of the survey in late September would have resulted in nearly all of the native species on the site being recorded. |
| Sources of information (historic/recent or new data) | No constraints | The flora of the Swan Coastal Plain and Geraldton area is relatively well documented, Dongara less so. |
| Proportion of the task achieved and further work that may need to be undertaken | No constraints | No follow-up survey required. |
| Timing/weather/season/cycle | No constraints | Generally average rainfall in winter 2011 on the Swan Coastal Plain. Late September survey ideal for identifying most species. No Threatened or Priority ephemeral species expected on the site requiring particular seasonal surveys outside of mid-Spring. |
| Intensity of survey (e.g. In retrospect was the intensity adequate) | No constraints | The network of tracks made access and coverage easy. Approximately 2 days spent walking and driving over the site. |
| Completeness (e.g. was relevant area fully surveyed) | No constraints | |
| Resources (e.g. degree of expertise available for plant identification) | No constraints | Experienced botanist undertook plant identifications mostly on site with some identification off-site using standard reference material. |
| Remoteness and/or access problems | No constraints | Easily accessible by vehicle and on foot. |
| Availability of contextual (e.g. bioregional) information for the study area. | No constraints | Geraldton Regional Flora and Vegetation Survey (WAPC, 2010) and Dongara to Cape Burney Vegetation Survey (Ecoscape, 2010) used for regional context. |

Fungi and nonvascular flora (e.g. algae, mosses and liverworts) were not specifically surveyed for during the survey.

## 3.4 Results

### 3.4.1 Flora

A total of 55 species were recorded during the 2011 spring flora survey (Appendix 3). This total consisted of 33 native species and 22 introduced species. The very low number of native species and high proportion of introduced species (40%) reflects the generally naturally low species richness of Quindalup dunes as well as the overall low condition of the site.

None of the species recorded was a Threatened (Declared Rare) or Priority listed flora.

### 3.4.2 Vegetation Types

Four separate Vegetation Associations were described and mapped on the site based on the structure and composition of the vegetation (Figure 2). However, one vegetation type, the *Acacia rostellifera* Tall Open to Closed Tall Scrub was by far the dominant vegetation type, representing about 90% of the native vegetation. The four vegetation types are described below.

**Ar** *Acacia rostellifera* **Tall Open Scrub to Closed Tall Scrub**

This is the main vegetation on the site. *Acacia rostellifera* ranges in height from 2-5m high with the taller stands typically on the lee side of the dunes and in the valleys. Density of *Acacia rostellifera* is high, ranging from 60-80%. As a result of the high canopy density, the understorey is sparsely vegetated. Most of the species are weeds with the main native species being *Rhagodia preissii* ssp *obovata* and the creeper *Clematis linearifolia.* Common weed species include *Sonchus asper, Sonchus oleraceus, Bromus diandrus* and *Euphorbia peplus.* The soil type was typically Brown-grey sand.

The quadrats surveyed in this area contained an average of 12.0 species (range 8-16). The quadrat in Very Good condition had a higher number of native species (13) than the other quadrats in Good condition (average 3.5, range 2-5) (Quadrats F1, F3, F7, F8, F10, Appendix 2).

**ArAh** *Acacia rostellifera/Alyogyne huegelii* **Open Heath**

A narrow band of this vegetation type occurred on the top of the eastern ridge in the Quindalup dunes on Lots 15 and 16 as well as a degraded part on the eastern side of Lot 1409. *Acacia rostellifera* was the dominant species but less dense (40%) and shorter (1.5-2m) than in the Ar vegetation above. *Alyogyne huegelii* was consistently dominant up to 2m high. Overall the vegetation type was dominated by weed species but was classified as being in Good condition. The soil type was yellow-grey sand.

The quadrats surveyed in this area contained an average of 13.5 species (range 13-14) of which 6 (range 4-8) were native (Quadrat F2, F11, Appendix 2).

**MlAr** *Melaleuca lanceolata* **Low Open Forest over** *Acacia rostellifera* **Tall Shrubland**

This vegetation type occurs in two stands, one large stand approximately 5ha in size at the northern end of Lot 17 and one smaller stand in the north-east corner of Lot 1409. The *Melaleuca lanceolata* (Rottnest Island Tea Tree) trees were up to 8m high and relatively dense with around a 50% canopy cover. The mid-storey of *Acacia rostellifera* was open (4m high and 20% cover) while the understorey iwas densely vegetated in ground covers. Native creepers *Zygophyllum fruticulosum* and *Clematis linearifolia* were common. The condition of the 5ha parcel of this vegetation type was mostly Very Good with the smaller parcel in Degraded condition. The soil type was Dark grey sand.

The quadrat surveyed in the larger stand contained 13 species of which 10 were native (Quadrat F12, Appendix 2).

**EoAr** *Eucalyptus obtusiflora* **Tree Mallee over** *Acacia rostellifera* **Tall Open Scrub**

A very small natural stand of *Eucalyptus obtusiflora* (Dongara Mallee) occurred on the southeastern end of Lot 15. Several *Eucalyptus obtusiflora* trees were present up to 6-7m high with an open mid-storey of *Acacia rostellifera* 2m high and a weedy understorey. The soil type was brown loamy sand.

The quadrat surveyed in the larger stand contained 7 species of which only 2 were native (Quadrat F4, Appendix 2).

### 3.4.3 Vegetation Condition

The condition of the vegetation was assessed according to the system devised by Keighery and described in *Bush Forever* (Government of Western Australia, 2000a). Keighery's condition rating scale ranges from Pristine (where the vegetation exhibits no visible signs of disturbance) to Completely Degraded (where the vegetation structure in no longer intact and without native plant species) (Table 1).

The vegetation condition of the site was mostly rated as Good (Figure 2). The rating of Good indicates that the upper *Acacia rostellifera* canopy was considered to be in its natural structure whereas the understorey was significantly altered. The dominance of weeds in the understorey may be due to past clearing of the whole site with subsequent re-growth of the *Acacia rostellifera* trees, or to grazing the understorey, or as a result of high frequency of fires. Examination of historical aerial photographs available on the Landgate website show that in 1998, only 13 years ago, the area of native vegetation on the western Quindalup dune area was more extensive, particularly on Lot 1409. The vegetation appears to be denser than in 2011 with less tracks and firebreaks. The condition of the vegetation therefore is considered to be more as a result of grazing the understorey.

The vegetation structure in some of the *Acacia rostellifera* vegetation on Lot 1409 has been reduced to an extent that the areas were rated as Degraded. The larger stand of Rottnest Island Tea Tree was assessed as being in Very Good condition. One area of *Acacia rostellifera* vegetation near the south-west corner of Lot 15 had a lower dominance of weed species and was rated as Very Good.

**Table 3: Vegetation Condition Rating Scale.**

| | |
|---|---|
| Pristine | Pristine or nearly so, no obvious signs of disturbance. |
| Excellent | Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species. |
| Very Good | Vegetation structure altered, obvious signs of disturbance.<br>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 disturbance. Retains basic vegetation structure or ability to regenerate it.<br>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.<br>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 are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs. |

Source: Government of Western Australia, 2000.

### 3.4.4 Conservation Significance of Vegetation and Flora

*Vegetation – Regional Significance using Beard Vegetation Community Types*

According to Beard (1976) the vegetation on the site belongs to Beard's Vegetation Community 431 (*Acacia rostellifera* open shrubland). Vegetation Community 431 is restricted to the Geraldton Sandplains bioregion between Kalbarri and Dongara.

The Beard Vegetation Community 431 has 73.76% of its original extent of 4,460ha remaining (Ecoscape 2011 and WAPC 2010). The percentage remaining is greater than 30%, which is the EPA's minimum target retention for vegetation communities. However, the proportion of Community 431 that is within conservation reserves is very low with less than 1% reserved, or 46.75ha (WAPC 2010).

Conservation Reserve 23600 abuts the southern boundary of the site. The Reserve contains native vegetation mapped as Beard Vegetation Community 431. As Reserve 23600 is approximately 50ha in size, it is reasonable to assume that the only area of Vegetation Community 431 that is protected is actually the reserve abutting the site.

The criteria used by the EPA for identifying areas of regional significance (EPA 2008 - Guidance Statement 33) is the Comprehensive, Adequate and Representative (CAR) system. According to the CAR system, it is desirable to have representative and viable areas of each vegetation type reserved throughout its distribution. Reserve 23600 to the south of the site would appear to satisfy the protection of Vegetation Community 431 in this part of the Community's distribution. Two quadrats surveyed in the Reserve as part of this flora and vegetation survey (F6 and F9 in Appendix 2) confirm that the vegetation in the Reserve is very similar to the dominant *Acacia rostellifera* vegetation on the site. Therefore, as Reserve 23600 is completely covered in native vegetation in better condition than on the subject site the Reserve could be considered to adequately protect a representative example of vegetation community 431 in the Dongara area.

The conclusion in this report is that on the basis of the Beard vegetation community types the vegetation on the site is not considered to be regionally significant.

*Vegetation – Regional Significance using Dongara to Cape Burney Vegetation Survey*

A survey of the coastal strip between Dongara and Cape Burney was initiated by the Department of Planning, the City of Geraldton-Greenough and the Shire of Irwin to provide guidance for future planning of the area. The survey undertaken by Ecoscape (2010) described and mapped the vegetation types and condition in a 6,400ha area between Dongara and Cape Burney and included the survey area the subject of this report. Following statistical analysis of the quadrat data, a total of nine plant communities were identified.

The Dongara to Cape Burney Coastal Vegetation Survey mapped two vegetation types on the site as follows:

> Community 7 – Taller Dune Slope *Acacia rostellifera, Alyxia buxifolia, Melaleuca depressa* and *Templetonia retusa* shrubland
>
> Community 8 – Dune Swale and Greenough Alluvial Flats *Melaleuca* Forest or tall shrubland.

Community type 7 matches the description of vegetation types Ar and ArAh mapped in this report (Figure 2). Community type 8 matches the description of vegetation type MlAr mapped in this report (Figure 2).

The Dongara to Cape Burney survey mapped another community type (Community 9 – Mallee *Eucalyptus obtusiflora* and *Eucalyptus oraria*) immediately to the north but not on the site. The more detailed survey undertaken for this report considers that this community also occurs in a very small part of the site, coinciding with the EoAr vegetation type on Figure 2.

The Dongara to Cape Burney survey did not consider any of the nine vegetation communities described and mapped for that area had regional significance.

*Vegetation - Local*

Vegetation can have local significance for a number of reasons including the retention of bushland with linkage value, aesthetic value, and the protection of local flora and fauna.

The Dongara to Cape Burney Coastal Vegetation Survey considered that seven of the nine plant communities identified in that survey had local significance due to their restricted extent in the Dongara to Cape Burney study area.

The *Acacia rostellifera* dominated vegetation of Community 7 was not one of the locally significant vegetation types as it was found to be the most widespread vegetation community in the region.

The condition of the *Acacia rostellifera* dominated vegetation on the site was mostly in Good condition and indicated that the upper *Acacia rostellifera* canopy retained its natural structure whereas the understorey was significantly altered and was dominated by weeds. This survey concludes that the *Acacia rostellifera* dominated vegetation is not likely to be floristically different from the *Acacia rostellifera* vegetation in the adjoining Conservation Reserve and is in poorer condition. Given the low significance of the vegetation type, and its local protection in the Conservation Reserve, the *Acacia rostellifera* vegetation on the site is not considered to be locally significant.

Community 8, which represents the *Melaleuca lanceolata* vegetation on the site, was considered locally significant in the Dongara to Cape Burney Coastal Vegetation Survey as it was only recorded from 174ha in the Dongara to Cape Burney area. The large stand of *Melaleuca lanceolata* on the site is mostly in Very Good condition and is of a size (around 5ha) and uniform shape that could retain its current environmental values in the long term. This report recommends protection of as much of the large stand of *Melaleuca lanceolata* in Public Open Space as possible.

Community 9, which represents the small area of *Eucalyptus obtusiflora* on the site, was also considered to be locally significant as it only occupied 33ha of the area and was one of the least represented of the plant communities in the Dongara to Cape Burney study area. The area of vegetation on the site containing *Eucalyptus obtusiflora* was very small and in poor condition. However, given that this vegetation type is uncommon in the Dongara area, retention of this stand is recommended. To make the vegetation a viable size, additional areas of native vegetation on the site could be retained alongside this area, or the area could be made contiguous with the Reserve immediately adjacent to the south.

*Flora*

The coastal strip between Dongara and Cape Burney has a very low number of conservation significant species (Ecoscape 2010) and this survey confirmed that no Declared Rare Flora or Priority listed flora were recorded on the. The site therefore does not have a high conservation significance for flora species.

# 4 SUMMARY AND CONCLUSIONS

The flora and vegetation survey of Lots 10, 15, 16, 17 and 1409 Francisco Road Dongara resulted in the following findings:

- A total of 55 species were recorded during the spring flora survey, consisting of 33 native species and 22 introduced species. The very low number of native species and high proportion of introduced species (40%) reflects the generally naturally low species richness of Quindalup dunes as well as the overall low condition of the site;
- None of the species is a Threatened (Declared Rare) or Priority listed flora;
- Four vegetation types were described and mapped for the site. The most dominant vegetation was *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub. Two areas containing *Melaleuca lanceolata* (Rottnest Island Tea Tree) including a 5ha stand in Very Good condition occurs on the site as does a very small stand containing the Dongara Mallee (*Eucalyptus obtusiflora*);
- The condition of the vegetation was mostly Good and reflected the high proportion of weeds in the understorey which was most likely due to past grazing on the site;
- None of the vegetation types is a Threatened or Priority Ecological Community;
- The vegetation is mapped as Beard Vegetation Complex 431 (*Acacia rostellifera* open shrubland). Vegetation Community 431 has nearly 73.76% of its original extent remaining, however only around 1% of it is in secure reserves. The reserve protecting this Complex is Conservation Reserve 23600 located immediately south of the site and protects around 50ha of Community 431 in very good condition. The vegetation on the site is therefore considered to not have regional significance;
- The *Acacia rostellifera* dominated vegetation is considered by the Dongara to Cape Burney Coastal Vegetation Survey to be widespread and not have local significance;
- The larger *Melaleuca lanceolata* (Rottnest Island Tea Tree) stand and the area containing the Dongara Mallee (*Eucalyptus obtusiflora*) are considered to be locally significant as they are not widespread in the Dongara area. These areas are recommended for protection in Public Open Space.

# 6 REFERENCES


Beard, J.S. (1976). *The vegetation of the Dongara area, Western Australia: map and explanatory memoir, 1:250,000 series.* Vegmap Publications, Perth.

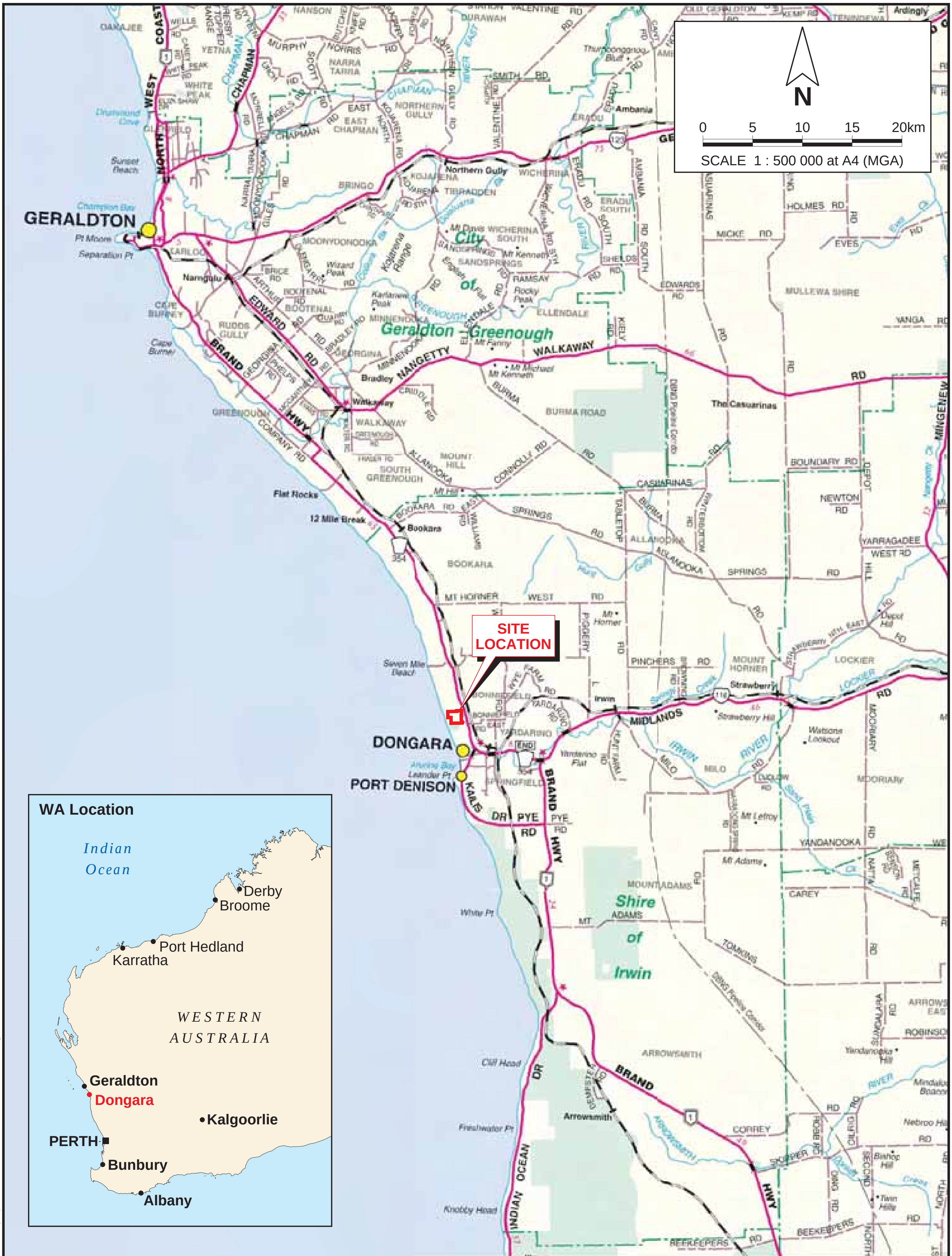
Ecoscape Pty Ltd (2010). *Dongara to Cape Burney Coastal Vegetation Survey.* Prepared for the Northern Agricultural Catchment Council.

Environmental Protection Authority (2008). *Environmental Guidance for Planning and Development*. Guidance Statement No. 33.

Landform Research (2005). *LandCapability and Geotechnical Assessment Lots 10, 15, 16 and 17 Francisco Road, Dongara.*

Western Australian Planning Commission (2010). *Geraldton Regional Flora and Vegetation Survey*. Prepared by the Department of Planning and supported by Ecoscape (Australia) Pty Ltd.

# FIGURES




pgv ENVIRONMENTAL

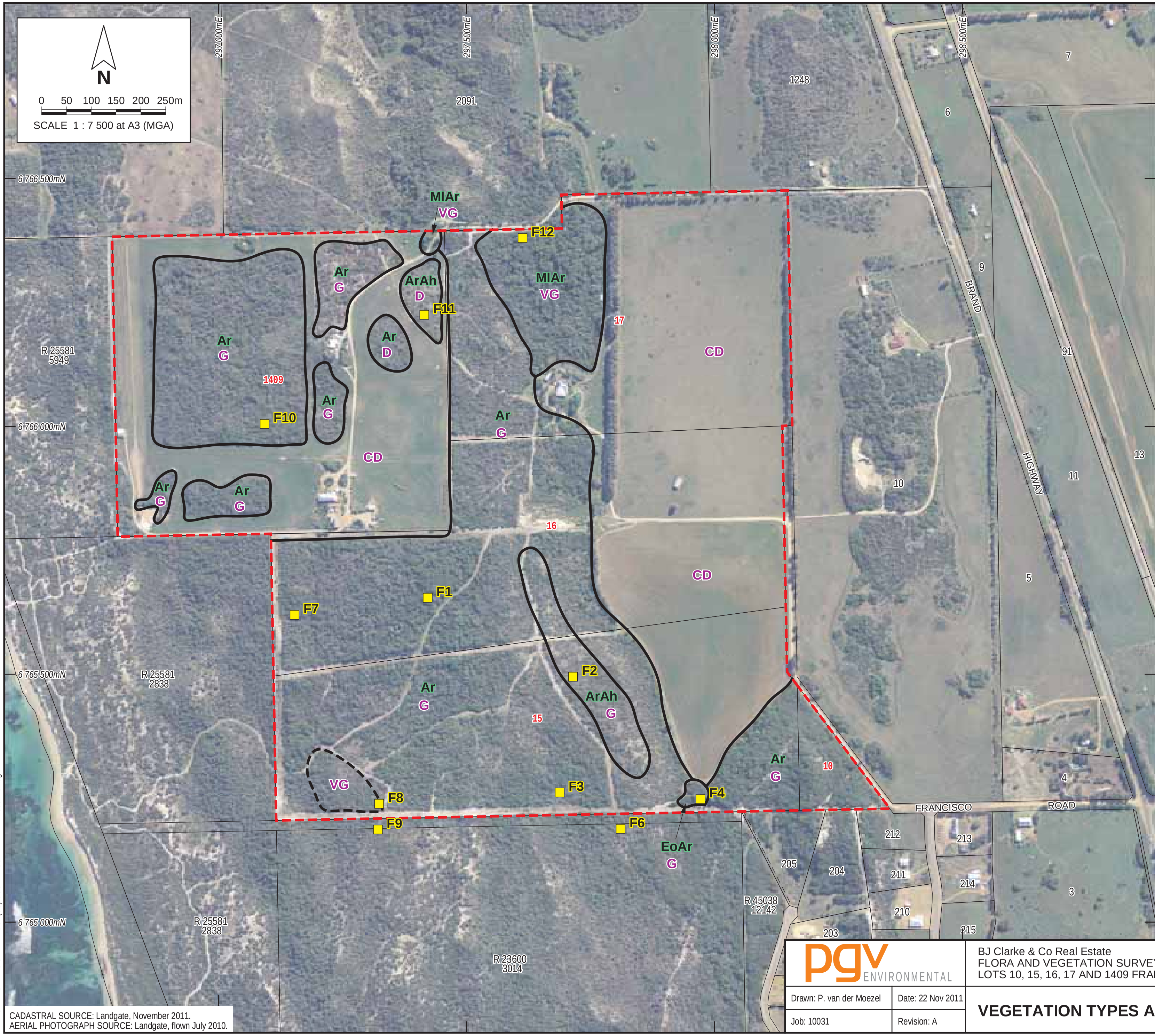
BJ Clarke & Co Real Estate
FLORA AND VEGETATION SURVEY
LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

| | |
|---|---|
| Drawn: P. van der Moezel | Date: 22 Nov 2011 |
| Job: 10031 | Revision: A |

## SITE LOCATION

Figure 1

PINPOINT CARTOGRAPHICS (08) 9562 7136 10031-f01.dgn




**Legend**

- Site Boundary
- Cadastral Boundary
- Quadrat Location
- Vegetation Type Boundary
- Vegetation Condition Boundary
- **Ar** Vegetation Type
- G Vegetation Condition

**Vegetation Legend**

**Ar** *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub

**ArAh** *Acacia rostellifera/Alyogyne huegelii* Open Heath

**MlAr** *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland

**EoAr** *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub

**Vegetation Condition Legend**
(Source: BUSH FOREVER Govt. of W.A., 2000)

**P - Pristine**
Pristine or nearly so, no obvious signs of disturbance.

**Ex - Excellent**
Vegetation structure intact, disturbance affecting individual species and weeds are non aggressive species.

**VG - 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.

**G - Good**
Vegetation structure significantly altered by very obvious signs of multiple disturbance. 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.

**D - 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.

**CD - Completely Degraded**
The structure of the vegetation is no longer intact and the areas is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora composing weed or crop species with isolated native trees or shrubs.

**Cl - Cleared**
No native vegetation remaining.

pgv ENVIRONMENTAL

BJ Clarke & Co Real Estate
FLORA AND VEGETATION SURVEY
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|---|---|
| Job: 10031 | Revision: A |

**VEGETATION TYPES AND CONDITION**

**Figure 2**

# APPENDIX 1

# DEC Database Searches

**DECLARED RARE AND PRIORITY FLORA LIST**
**16 September 2010**

| SPECIES / TAXON | CONS CODE | DEC REGION | DISTRIBUTION | FLOWER PERIOD |
|---|---|---|---|---|
| Anthocercis intricata | 3 | MW | Dongara, Port Gregory, Denham, Kalbarri | Jun-Sep |
| Comesperma rhadinocarpum | 2 | MW,SW | Mullewa, Kenwick, Cataby, (Greenough River, Irwin River) | Oct-Nov |
| Conostylis micrantha | T | MW | N of Irwin River | Jul-Aug |
| Cryptandra pendula | 1 | MW | Allanooka | Jul,Aug |
| Eucalyptus macrocarpa x pyriformis | 3 | MW,WB | N of Bolgart, Calingiri, Piawaning, Wongan Hills, Watheroo, Irwin View, Moora | - |
| Eucalyptus zopherophloia | 4 | MW | Dongara, Cliff Head, Illawong, Jurien Bay, Peron Peninsula, Zuytdorp, Eurardy | Nov-Jan |
| Haloragis foliosa | 3 | MW | Winchester, Arrowsmith, Leeman, Beekeepers Reserve, Cliff Head, Dongara | Oct |
| Stylidium carnosum subsp. narrow leaves (JA Wege 490) | 1 | MW | Dongara, Lake Indoon | Sep,Oct |
| Stylidium pseudocaespitosum | 2 | MW | Bookara, Walkaway, Burma Road NR | Sep |

WAHERB SPECIMEN DATABASE
GENERAL ENQUIRY

Acacia telmica
A.R.Chapman & Maslin (Fabaceae)
CONSERVATION STATUS:3
Coll.: A.M. Ashby 5037 Date: 06 08 1974 ( PERTH 00806110 )
LOCALITY Ca 65 km S of Geraldton, found 50 yards from Milo road near Dongara WA
LAT 29 Deg 15 Min Sec S LONG 114 Deg 59 Min Sec E
Previous det.: Acacia telmica A.R.Chapman & Maslin

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: R. Davis 3244 Date: 28 05 1997 ( PERTH 04869451 )
LOCALITY Brand Highway, 5.8 km S of Dongara turnoff, WA
LAT 29 Deg 18 Min 39.500 Sec S LONG 115 Deg 0 Min 32.200 Sec E
Erect, climbing shrub 2 m high x 2 m wide. Sprawling over other shrubs. Flowers white, faint smell. Hard, smooth bark.
Plain, dry, littered, brown sandy clay over limestone. Scrub, Acacia rostellifera.
Abundance: occasional.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: J.S. Beard B 2532 Date: 02 06 1963 ( PERTH 06007309 )
LOCALITY Port Denison Golf Course, WA
LAT 29 Deg 16 Min Sec S LONG 114 Deg 55 Min Sec E
Spreading, partly scandent shrub; 6 ft high; flowers white. On sand and limestone. In mallee.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: R. Davis 9841 Date: 18 07 2001 ( PERTH 05872863 )
LOCALITY 9.6 km SSE along Kalis Street from Port Denison, Dongara, alternative route, WA
LAT 29 Deg 18 Min 59.200 Sec S LONG 114 Deg 59 Min 16.500 Sec E
Erect, compact, perennial shrub. 2 m high x 2 m wide. White flowers. Immature fruits present. Growth phase active.
Hill. Brown/grey sand/loam over limestone. Scrubland. 80+% of population flowering.
Frequency:occasional.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: G. Woodman, C. Godden, A. Harris & F. ARC 47.1 Date: 03 08 2004 ( PERTH 07130880 )
LOCALITY Immediately E of Port Denison, Shire of Irwin WA
LAT 29 Deg 16 Min 17.500 Sec S LONG 114 Deg 55 Min 44.300 Sec E
Sand dune crest. Pale brown sand. Low Forest over mixed shrubland over grasses and herbs.
Associated species:
Alyogyne huegelii, Rhagodia preissii subsp. obovata, Acanthocarpus preissii, Acacia rostellifera, Myoporum tetrandrum.
Healthy population.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: W.E. Blackall 2643 Date: 16 09 1932 ( PERTH 01243802 )
LOCALITY Dongara, S of Geraldton, within 200 yards of sea WA
LAT 29 Deg 14 Min 35.000 Sec S LONG 114 Deg 55 Min 54.000 Sec E

Loose straggling shrub, 3-4 ft. Flowers white. Checked in W.E. Blackall's collecting book. M.A. Lewington 13/8/2009
Previous det.: Anthocercis intricata F. Muell.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: W.E. Blackall 2643 Date: 16 09 1932 ( PERTH 01243810 )
LOCALITY Dongara, S of Geraldton, within 200 yards of sea WA
LAT 29 Deg 14 Min 35.000 Sec S LONG 114 Deg 55 Min 54.000 Sec E
Loose straggling shrub, 3-6 ft. Flowers white. Checked in W.E. Blackall's collecting book. From identical comment
and location, this is an unrecognised duplicate of 2643. M.A. Lewington 13/8/2009.
Previous det.: Anthocercis intricata F. Muell.

Banksia elegans
Meisn. (Proteaceae)
CONSERVATION STATUS:4
Coll.: J.S. Beard 7225 Date: 31 10 1974 ( PERTH 1149717 )
LOCALITY 7 miles W [E?] of Geraldton Highway at a point 9 miles N of Dongara. [Ca 8 km W of Mount Horner]. WA
LAT 29 Deg 7 Min Sec S LONG 115 Deg 0 Min Sec E
Shrub 5 ft, flower greenish-yellow. Scrub heath. New locality?

Calytrix eneabbensis
Craven (Myrtaceae)
CONSERVATION STATUS:4
Coll.: F.W. Humphreys 48 Date: 21 10 1966 ( PERTH 1022520 )
LOCALITY S of turnoff to Eneabba on road from Dongara. WA
LAT 29 Deg 15 Min Sec S LONG 114 Deg 56 Min Sec E
Previous det.: Calytrix aff. gracilis

Dampiera tephrea
Rajput & Carolin (Goodeniaceae)
CONSERVATION STATUS:2
Coll.: G. Woodman, C. Godden, A. Harris & F. ARC 126.2 Date: 12 08 2004 ( PERTH 07130929 )
LOCALITY S of Dongara and immediately E of Brand Highway WA
LAT 29 Deg 18 Min 15.000 Sec S LONG 115 Deg 0 Min 37.700 Sec E
Upper crest. Yellow-brown sand over limestone. Degraded Heath dominated by Melaleuca. Melaleuca ? leuropoma, Hakea prostrata,
Guichenotia ledifolia, Petrophile brevifolia, Scholtzia umbellifera, Acanthocarpus preissii, Muelenbeckia adpressa. Healthy population.

Dampiera tephrea
Rajput & Carolin (Goodeniaceae)
CONSERVATION STATUS:2
Coll.: G. Woodman, C. Godden, A. Harris & F. ARC 88.3 Date: 09 08 2004 ( PERTH 07130937 )
LOCALITY N of Dongara WA
LAT 29 Deg 10 Min 24.800 Sec S LONG 114 Deg 57 Min 17.900 Sec E
Mid-upper slope. Brown sand over limestone. Heath. Melaleuca ? systena, Jacksonia hakeoides, Acacia rostellifera,
Scholtzia umbellifera, Desmocladus asper, Acacia pulchella var pulchella, Conostylis candicans subsp. calcicola.

Eucalyptus ebbanoensis
subsp. photina Brooker & Hopper (Myrtaceae)
CONSERVATION STATUS:4
Coll.: A.S. George 7854 Date: 04 09 1966 ( PERTH 1370952 )
LOCALITY 27 miles SE of Walkaway, WA
LAT 29 Deg 16 Min Sec S LONG 115 Deg 0 Min 0.000 Sec E

Smooth-barked mallee to 3 m.
Previous det.: Eucalyptus ebbanoensis subsp. photina Brooker & Hopper
Grevillea erinacea
Meisn. (Proteaceae)
CONSERVATION STATUS:3
Coll.: R. Davis 9859 Date: 19 07 2001 ( PERTH 05874319 )
LOCALITY 11.7 km E along Mount Horner West Road from junction of Brand Highway, ca 18 km NNE of Dongara, WA
LAT 29 Deg 6 Min 58.300 Sec S LONG 115 Deg 0 Min 53.100 Sec E
Erect, open, perennial shrub. 1.7 m high x 1.5 m wide. Deep tap roots, tight bark texture. Mature fruits present. Growth phase active. Brown loam.
Banksia woodland. 80% of population flowering.
Frequency:occasional.

Grevillea tenuiloba
C.A.Gardner (Proteaceae)
CONSERVATION STATUS:3
Coll.: R. Wilkins s.n. Date: 01 09 1982 ( PERTH 1021338 )
LOCALITY Grid square 1504, Irwin River WA
LAT 29 Deg 15 Min Sec S LONG 115 Deg 0 Min Sec E
Semi prostrate shrub. Flowers orange.
Liparophyllum congestiflorum
(F.Muell.) Tippery & Les (Menyanthaceae)
CONSERVATION STATUS:4
Coll.: A.S. George 9224 Date: 18 10 1967 ( PERTH 1099108 )
LOCALITY Near 257 mile peg, Geraldton Highway. [ca 46 km N of Mingenew on the Geraldton Highway) WA
LAT 29 Deg 15 Min 0.000 Sec S LONG 115 Deg 0 Min 0.000 Sec E
Damp, sandy creek bed. Acacia cyanophylla.
Previous det.: Villarsia congestiflora F.Muell.

A search was undertaken on the Department's Threatened Ecological Communities database. Please note that there are no known occurrences of threatened ecological communities recorded within this boundary.

Please note not all priority ecological communities are currently recorded on our database. You may like to view the current list in related documents at http://www.dec.wa.gov.au/content/view/849/2017/ .

Attached are the conditions under which this information has been supplied. The information supplied should be regarded as an indication only of the threatened and priority ecological communities that may be present.

It would be appreciated if any occurrences of threatened and priority ecological communities encountered by you in the area could be reported to this Department to ensure their ongoing management. An occurrence report form and associated manual can be found at http://www.dec.wa.gov.au/content/view/5388/2237/.

Search area response information is only accurate at the time of provision. Over time, new occurrences or modifications to existing occurrences may occur as information becomes available. It is recommended that searches be re-submitted every six months where projects occur over a long period of time.

# APPENDIX 2

# Quadrat Data

**QUADRAT F1**

**29°13.301'S 114°54.955'E**

**Vegetation**: *Acacia rostellifera* Closed Tall Scrub
**Condition**: Good
**Soil Type**: Brown-grey sand
**Landform**: Lower slope of dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 3 | 80 |
| **Euphorbia terracina* | 0.8 | 2 |
| **Urospermum picroides* | 0.6 | 70 |
| **Sonchus oleraceus* | 0.5 | 10 |
| **Avena fatua* | 0.5 | 1 |
| **Bromus diandrus* | 0.5 | 1 |
| *Rhagodia baccata* | 0.5 | <1 |
| **Poa annua* | 0.3 | 2 |

* introduced species

## QUADRAT F2

**29°13.390'S 114°55.134'E**

**Vegetation**: *Acacia rostellifera/ Alyogne sp* Open Heath
**Condition**: Good
**Soil Type**: Yellow-grey sand
**Landform**: Upper slope of moderate dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 1.5-2 | 40 |
| *Alyogyne huegelii* | 2 | 5 |
| *Austrostipa elegantissima* | 1.2 | 2 |
| **Avena fatua* | 1 | 10 |
| *Diplolaena grandiflora* | 1 | 1 |
| *Rhagodia baccata* | 1 | 1 |
| **Vulpia myuros* | 0.8 | 15 |
| **Brassica tournefortii* | 0.8 | 2 |
| *Ptilotus divaricatus* | 0.8 | 1 |
| **Urospermum picroides* | 0.5 | 2 |
| *Threlkeldia diffusa* | 0.5 | <1 |
| **Sonchus oleraceus* | 0.4 | 1 |
| **Euphorbia terracina* | 0.3 | 1 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

## QUADRAT F3

**29°13.516'S 114°55.115'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Good
**Soil Type**: Brown-grey sand
**Landform**: Bottom of valley

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 3 | 70 |
| **Avena fatua* | 1 | 5 |
| *Rhagodia baccata* | 1 | 1 |
| **Brassica tournefortii* | 0.5 | <1 |
| **Urospermum picroides* | 0.4 | 50 |
| **Sonchus oleraceus* | 0.4 | 10 |
| **Euphorbia peplus* | 0.4 | 2 |
| **Vulpia myuros* | 0.3 | 1 |
| *Threlkeldia diffusa* | 0.3 | <1 |
| **Ehrharta calycina* | 0.3 | <1 |
| **Arctotheca calendula* | 0.2 | <1 |
| **Solanum nigrum* | 0.1 | <1 |
| **Trifolium dubium* | 0.1 | <1 |
| *Clematis linearifolia* | creeper | 2 |

* introduced species

**QUADRAT F4**

**29°13.526'S 114°55.290'E**

**Vegetation**: *Eucalyptus obrusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub
**Condition**: Degraded - Good
**Soil Type**: Brown loamy sand
**Landform**: Bottom of valley

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Eucalyptus obtusiflora* | 6-7 | 30 |
| **Lycium ferocissimum* | 2 | 40 |
| *Acacia rostellifera* | 2 | 10 |
| **Poa annua* | 0.3 | 20 |
| **Sonchus oleraceus* | 0.3 | 10 |
| **Cerastium glomeratum* | 0.3 | 10 |
| **Euphorbia peplus* | 0.3 | 5 |

* introduced species

## QUADRAT F6

**29°13.557'S 114°55.190'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Good
**Soil Type**: Yellowish-grey sand
**Landform**: Upper slope of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 2-4 | 40 |
| *Alyogyne huegelii* | 1.5 | 5 |
| *Austrostipa elegantissima* | 1.2 | 10 |
| **Avena fatua* | 1 | 5 |
| *Rhagodia baccata* | 1 | 1 |
| **Urospermum picroides* | 0.3 | 2 |
| **Sonchus oleraceus* | 0.5 | 5 |
| **Bromus diandrus* | 0.5 | 5 |
| *Ptilotus divaricatus* | 0.4 | 1 |
| **Euphorbia peplus* | 0.3 | 2 |
| **Ehrharta calycina* | 0.3 | 2 |
| *Zygophyllum fruticulosum* | creeper | 20 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

**QUADRAT F7**

**29°13.317'S 114°54.789'E**

**Vegetation**: *Acacia rostellifera* Closed Tall Scrub
**Condition**: Good
**Soil Type**: Brownish sand
**Landform**: Upper slope of dune

**QUADRAT (10 x 10m) Pegs:** Non-permanent quadrat

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 5 | 80 |
| *Acanthocarpus preissii* | 1 | 1 |
| *Rhagodia baccata* | 0.6 | <1 |
| **Urospermum picroides* | 0.3 | 25 |
| **Sonchus oleraceus* | 0.3 | 2 |
| **Bromus diandrus* | 0.3 | 30 |
| **Euphorbia peplus* | 0.2 | 15 |
| **Lysimachia arvensis* | 0.3 | 2 |
| **Euphorbia terracina* | 0.3 | 1 |
| **Poa annua* | 0.4 | <1 |
| *Clematis linearifolia* | creeper | 25 |
| *Zygophyllum fruticulosum* | creeper | 1 |

* introduced species

## QUADRAT F8

**29°13.525'S   114°54.890'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Very Good
**Soil Type**: Whitish grey sand
**Landform**: Top of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 2 | 60 |
| *Leptomeria empetriformis* | 1.2 | <1 |
| *Diplolaena grandiflora* | 1 | 10 |
| *Austrostipa flavescens* | 1 | <1 |
| **Avena fatua* | 1 | <1 |
| *Rhagodia baccata* | 1 | 1 |
| **Bromus diandrus* | 0.3 | <1 |
| *Enchylaena tomentosa* | 0.4 | 2 |
| *Scaevola crassifolia* | 0.4 | 1 |
| *Acanthocarpus preissii* | 0.3 | 1 |
| **Wahlenbergia capensis* | 0.2 | 1 |
| *Parietaria debilis* | 0.2 | 1 |
| *Trachymene pilosa* | 0.1 | 10 |
| *Calandrinia liniflora* | 0.1 | <1 |
| *Zygophyllum fruticulosum* | creeper | 20 |
| *Cassytha racemosa* | creeper | 1 |

* introduced species

## QUADRAT F9

**29°13.553'S 114°54.888'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Very Good
**Soil Type**: Brownish-grey sand
**Landform**: Top of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 1.5-3 | 40 |
| *Austrostipa flavescens* | 1 | 2 |
| **Avena fatua* | 1 | <1 |
| **Bromus diandrus* | 0.4 | 2 |
| *Parietaria debilis* | 0.4 | <1 |
| *Acanthocarpus preissii* | 0.4 | <1 |
| *Threlkeldia diffusa* | 0.3 | 5 |
| *Senecio pinnatifolius var. maritimus* | 0.3 | 1 |
| **Ehrharta calycina* | 0.3 | 1 |
| *Calandrinia liniflora* | 0.2 | <1 |
| *Trachymene pilosa* | 0.1 | <1 |
| **Lysimachia arvensis* | 0.1 | <1 |
| **Crassula glomerata* | 0.1 | <1 |
| *Zygophyllum fruticulosum* | creeper | 40 |
| *Cassytha racemosa* | creeper | 1 |
| *Thysanotus patersonii* | creeper | <1 |

* introduced species

**QUADRAT F10**

**29°13.108'S 114°54.756'E**

**Vegetation**: *Acacia rostellifera* Closed Tall Scrub
**Condition**: Good
**Soil Type**: Grey sand
**Landform**: Lower valley slope

**QUADRAT (10 x 10m)** **Peg:** Non-permanent quadrat

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 3-5 | 80 |
| *Rhagodia baccata* | 1.5 | 1 |
| **Lycium ferocissimum* | 1.2 | 2 |
| **Euphorbia terracina* | 0.8 | 30 |
| **Bromus diandrus* | 0.4 | 1 |
| **Urospermum picroides* | 0.4 | 5 |
| **Sonchus oleraceus* | 0.4 | 5 |
| **Euphorbia peplus* | 0.3 | 20 |
| **Ehrharta calycina* | 0.8 | 1 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

**QUADRAT F11**

**29°12.992'S 114°54.957'E**

**Vegetation**: *Acacia rostellifera* Shrubland
**Condition**: Degraded
**Soil Type**: Grey sand
**Landform**: Top of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 1.5 | 10 |
| *Rhagodia baccata* | 1 | 1 |
| **Lycium ferocissimum* | 1 | 20 |
| **Avena fatua* | 1 | 10 |
| *Anthobolus foveolatus* | 1 | 2 |
| *Acanthocarpus preissii* | 0.5 | 5 |
| **Brassica tournefortii* | 0.5 | 1 |
| **Bromus diandrus* | 0.4 | 70 |
| **Urospermum picroides* | 0.4 | 2 |
| **Salsola tragus* | 0.4 | <1 |
| **Sonchus oleraceus* | 0.3 | 1 |
| **Ehrharta calycina* | 0.3 | 1 |
| **Euphorbia peplus* | 0.2 | 10 |

* introduced species

**QUADRAT F12**

**29°12.910'S 114°55.081'E**

**Vegetation**: *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland
**Condition**: Very Good
**Soil Type**: Dark grey sand
**Landform**: Lower to mid-slope of dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Melaleuca lanceolata* | 8 | 50 |
| *Acacia rostellifera* | 4 | 20 |
| *Spyridium globulosum* | 1.2 | 1 |
| *Rhagodia sp* | 1 | 75 |
| *Rhagodia baccata* | 1 | 10 |
| *Diplolaena grandiflora* | 1 | 1 |
| *Acanthocarpus preissii* | 0.5 | 2 |
| *Enchylaena tomentosa* | 0.5 | 5 |
| **Parietaria debilis* | 0.3 | 20 |
| **Poa annua* | 0.3 | 10 |
| **Sonchus oleraceus* | 0.3 | <1 |
| *Zygophyllum fruticulosum* | creeper | 2 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

# APPENDIX 3

## Flora List

**SPECIES LIST – Lots 10, 15,16,17 and 1409 Francisco Road**

**MONOCOTYLEDONS**

ASPARAGACEAE
*Acanthocarpus preissii*
*Thysanotus patersonii*

POACEAE
*Austrostipa elegantissima*
*Austrostipa flavescens*
**Avena fatua*
**Briza maxima*
**Bromus diandrus*
**Ehrharta calycina*
**Poa annua*
**Vulpia myuros*

**DICOTYLEDONS**

AMARANTHACEAE
*Ptilotus divaricatus*

APIACEAE
*Trachymene pilosa*

ASTERACEAE
**Arctotheca calendula*
*Senecio pinnatifolius* var. *maritimus*
**Urospermum picroides*
**Sonchus oleraceus*

BORAGINACEAE
**Echium plantagineum*

BRASSICACEAE
**Brassica tournefortii*

CAMPANULACEAE
**Wahlenbergia capensis*

CARYOPHYLLACEAE
**Cerastium glomeratum*

CHENOPODIACEAE
*Enchylaena tomentosa*
*Rhagodia preissii* subsp. *latifolia*
*Rhagodia sp.*
**Salsola tragus*
*Threlkeldia diffusa*

DILLENIACEAE
*Hibbertia subvaginata*

EUPHORBIACEAE
**Euphorbia peplus*
**Euphorbia terracina*

FABACEAE
*Acacia rostellifera*
**Trifolium dubium*
**Trifolium sp.*

GOODENIACEAE
*Scaevola crassifolia*

LAURACEAE
*Cassytha racemosa*

LORANTHACEAE
*Anthobolus foveolatus*
*Amyema preissii*

MALVACEAE
*Alyogyne huegelii*
*Rulingia borealis*

MYRTACEAE
*Eucalyptus obtusiflora subsp. dongarraensis*
*Melaleuca cardiophylla*
*Melaleuca lanceolata*

PORTULACCACEAE
*Calandrinia liniflora*

PRIMULACEAE
**Lysimachia arvensis*

RANUNCULACEAE
*Clematis linearifolia*

RHAMNACEAE
*Stenanthemum notiale*

RUTACEAE
*Diplolaena grandiflora*

SANTALACEAE
*Anthobolus foveolatus*
*Santalum acuminatum*

SOLANACEAE

*Anthocercis littorea*
**Lycium ferocissimum*
**Solanum nigrum*
*Solanaceae sp.*

STERCULIACEAE
*Rulingia borealis*

URTICACEAE
*Parietaria debilis*

ZYGOPHYLLACEAE
*Zygophyllum fruticulosum*

# APPENDIX 4

## Level 1 Fauna Assessment 2012 (PGV Environmental)

# LOTS 15, 16, 17, 1409 AND PT LOT 10 FRANCISCO ROAD, DONGARA

## LEVEL 1 FAUNA ASSESSMENT

| | |
|---|---|
| Prepared for: | Ben Clarke |
| Report Date: | 18 June 2012 |
| Version: | 2 |
| Report No. | 2012-51 |

PGV ENVIRONMENTAL

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Figure 1: Site Location

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**Appendices**


Appendix 1: DEC Database Search Results

Appendix 2: NatureMaps Database Reports

Appendix 3: Conservation Codes

Appendix 4: Protected Matter Search Tool Report

# 1 INTRODUCTION

## 1.1 Background

Lots 10, 15, 16, 17 and 1409 Francisco Road, Dongara (the site) are located close to the coast to the west of Brand Highway approximately 3km north of the Dongara town centre. The site is currently being considered by the Department of Planning for its potential urban development to accommodate the future expansion of Dongara.

The owners of the lots are assisting the Department of Planning by undertaking planning and environmental work to investigate the opportunities and constraints to future urban development. This Level 1 Fauna Assessment has been commissioned by the landowners as part of those investigations.

## 1.2 Level 1 Fauna Assessment

The Level 1 Fauna Assessment was undertaken in accordance with EPA *Guidance for Assessment of Environmental Factors: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, No. 56* (EPA, 2004). This assessment involves a 'desktop' study of the site and a site investigation.

The scope of works for the Level 1 Fauna Assessment included desktop searches of databases such as:

- A review of the Department of Environment and Conservation's (DEC) NatureMaps database to identify fauna that has been previously recorded in the project vicinity. This database includes records from the Western Australian Museum, the DEC Fauna Returns database, the Swan Coastal Plain survey and other opportunistic records lodged with the DEC;
- A review of the DEC's Threatened and Priority Species database to identify potential scheduled and threatened species within the region; and
- A review of the Commonwealth Government's database of fauna of national environmental significance to identify species potentially occurring within the area that are protected under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* or international migratory bird agreements (JAMBA/CAMBA).

A level 2 Flora and Vegetation Survey was undertaken on the site in 2011 by PGV Environmental (PGV, 2011) and the results of this study and observations from the survey have been included to identify available fauna habitat types and condition. A landowner that has lived on part of the site for over twenty years was also interviewed.

This Level 1 Fauna Assessment also includes:

- A review of the significance of the site for conservation significant species in a local and regional context;
- Advice on project requirements to satisfy the Commonwealth EPBC Act 1999 or State Legislation; and
- Recommendations on:

- any additional species-specific searches that may be required for conservation significant species within the site; and
- appropriate methodologies for any follow-up comprehensive fauna surveys necessary to identify species of conservation significance or fauna assemblages that are important and likely to be impacted with the construction work.

# 2 EXISTING ENVIRONMENT

## 2.1 Land Use

Part Lot 10 west of Francisco Road currently consists of undeveloped native vegetation. The eastern portions of Lots 15, 16 and 17 have been cleared for agriculture while the western portions contain native vegetation. The native vegetation on these lots has been grazed in the past. A residential dwelling exists on Lot 17. Lot 1409 contains two residential dwellings, some cleared land for horse paddocks, and a central area of native vegetation.

The lots are zoned General Farming in the Shire of Irwin Town Planning Scheme No. 5.

Several tracks and firebreaks occur in the vegetated part of Lots 15, 16 and 17. The beach is located approximately 450m west of Lot 15 and 270m west of Lot 1409. The lots are separated from the coast by two Local Reserves (25581 5949 and 25581 2838) as well as a strip of Unallocated Crown Land.

Conservation Reserve 23600 abuts Lot 15 to the south and consists of native vegetation similar to that on Lot 15 and 16.

Private lots 204, 205 and 212 are located south of Part Lot 10 and a part of Lot 15 and contain native vegetation.

The balance of Part Lot 10 east of Francisco Rd abuts the eastern side of the site and has been predominantly cleared for agriculture.

Private Lots 2092, 2091 and 1248 occur to the north of the site and have been partially cleared for agriculture but retain native vegetation on the majority of the land.

## 2.2 Topography and Landform

The site is located close to the coast and includes undulating coastal Quindalup dunes on the western side and the flatter Tamala limestone landform on the eastern side. Generally the clearing for agriculture has occurred on the eastern Tamala limestone landform although some of the coastal soils on Lot 1409 have been cleared for horse paddocks.

The eastern cleared area is relatively flat from west to east but slopes generally from the north down to the south. Elevation on the eastern portion ranges from 32mAHD down to 9m AHD.

The western dunal area is undulating and ranges in elevation from 20m - 38m AHD on Lots 15-27 and 12m – 33m AHD on Lot 1409.

## 2.3 Geology and Soils

Soils on the site have been described by Landform Research (2005). The eastern Tamala limestone soils are brown sands grading to earthy sands overlying limestone at variable depth. The western Quindalup Dune soils are relatively old Quindalup dunes and therefore contain a brown to cream brown sand with minor clay and calcareous materials. The coarser nature of the older Quindalup

dunes makes them less susceptible to erosion than younger phase Quindalup dunes (Landform Research, 2005).

## 2.4 Hydrology

There are no surface water features such as creeklines, drainage lines or wetlands on the site.

Groundwater occurs under the site at an average level of around 2m AHD (Landform Research, 2005) indicating a minimum depth to groundwater of around 10m.

## 2.5 Vegetation and Flora

### 2.5.1 Vegetation Types

Four separate Vegetation Associations were described and mapped on the site (Figure 2) during a Spring Flora Survey conducted by PGV Environmental (PGV, 2011). The four vegetation types have limited diversity and are described below.

**Ar** *Acacia rostellifera* **Tall Open Scrub to Closed Tall Scrub**

This is the main vegetation on the site. The density of *Acacia rostellifera* is high, ranging from 60-80%. As a result of the high canopy density, the understorey is sparsely vegetated. Most of the species are weeds with the main native species being *Rhagodia preissii* ssp *obovata* and the creeper *Clematis linearifolia.* Common weed species include *Sonchus asper, Sonchus oleraceus, Bromus diandrus* and *Euphorbia peplus* (PGV, 2011).

**ArAh** *Acacia rostellifera/Alyogyne huegelii* **Open Heath**

A narrow band of this vegetation type occurred on the top of the eastern ridge in the Quindalup dunes on Lots 15 and 16 as well as a degraded part on the eastern side of Lot 1409. *Acacia rostellifera* was the dominant species but less dense (40%) than in the Ar vegetation above. *Alyogyne huegelii* was consistently dominant (PGV, 2011).

**MlAr** *Melaleuca lanceolata* **Low Open Forest over** *Acacia rostellifera* **Tall Shrubland**

This vegetation type occurs in two stands, one large stand approximately 5ha in size at the northern end of Lot 17 and one smaller stand in the north-east corner of Lot 1409. The *Melaleuca lanceolata* (Rottnest Island Tea Tree) trees were relatively dense with around a 50% canopy cover. The mid-storey of *Acacia rostellifera* was open (4m high and 20% cover) while the understorey was densely vegetated in ground covers. Native creepers *Zygophyllum fruticulosum* and *Clematis linearifolia* were common (PGV, 2011).

**EoAr** *Eucalyptus obtusiflora* **Tree Mallee over** *Acacia rostellifera* **Tall Open Scrub**

A very small natural stand of *Eucalyptus obtusiflora* (Dongara Mallee) occurred on the south-eastern end of Lot 15. Several *Eucalyptus obtusiflora* trees were present up to 6-7m high with an open mid-storey of *Acacia rostellifera* 2m high and a weedy understorey. The soil type was brown loamy sand (PGV, 2011).

### 2.5.2 Vegetation Condition

The vegetation condition of the site is mostly rated as Good (Figure 2). The rating of Good indicates that the upper *Acacia rostellifera* canopy was considered to be in its natural structure whereas the understorey was significantly altered. The dominance of weeds in the understorey may be due to past clearing of the whole site with subsequent re-growth of the *Acacia rostellifera* trees, or to grazing the understorey, or as a result of high frequency of fires (PGV, 2011).

The vegetation structure in some of the *Acacia rostellifera* vegetation on Lot 1409 has been reduced to an extent that the areas were rated as Degraded. The larger stand of Rottnest Island Tea Tree was assessed as being in Very Good condition. One area of *Acacia rostellifera* vegetation near the south-west corner of Lot 15 had a lower dominance of weed species and was rated as Very Good (PGV, 2011).

# 3 METHODOLOGY

## 3.1 Site Observations

The description of fauna habitats in this report was made based on the results of the 2011 Flora and Vegetation Assessment conducted by PGV Environmental.

## 3.2 Database Search

A desktop search of the DEC's NatureMap online database, DEC Threatened Fauna Database and the EPBC Protected Matters online database was used to develop a list of significant species that potentially could be present on the site. This list was then reviewed in the context of habitats present on the site and anecdotal evidence to determine the likelihood for these species to utilise the site.

## 3.3 Limitations

The conditions that the assessment was undertaken in are presented in Table 2 in order to assess the adequacy of the assessment. In summary, there were no constraints to the assessment.

**Table 1: Fauna Assessment Limitations and Constraints**

| **Possible limitations** | **Constraint (yes/no); significant, moderate or negligible** | **Comment** |
|---|---|---|
| Competency and experience of the consultant carrying out the assessment | No | The Environmental Consultants that undertook this assessment have appropriate training and experience in conducting Level one vertebrate fauna assessments throughout Western Australia. |
| Scope | No | All components required for a Level 1 Fauna assessment have been completed. |
| Proportion of fauna identified, recorded and/or collected | Yes Negligible | An on-site terrestrial fauna assessment has not been undertaken within the site; however, a large proportion of the site is degraded habitat. While the terrestrial fauna in the study area has not been directly assessed, there is sufficient data to assess the impact of development on the likely faunal assemblage. |
| Sources of information | No | Vertebrate fauna information was available from appropriate database searches and both published and unpublished reports. |
| Proportion of the task achieved | No | The assessment fulfils all of the objectives. |
| Timing/weather/season / cycle | No | The site observations were undertaken in spring weather conditions which were appropriate for this type of assessment. |

| Possible limitations | Constraint (yes/no); significant, moderate or negligible | Comment |
|---|---|---|
| Disturbances which affected results of the assessment | No | A large portion of the site is predominantly disturbed or has cleared vegetation as an understorey. This impact has been taken into account in this assessment. |
| Intensity of assessment effort | No | The intensity of the assessment is sufficient for a Level 1 Fauna Assessment. |
| Completeness | No | All major habitat types were visited. |
| Resources | No | Adequate resources were available. |
| Remoteness and/or access problems | No | There were no access problems. |
| Availability of contextual information for the region | No | DEC Threatened and Priority species lists, EPBC Act Protected Matters Search, NatureMap database search and results of previous assessments in both the surrounding area and the bioregion were available to provide comparison at both a local and regional level. |

Negligible – less than 20%; Moderate – 20-60%; Significant – greater than 60%

# 4 RESULTS

## 4.1 Fauna Habitats

Fauna habitats on the site consist of Scrub/Shrubland (Plate 1), Open Heath (Plate 2) and Low Open Forest (Plate 3) with areas of cleared land used for rural purposes (Background Plate 2). There are no areas considered to be habitat that are woodland or forest as very small area of EoAr (*Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub) consists of only two trees.

**Plate 1: Scrub/Shrubland Habitat**

**Plate 2: Open Heath /Cleared Land Habitat**

**Plate 3: Low Open Forest Habitat**

Fauna habitat can be assessed according to the following categories:

> *High quality fauna habitat – These areas closely approximate the vegetation mix and quality that would have been in the area prior to any disturbance. The habitat has connectivity with other habitats and is likely to contain the most natural vertebrate fauna assemblage.*
>
> *Very good fauna habitat - These areas show minimal signs of disturbance (e.g. grazing, clearing, fragmentation, weeds) and generally retain many of the characteristics of the habitat if it had not been disturbed. The habitat has connectivity with other habitats and fauna assemblages in these areas are likely to be minimally effected by disturbance.*

*Good fauna habitat – These areas showed signs of disturbance (e.g. grazing, clearing, fragmentation, weeds) but generally retain many of the characteristics of the habitat if it had not been disturbed. The habitat has connectivity with other habitats and fauna assemblages in these areas are likely to be affected by disturbance.*

*Disturbed fauna habitat – These areas showed signs of significant disturbance. Many of the trees, shrubs and undergrowth are cleared. These areas may be in the early succession and regeneration stages. Areas may show signs of significant grazing, contain weeds or have been damaged by vehicle or machinery. Habitats are fragmented or have limited connectivity with other fauna habitats. Fauna assemblages in these areas are likely to differ significantly from what might be expected in the area had the disturbance not occurred.*

*Highly degraded fauna habitat – These areas often have a significant loss of vegetation, an abundance of weeds, and a large number of vehicle tracks or are completely cleared. Limited or no fauna habitat connectivity. Faunal assemblages in these areas are likely to be significantly different to what might have been in the area pre-disturbance .* (Coffey Environments, 2009)

The vegetated areas in Lots 10, 15, 16 and 17 are linked to other areas of vegetation to the north, south and west. The vegetation is in Good to Very Good Condition however there are many tracks crossing the vegetated portion of the site (Figure 2). Therefore the fauna habitat in the vegetated parts of these lots would be considered to be Good Fauna Habitat.

Lot 1409 has vegetation in Degraded to Good condition and is not connected to surrounding vegetation (Figure 2). Therefore this habitat is considered to be Disturbed Fauna Habitat.

Parts of the site have been cleared in parts for agriculture and fully grazed for a number of years (Figure 2). These are classified as Highly Degraded Fauna Habitat.

## 4.2 DEC Database Search Results

A search of the DEC Threatened Fauna Database (Appendix 1) indicates that 5 species that are listed as rare or priority have been located in the vicinity of the sites. Four of these species were also identified in the Naturemaps database searches and no additional species were identified (Appendix 2; DEC, 2012a). Table 2 lists the species identified in each of these database searches.

**Table 2: List of Fauna Species Identified from DEC Database Searches.**

| **Scientific Name** | **Common Name** | **Status under Wildlife Cons. Act** | **Status under EPBC Act** |
|---|---|---|---|
| *Anous tenuirostris* subsp. *melanops* | Australian Lesser Noddy | Threatened | Vulnerable |
| *Calyptorhynchus latirostris* | Carnaby's Cockatoo | Schedule 1 | Endangered |
| *Falco peregrinus* subsp. *macropus* | Peregrine Falcon | Schedule 4 | NA |
| *Morelia spilota* subsp. *imbricata* | Carpet Python | Schedule 4 | NA |
| *Neelaps calonotos* | Black-striped Snake | Priority 3 | NA |

The DEC classifies fauna under five different Priority codes and rare and endangered fauna are classified under the Wildlife Conservation (Specially Protected Fauna) Notice 2008 into four schedules of taxa (DEC, 2011). These are outlined in Appendix 3.

## 4.3 Protected Matters Search Tool

A search of the Commonwealth Department of Sustainability, Environment, Water, Population and Communities Protected Matters Search Tool (SEWPaC, 2012a) was undertaken (Appendix 4). This database generates a report that with indicative information on matters of national environmental significance or other matters protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) within an area of interest. The results of the database search are in Appendix 4 and summarised in Table 3.

**Table 3: Results from the Protected Matters Search Tool**

| Life-form | Scientific Name | Common Name | Status under EPBC Act |
|---|---|---|---|
| Birds | *Calyptorhynchus latirostris* | Carnaby's Black Cockatoo | Endangered |
| | *Leipoa ocellata* | Malleefowl | Vulnerable |
| Migratory Marine Birds | *Apus pacificus* | Fork-tailed Swift | Marine/ Migratory |
| | *Ardea alba* | Great Egret, White Egret | Marine/ Migratory |
| | *Ardea ibis* | Cattle Egret | Marine/ Migratory |
| Migratory Terrestrial Species | *Haliaeetus leucogaster* | White-bellied Sea-Eagle | Marine/ Migratory |
| | *Merops ornatus* | Rainbow Bee-eater | Marine/ Migratory |

The definitions of conservation codes under the EPBC Act are in Appendix 3.

## 4.4 Conservation Significant Species

Outlined below is a short description of each of the species that were identified in the DEC database searches and Protected Matters Search Tool search and their preferred habitat in Table 3. The preferred habitat has been compared to the habitats on the site and the likelihood of each species to be present on the site determined.

**Australian Lesser Noddy (***Anous tenuirostris* **subsp.** *Melanops***)**

The Australian Lesser Noddy is a social bird that flies in large flocks. The Australian Lesser Noddy usually occupies coral-limestone islands that are densely fringed with White Mangrove Avicennia marina. It occasionally occurs on shingle or sandy beaches and feeds on small fish (SEWPaC, 2012b).

There are no mangroves or beaches on the site and therefore this species is highly unlikely to occur.

**Carnaby's Black Cockatoo (***Calyptorhynchus latirostris***)**

Carnaby's Cockatoo is found in the south-west of Australia from Kalbarri through to Ravensthorpe. It has a preference for feeding on the seeds of *Banksia, Dryandra, Hakea, Eucalyptus, Grevillea, Pinus* and *Allocasuarina* spp. It is nomadic often moving toward the coast after breeding. It breeds in tree hollows that are 2.5 – 12m above the ground and have an entrance 23-30cm with a depth of 1-2.5m.

Nesting mostly occurs in smooth-barked trees (e.g. Salmon Gum, Wandoo, Red Morrell). Eggs are laid from July to October, with incubation lasting 29 days (SEWPaC, 2012b).

There were no plant species identified in the Flora and Vegetation Survey (PGV, 2011) that are recognised foraging habitat. There is no breeding, potential breeding or roosting habitat on the site. Therefore this species is highly unlikely to occur on the site.

**Peregrine Falcon (*Falco peregrinus*, *Falco peregrinus* subsp. *macropus*)**

The Peregrine falcon is found in a variety of habitats from woodlands to open grasslands and coastal cliffs. It feeds almost entirely on other birds and sometimes rabbits and other moderate sized mammals, bats and reptiles (DEC, 2012b).

The Peregrine Falcon may occasionally fly over the site but the absence of coastal cliffs and scarcity of woodlands means this species is unlikely to frequent the site.

**Carpet Python (*Morelia spilota imbricata*)**

The Carpet Python is a large snake found across the south-west of Western Australia, from Northampton, south to Albany and eastwards to Kalgoorlie including undisturbed remnant bushland near Perth and the Darling Ranges. This subspecies has been recorded from semi-arid coastal and inland habitats, Banksia woodland, Eucalypt woodlands and grasslands (AROD, 2012).

This species is known from a number of locations in Dongara including in rural buildings. Individuals have been seen on the site in sheds and other buildings.

**Black-striped Snake (*Neelaps calonotos*)**

The Black-striped snake has a limited distribution, inhabiting areas with sandy soils that support heathlands and Banksia/Eucalypt Woodlands (Nevill, 2005) on the Swan Coastal Plain generally in the lower west coast from Lancelin to Mandurah (Storr et al, 1999).

The vegetation and soil on the site is not the preferred habitat of this species and Dongara is outside of its usual range. Therefore the Black -striped Snake is Unlikely to be present on the site.

**Malleefowl (*Leipoa ocellata*)**

Malleefowl have been found in mallee regions of southern Australia from approximately the 26th parallel of latitude southwards. Malleefowl are now only found throughout these regions in fragmented patches due to clearing of land for agriculture, increased fire frequency, competition with exotic herbivores (sheep, rabbits, goats and cattle) and kangaroos, predation by foxes and cats, inbreeding as a result of fragmentation and possibly hunting for food (SEWPaC, 2012b).

Malleefowl are unlikely to be found on the site due the lack of appropriate mallee habitat.

**Fork-tailed Swift (*Apus pacificus*)**

The Fork-tailed Swift is almost exclusively aerial and is not known to breed in Australia. They are seen in inland plains but sometimes above foothills or in coastal areas. They often occur over cliffs and beaches and also over islands and sometimes well out to sea. They also occur over settled areas, including towns, urban areas and cities (SEWPaC, 2012b).

This species may fly over the site on occasion.

**Great Egret, White Egret (*Ardea alba* (*modesta*))**

The Eastern Great Egret has been reported in a wide range of wetland habitats and usually frequents shallow waters (SEWPaC, 2012b). This species feeds on fish, insects, crustaceans, molluscs, frogs, lizards, snakes and small birds and mammals (SEWPaC, 2012b).

This species is highly unlikely to be found on the site as there are no wetlands or permanent water bodies on the site.

**Cattle Egret (*Ardea ibis*)**

The Cattle Egret occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands with breeding in Western Australia recorded in the far north in Wyndham in colonies in wooded swamps such as mangrove forests (SEWPaC, 2012b). This species forages away from water on low lying grasslands, improved pastures and croplands generally in areas that have livestock, eating insects, frog, lizards and small mammals (SEWPaC, 2012b).

This species has not been recorded in the area previously however it may occasionally visit the site.

**White-bellied Sea-Eagle (*Haliaeetus leucogaster*)**

The White-bellied Sea-Eagle is found in coastal habitats with large areas of open water, especially those close to the sea-shore. This species feeds opportunistically on a variety of fish, birds, reptiles, mammals and crustaceans, and on carrion and offal (SEWPaC, 2012b).

The site does not contain open water and therefore appropriate habitat for this species. The landowner is aware of Sea-eagles in the Dongara area but has never recorded any Sea-eagles on his property. Therefore the White-bellied Sea-eagle is unlikely to be found on the site.

**Rainbow Bee-eater (*Merops ornatus*)**

The Rainbow Bee-eater is a migratory bird that arrives in the south-west of WA in late September – early October and nests in a burrow dug in the ground. It is found across the better-watered parts of WA including islands preferring lightly wooded, sandy country near open water (SEWPaC, 2012b).

The site contains sandy soil habitat that may be suitable for this species and the Rainbow Bee-eater could potentially occur on the site.

# 5 SUMMARY AND CONCLUSIONS

## 5.1 Summary

The Level 1 Fauna Assessment of Lots 10, 15, 16, 17 and 1409 Francisco Road Dongara resulted in the following findings.

*Fauna Habitat*

- There are four habitats on the site that consist of Scrub/Shrubland, Open Heath, Low Open Forest and Cleared Pasture.
- The vegetated areas in Lots 10, 15, 16 and 17 was considered to be Good Fauna Habitat.
- Vegetated areas in Lot 1409 were considered to be Disturbed Fauna Habitat.
- The areas of Cleared Land were classified as Highly Degraded Fauna Habitat.

*Conservation Significant Species*

- Five conservation significant species were identified in the DEC Database as being recorded in the Dongara region. Of these four were also identified in Naturemaps search;
- The Protected Matters Search Tool identified a further six conservation significant species that could occur in the Dongara area;
- The Carpet Python (*Morelia spilota imbricata*) is known to occur on the site;
- The Peregrine Falcon (*Falco peregrinus, Falco peregrinus* subsp. *macropus*), Fork-tailed Swift (*Apus pacificus*), Cattle Egret (*Ardea ibis*) and Rainbow Bee-eater (*Merops ornatus*) were identified as potentially visiting the site.
- The remainder of the species were considered to be unlikely or highly unlikely to be found on the site due to the absence of appropriate habitat type;

*Further Studies*

Due to the low level of diversity of fauna habitat and the fact that it Good to Highly Degraded Fauna Habitat PGV Environmental believes that it is not necessary to undertake further fauna studies on the site.

*Environmental Approval Requirements*

The Rainbow Bee-eater and the Carpet Python were the only Conservation Significant species deemed to be likely to utilise the habitat on the site (rather than temporarily visit). It is not expected that this site contains significant habitat for these species. Therefore development is unlikely to a significant impact on any species protected under the *Wildlife Conservation Act 1950* or the EPBC Act.

## 5.2 Conclusion

Development of the site for urban purposes will result in most of the Scrub/Shrubland and Open Heath fauna habitat being cleared and retention of the Low Open Forest habitat. PGV Environmental considers that development of the site is highly unlikely to cause a significant impact on any fauna species of conservation significance due to the low usage potential of the site by a few species and the presence of similar habitat in adjoining reserves and the wider Dongara area.

# 6 REFERENCES


Australian Reptile Online Database (AROD) (2012) Australian Reptile Online Database http://www.arod.com.au/arod/reptilia/Squamata/Boidae/Morelia/spilota Accessed June, 2012

Coffey Environments (2009) *Rockingham Industry Zone Fauna Risk Assessment* Report No. 2005/55 for Landcorp.

Department of Environment and Conservation (DEC) (2012a) Naturemaps Database Accessed June 2012 http://naturemap.dec.wa.gov.au/ Government of Western Australia, Perth.

Department of Environment and Conservation (DEC) (2012b) Fauna Species Profiles Accessed June 2012 http://www.dec.wa.gov.au/content/view/3432/1999/1/1/ Government of Western Australia, Perth.

Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) (2012a). *Protected Matters Search Tool* Commonwealth of Australia Accessed June 2012 http://www.environment.gov.au/apps/boobook/mapservlet?app=ert

Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) (2012b). Species Profile and Threats (SPRAT) Database. Accessed June 2012 http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl Commonwealth of Australia

Environmental Protection Authority (EPA) (2004). *Guidance for Assessment of Environmental Factors: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, No. 56.* Government of Western Australia, Perth.

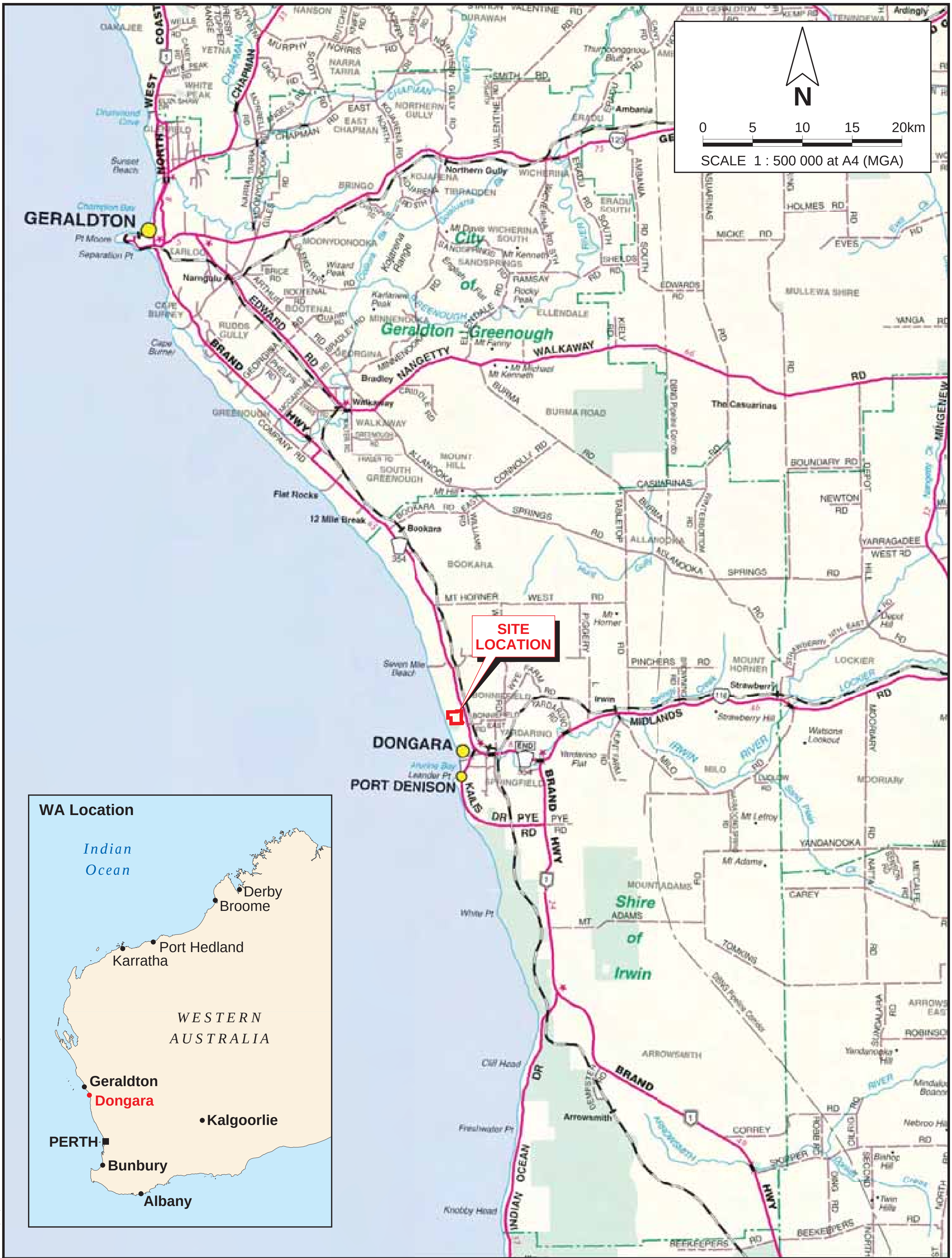
Landform Research (2005). *LandCapability and Geotechnical Assessment Lots 10, 15, 16 and 17 Francisco Road, Dongara.*

Nevill, S (ed) (2005) *Guide to the Wildlife of the Perth Region*. Simon Nevill Publications, Perth, Western Australia

PGV Environmental (2011) *Lots 10, 15, 16, 17 And 1409 Francisco Road, Dongara Flora and Vegetation Survey* Report Number 2011-27 Western Australia

Storr, G.M., Smith, L.A. and Johnstone R.E. (1999) *Lizards of Western Australia* I: Skinks. Revised Edition, WA Museum, Perth, Western Australia.

# FIGURES




BJ Clarke & Co Real Estate
LEVEL ONE FAUNA ASSESSMENT
LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

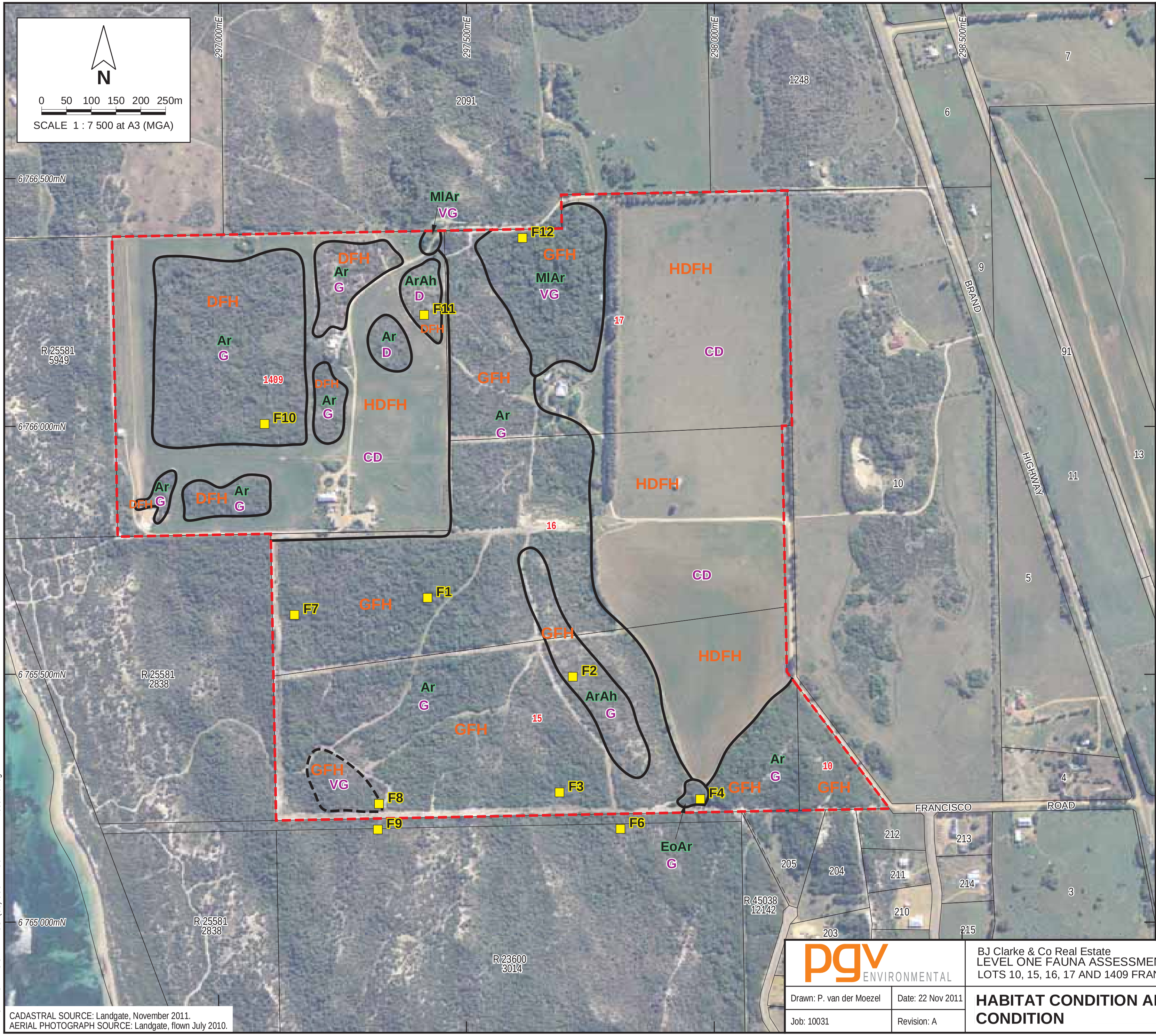
| | |
|---|---|
| Drawn: P. van der Moezel | Date: 22 Nov 2011 |
| Job: 10031 | Revision: A |

**SITE LOCATION**

**Figure 1**

PINPOINT CARTOGRAPHICS (08) 9562 7136

10031-f01.dgn




**Legend**

- Site Boundary
- Cadastral Boundary
- Quadrat Location
- Vegetation Type Boundary
- Vegetation Condition Boundary
- **Ar** Vegetation Type
- **G** Vegetation Condition
- **GFH** Habitat Condition

**Vegetation Legend**
(Source: PGV, 2011)

**Ar** *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub

**ArAh** *Acacia rostellifera/Alyogyne huegelii* Open Heath

**MIAr** *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland

**EoAr** *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub

**Vegetation Condition Legend**
(Source: BUSH FOREVER Govt. of W.A., 2000)

P – Pristine

Ex – Excellent

VG - Very Good

G – Good

D – Degraded

CD - Completely Degraded

Cl – Cleared

**Habitat Condition Legend**
(Source: Coffey Environments, 2009)

HQFH - High Quality Fauna Habitat

VGFH - Very Good Fauna Habitat

GFH - Good Fauna Habitat

DFH - Disturbed Fauna Habitat

HDFH - Highly Degraded Fauna Habitat

pgv ENVIRONMENTAL

BJ Clarke & Co Real Estate
LEVEL ONE FAUNA ASSESSMENT
LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

| Drawn: P. van der Moezel | Date: 22 Nov 2011 |
|---|---|
| Job: 10031 | Revision: A |

**HABITAT CONDITION AND VEGETATION TYPES AND CONDITION**

**Figure 2**

# APPENDIX 1

## DEC Database Search Results

| NAME | SOURCE_CODE | SOURCE_ID | NAME_ID | FAMILY | GENUS |
|---|---|---|---|---|---|
| Anous tenuirostris subsp. melanops | WAMSPECIMENS | A2692\|24506\|01/07/1924 | 24506 | Laridae | Anous |
| Anous tenuirostris subsp. melanops | WAMSPECIMENS | A2691\|24506\|01/07/1924 | 24506 | Laridae | Anous |
| Calyptorhynchus latirostris | BIRDATLAS2 | 99791\|794 | 24734 | Psittacidae | Calyptorhynchus |
| Calyptorhynchus latirostris | BIRDATLAS2 | 434328\|794 | 24734 | Psittacidae | Calyptorhynchus |
| Falco peregrinus | BIRDATLAS2 | 8735\|237 | 25624 | Falconidae | Falco |
| Falco peregrinus subsp. macropus | WAMSPECIMENS | A28544\|24475\|31/01/1900 | 24475 | Falconidae | Falco |
| Morelia spilota subsp. imbricata | WAMSPECIMENS | R12029\|25240\|// | 25240 | Boidae | Morelia |
| Neelaps calonotos | TFAUNA | 15146 | 25249 | Elapidae | Neelaps |
| Neelaps calonotos | WAMSPECIMENS | R141838\|25249\|30/07/2000 | 25249 | Elapidae | Neelaps |

| SPECIES | INFRARANK | INFRANAME | AUTHOR | VERNACULAR | KINGDOM |
|---|---|---|---|---|---|
| tenuirostris | subsp. | melanops | Gould | | Animalia |
| tenuirostris | subsp. | melanops | Gould | | Animalia |
| latirostris | | | Carnaby | Carnaby's Cockatoo | Animalia |
| latirostris | | | Carnaby | Carnaby's Cockatoo | Animalia |
| peregrinus | | | Tunstall | Peregrine Falcon | Animalia |
| peregrinus | subsp. | macropus | Swainson | | Animalia |
| spilota | subsp. | imbricata | (Smith) | Carpet Python | Animalia |
| calonotos | | | (A.M.C. DumΘril, Bibron & A. DumΘril) | Black-striped Snake | Animalia |
| calonotos | | | (A.M.C. DumΘril, Bibron & A. DumΘril) | Black-striped Snake | Animalia |

| CONSV_CODE | CLASS | SITE_NAME | DAY | MONTH | YEAR | LOCALITY_NAME |
|---|---|---|---|---|---|---|
| T | BIRD | | 01 | 07 | 1924 | DONGARA |
| T | BIRD | | 01 | 07 | 1924 | DONGARA |
| T | BIRD | Dongara Oval | 12 | 08 | 2000 | DONGARA |
| T | BIRD | Dongarra | 10 | 10 | 2004 | DONGARA |
| S | BIRD | 100 acre home block, Port Denison | 31 | 01 | 1999 | SPRINGFIELD |
| S | BIRD | | 31 | 01 | 1900 | DONGARA |
| S | REPTILE | DONGARA | | | | DONGARA |
| 3 | REPTILE | ~5km SSE of Port Denison, near Dongara | 30 | 07 | 2000 | PORT DENISON |
| 3 | REPTILE | 5KM SSE PORT DENISON | 30 | 07 | 2000 | PORT DENISON |

# APPENDIX 2

## NatureMaps Database Reports

# NatureMap Species Report

*Created By Guest user on 13/06/2012*

| | |
|---|---|
| **Kingdom** | Animalia |
| **Conservation Status** | Conservation Taxon (T, X, IA, S, P1-P5) |
| **Current Names Only** | Yes |
| **Core Datasets Only** | Yes |
| **Method** | 'By Circle' |
| **Centre** | 114°54' 59'' E,29°13' 19'' S |
| **Buffer** | 5km |

| | | |
|---|---|---|
| **Area (ha)** | | 7853.98 |
| **Taxa:** | Naturalised | 0 |
| | Native | 4 |
| **Endemics:** | | 0 |
| **Families:** | | 4 |
| **Genera:** | | 4 |
| **Conservation Status:** | S | 2 |
| | T | 2 |
| **MS Status:** | - | 4 |
| **Rank:** | subsp. | 3 |
| | - | 1 |

## Top Ten Families

| | Species | Records |
|---|---|---|
| 1. Laridae | 1 | 2 |
| 2. Psittacidae | 1 | 2 |
| 3. Boidae | 1 | 1 |
| 4. Falconidae | 1 | 1 |

## Top Ten Genera

| | Species | Records |
|---|---|---|
| 1. *Anous* | 1 | 2 |
| 2. *Calyptorhynchus* | 1 | 2 |
| 3. *Falco* | 1 | 1 |
| 4. *Morelia* | 1 | 1 |

## [1]Endemic To Query Area

| Name ID | Species | Conservation Status |
|---|---|---|

**Conservation Codes**
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

# APPENDIX 3

## Conservation Codes

**Western Australian and Commonwealth of Australia Conservation Codes**

In Western Australia, all native fauna species are protected under the *Wildlife Conservation Act 1950-1979*. Fauna species that are considered rare, threatened with extinction or have a high conservation value are specially protected under the Act. In addition, some species of fauna are covered under the 1991 ANZECC convention, while certain birds are listed under the Japan and Australian Migratory Bird Agreement (JAMBA) and the China and Australian Migratory Bird Agreement (CAMBA). In addition to the above classification, DEC also classify fauna under five different Priority codes and rare and endangered fauna are classified under the Wildlife Conservation (Specially Protected Fauna) Notice 2006 into four schedules of taxa.

Schedule 1

*Fauna which are rare or likely to become extinct and are declared to be fauna in need of special protection.*

Schedule 2

*Fauna which are presumed to be extinct and are declared to be fauna in need of special protection.*

Schedule 3

*Birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction which are declared to be fauna in need of special protection.*

Schedule 4

*Fauna that are in need of special protection, otherwise than for the reasons mentioned in Schedule 1, 2 or 3.*

In addition to the above classification, the DEC also classifies fauna under five different priority codes:

Priority One: Taxa with few, poorly known populations on threatened lands

*Taxa which are known from few specimens or sight records from one or a few localities on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, active mineral leases. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.*

Priority Two: Taxa with few, poorly known populations on conservation lands

*Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation, e.g. national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.*

Priority Three: Taxa with several, poorly known populations, some on conservation lands

*Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.*

Priority Four: Taxa in need of monitoring

*Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.*

Priority Five: Taxa in need of monitoring (conservation dependent)

*Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.*

The Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* has the following nine conservation codes for Flora and Fauna.

Extinct

*Taxa not definitely located in the wild during the past 50 years*

Extinct in the Wild

*Taxa known to survive only in captivity*

Critically Endangered

*Taxa facing an extremely high risk of extinction in the wild in the immediate future*

Endangered

*Taxa facing a very high risk of extinction in the wild in the near future*

Vulnerable

*Taxa facing a high risk of extinction in the wild in the medium-term*

Near Threatened

*Taxa that risk becoming Vulnerable in the wild*

Conservation Dependent

*Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.*

Data Deficient (Insufficiently Known)

*Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.*

Least Concern

*Taxa that are not considered Threatened*

# APPENDIX 4

## Protected Matters Search Tool Report

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

# EPBC Act Protected Matters Report

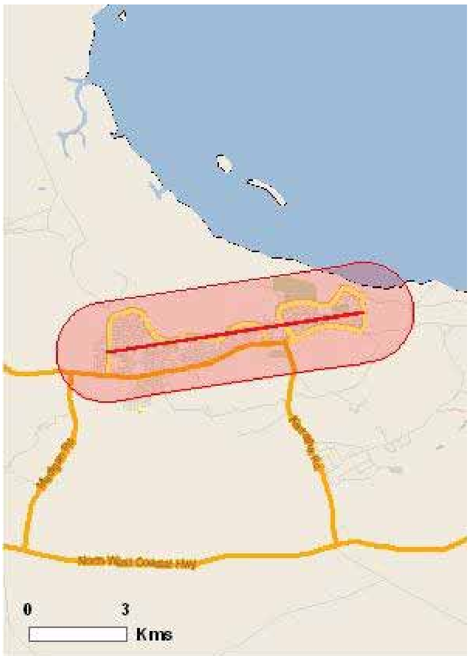
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

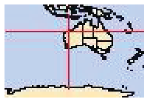
Report created: 08/06/12 17:16:32


Summary
Details
Matters of NES
Other Matters Protected by the EPBC Act
Extra Information
Caveat
Acknowledgements




Coordinates
Buffer: 1.5Km



## Summary

### Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html

| | |
|---|---|
| World Heritage Properties: | None |
| National Heritage Places: | None |
| Wetlands of International | None |
| Great Barrier Reef Marine Park: | None |
| Commonwealth Marine Areas: | None |
| Threatened Ecological Communities: | None |
| Threatened Species: | 14 |
| Migratory Species: | 23 |

## Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.

| | |
|---|---|
| Commonwealth Lands: | 1 |
| Commonwealth Heritage Places: | None |
| Listed Marine Species: | 58 |
| Whales and Other Cetaceans: | 11 |
| Critical Habitats: | None |
| Commonwealth Reserves: | None |

## Extra Information

This part of the report provides information that may also be relevant to the area you have

| | |
|---|---|
| Place on the RNE: | 2 |
| State and Territory Reserves: | None |
| Regional Forest Agreements: | None |
| Invasive Species: | 6 |
| Nationally Important Wetlands: | None |

# Details

## Matters of National Environmental Significance

### Threatened Species [ Resource Information ]

| Name | Status | Type of Presence |
|---|---|---|
| BIRDS | | |
| Macronectes giganteus<br>Southern Giant-Petrel [1060] | Endangered | Species or species habitat may occur within area |

| Name | Status | Type of Presence |
|---|---|---|
| MAMMALS | | |
| Dasyurus hallucatus<br>Northern Quoll [331] | Endangered | Species or species habitat likely to occur within area |
| Macrotis lagotis<br>Greater Bilby [282] | Vulnerable | Species or species habitat likely to occur within area |
| Megaptera novaeangliae<br>Humpback Whale [38] | Vulnerable | Species or species habitat known to occur within area |
| Rhinonicteris aurantia (Pilbara form)<br>Pilbara Leaf-nosed Bat [82790] | Vulnerable | Species or species habitat likely to occur within area |
| REPTILES | | |
| Aipysurus apraefrontalis<br>Short-nosed Seasnake [1115] | Critically Endangered | Species or species habitat likely to occur within area |
| Caretta caretta<br>Loggerhead Turtle [1763] | Endangered | Species or species habitat likely to occur within area |
| Chelonia mydas<br>Green Turtle [1765] | Vulnerable | Species or species habitat likely to occur within area |
| Dermochelys coriacea<br>Leatherback Turtle, Leathery Turtle, Luth [1768] | Endangered | Species or species habitat likely to occur within area |
| Eretmochelys imbricata<br>Hawksbill Turtle [1766] | Vulnerable | Species or species habitat likely to occur within area |
| Liasis olivaceus barroni<br>Olive Python (Pilbara subspecies) [66699] | Vulnerable | Species or species habitat may occur within area |
| Natator depressus<br>Flatback Turtle [59257] | Vulnerable | Species or species habitat likely to occur within area |
| SHARKS | | |
| Pristis clavata<br>Dwarf Sawfish, Queensland Sawfish [68447] | Vulnerable | Species or species habitat likely to occur within area |
| Rhincodon typus<br>Whale Shark [66680] | Vulnerable | Species or species habitat may occur within area |

## Migratory Species [ Resource Information ]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

| Name | Threatened | Type of Presence |
|---|---|---|
| Migratory Marine Birds | | |
| Apus pacificus<br>Fork-tailed Swift [678] | | Species or species habitat may occur within area |
| Ardea alba<br>Great Egret, White Egret [59541] | | Species or species habitat may occur within area |
| Ardea ibis<br>Cattle Egret [59542] | | Species or species habitat may occur within area |

| Name | Threatened | Type of Presence |
|---|---|---|
| Macronectes giganteus | | |
| Southern Giant-Petrel [1060] | Endangered | Species or species habitat may occur within area |
| **Migratory Marine Species** | | |
| Balaenoptera edeni | | |
| Bryde's Whale [35] | | Species or species habitat may occur within area |
| Caretta caretta | | |
| Loggerhead Turtle [1763] | Endangered | Species or species habitat likely to occur within area |
| Chelonia mydas | | |
| Green Turtle [1765] | Vulnerable | Species or species habitat likely to occur within area |
| Dermochelys coriacea | | |
| Leatherback Turtle, Leathery Turtle, Luth [1768] | Endangered | Species or species habitat likely to occur within area |
| Dugong dugon | | |
| Dugong [28] | | Species or species habitat known to occur within area |
| Eretmochelys imbricata | | |
| Hawksbill Turtle [1766] | Vulnerable | Species or species habitat likely to occur within area |
| Megaptera novaeangliae | | |
| Humpback Whale [38] | Vulnerable | Species or species habitat known to occur within area |
| Natator depressus | | |
| Flatback Turtle [59257] | Vulnerable | Species or species habitat likely to occur within area |
| Orcinus orca | | |
| Killer Whale, Orca [46] | | Species or species habitat may occur within area |
| Rhincodon typus | | |
| Whale Shark [66680] | Vulnerable | Species or species habitat may occur within area |
| Sousa chinensis | | |
| Indo-Pacific Humpback Dolphin [50] | | Species or species habitat may occur within area |
| Tursiops aduncus (Arafura/Timor Sea populations) | | |
| Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900] | | Species or species habitat likely to occur within area |
| **Migratory Terrestrial Species** | | |
| Haliaeetus leucogaster | | |
| White-bellied Sea-Eagle [943] | | Species or species habitat likely to occur within area |
| Hirundo rustica | | |
| Barn Swallow [662] | | Species or species habitat may occur within area |
| Merops ornatus | | |
| Rainbow Bee-eater [670] | | Species or species habitat may occur within area |
| **Migratory Wetlands Species** | | |
| Ardea alba | | |
| Great Egret, White Egret [59541] | | Species or species habitat may occur within area |
| Ardea ibis | | |
| Cattle Egret [59542] | | Species or species |

| Name | Threatened | Type of Presence |
|---|---|---|
| | | habitat may occur within area |
| Charadrius veredus<br>Oriental Plover, Oriental Dotterel [882] | | Species or species habitat may occur within area |
| Glareola maldivarum<br>Oriental Pratincole [840] | | Species or species habitat may occur within area |

## Other Matters Protected by the EPBC Act

### Commonwealth Lands [ Resource Information ]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

| Name |
|---|
| Commonwealth Land - |

### Listed Marine Species [ Resource Information ]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

| Name | Threatened | Type of Presence |
|---|---|---|
| Birds | | |
| Apus pacificus<br>Fork-tailed Swift [678] | | Species or species habitat may occur within area |
| Ardea alba<br>Great Egret, White Egret [59541] | | Species or species habitat may occur within area |
| Ardea ibis<br>Cattle Egret [59542] | | Species or species habitat may occur within area |
| Charadrius veredus<br>Oriental Plover, Oriental Dotterel [882] | | Species or species habitat may occur within area |
| Glareola maldivarum<br>Oriental Pratincole [840] | | Species or species habitat may occur within area |
| Haliaeetus leucogaster<br>White-bellied Sea-Eagle [943] | | Species or species habitat likely to occur within area |
| Hirundo rustica<br>Barn Swallow [662] | | Species or species habitat may occur within area |
| Macronectes giganteus<br>Southern Giant-Petrel [1060] | Endangered | Species or species habitat may occur within area |
| Merops ornatus<br>Rainbow Bee-eater [670] | | Species or species habitat may occur within area |
| Fish | | |
| Bulbonaricus brauni<br>Braun's Pughead Pipefish, Pug-headed Pipefish [66189] | | Species or species habitat may occur within area |
| Campichthys tricarinatus<br>Three-keel Pipefish [66192] | | Species or species habitat may occur within |

| Name | Threatened | Type of Presence |
|---|---|---|
| | | area |
| Choeroichthys brachysoma<br>Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194] | | Species or species habitat may occur within area |
| Choeroichthys suillus<br>Pig-snouted Pipefish [66198] | | Species or species habitat may occur within area |
| Doryrhamphus janssi<br>Cleaner Pipefish, Janss' Pipefish [66212] | | Species or species habitat may occur within area |
| Doryrhamphus negrosensis<br>Flagtail Pipefish, Masthead Island Pipefish [66213] | | Species or species habitat may occur within area |
| Festucalex scalaris<br>Ladder Pipefish [66216] | | Species or species habitat may occur within area |
| Filicampus tigris<br>Tiger Pipefish [66217] | | Species or species habitat may occur within area |
| Halicampus brocki<br>Brock's Pipefish [66219] | | Species or species habitat may occur within area |
| Halicampus grayi<br>Mud Pipefish, Gray's Pipefish [66221] | | Species or species habitat may occur within area |
| Halicampus nitidus<br>Glittering Pipefish [66224] | | Species or species habitat may occur within area |
| Halicampus spinirostris<br>Spiny-snout Pipefish [66225] | | Species or species habitat may occur within area |
| Haliichthys taeniophorus<br>Ribboned Pipehorse, Ribboned Seadragon [66226] | | Species or species habitat may occur within area |
| Hippichthys penicillus<br>Beady Pipefish, Steep-nosed Pipefish [66231] | | Species or species habitat may occur within area |
| Hippocampus angustus<br>Western Spiny Seahorse, Narrow-bellied Seahorse [66234] | | Species or species habitat may occur within area |
| Hippocampus histrix<br>Spiny Seahorse, Thorny Seahorse [66236] | | Species or species habitat may occur within area |
| Hippocampus kuda<br>Spotted Seahorse, Yellow Seahorse [66237] | | Species or species habitat may occur within area |
| Hippocampus planifrons<br>Flat-face Seahorse [66238] | | Species or species habitat may occur within area |
| Micrognathus micronotopterus<br>Tidepool Pipefish [66255] | | Species or species habitat may occur within area |
| Solegnathus hardwickii<br>Pallid Pipehorse, Hardwick's Pipehorse [66272] | | Species or species habitat may occur within area |

| Name | Threatened | Type of Presence |
|---|---|---|
| Solegnathus lettiensis | | |
| Gunther's Pipehorse, Indonesian Pipefish [66273] | | Species or species habitat may occur within area |
| Solenostomus cyanopterus | | |
| Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183] | | Species or species habitat may occur within area |
| Solenostomus paegnius | | |
| Rough-snout Ghost Pipefish [68425] | | Species or species habitat may occur within area |
| Syngnathoides biaculeatus | | |
| Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279] | | Species or species habitat may occur within area |
| Trachyrhamphus bicoarctatus | | |
| Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280] | | Species or species habitat may occur within area |
| Trachyrhamphus longirostris | | |
| Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281] | | Species or species habitat may occur within area |
| Mammals | | |
| Dugong dugon | | |
| Dugong [28] | | Species or species habitat known to occur within area |
| Reptiles | | |
| Acalyptophis peronii | | |
| Horned Seasnake [1114] | | Species or species habitat may occur within area |
| Aipysurus apraefrontalis | | |
| Short-nosed Seasnake [1115] | Critically Endangered | Species or species habitat likely to occur within area |
| Aipysurus duboisii | | |
| Dubois' Seasnake [1116] | | Species or species habitat may occur within area |
| Aipysurus eydouxii | | |
| Spine-tailed Seasnake [1117] | | Species or species habitat may occur within area |
| Aipysurus laevis | | |
| Olive Seasnake [1120] | | Species or species habitat may occur within area |
| Aipysurus tenuis | | |
| Brown-lined Seasnake [1121] | | Species or species habitat may occur within area |
| Astrotia stokesii | | |
| Stokes' Seasnake [1122] | | Species or species habitat may occur within area |
| Caretta caretta | | |
| Loggerhead Turtle [1763] | Endangered | Species or species habitat likely to occur within area |
| Chelonia mydas | | |
| Green Turtle [1765] | Vulnerable | Species or species habitat likely to occur within area |
| Dermochelys coriacea | | |
| Leatherback Turtle, Leathery Turtle, Luth [1768] | Endangered | Species or species habitat likely to occur within area |
| Disteira kingii | | |
| Spectacled Seasnake [1123] | | Species or species habitat may occur within |

| Name | Threatened | Type of Presence |
|---|---|---|
| | | area |
| Disteira major<br>Olive-headed Seasnake [1124] | | Species or species habitat may occur within area |
| Emydocephalus annulatus<br>Turtle-headed Seasnake [1125] | | Species or species habitat may occur within area |
| Ephalophis greyi<br>North-western Mangrove Seasnake [1127] | | Species or species habitat may occur within area |
| Eretmochelys imbricata<br>Hawksbill Turtle [1766] | Vulnerable | Species or species habitat likely to occur within area |
| Hydrelaps darwiniensis<br>Black-ringed Seasnake [1100] | | Species or species habitat may occur within area |
| Hydrophis czeblukovi<br>Fine-spined Seasnake [59233] | | Species or species habitat may occur within area |
| Hydrophis elegans<br>Elegant Seasnake [1104] | | Species or species habitat may occur within area |
| Hydrophis mcdowelli<br>null [25926] | | Species or species habitat may occur within area |
| Hydrophis ornatus<br>a seasnake [1111] | | Species or species habitat may occur within area |
| Natator depressus<br>Flatback Turtle [59257] | Vulnerable | Species or species habitat likely to occur within area |
| Pelamis platurus<br>Yellow-bellied Seasnake [1091] | | Species or species habitat may occur within area |

## Whales and other Cetaceans [ Resource Information ]

| Name | Status | Type of Presence |
|---|---|---|
| Mammals | | |
| Balaenoptera acutorostrata<br>Minke Whale [33] | | Species or species habitat may occur within area |
| Balaenoptera edeni<br>Bryde's Whale [35] | | Species or species habitat may occur within area |
| Delphinus delphis<br>Common Dophin, Short-beaked Common Dolphin [60] | | Species or species habitat may occur within area |
| Grampus griseus<br>Risso's Dolphin, Grampus [64] | | Species or species habitat may occur within area |
| Megaptera novaeangliae<br>Humpback Whale [38] | Vulnerable | Species or species habitat known to occur within area |
| Orcinus orca<br>Killer Whale, Orca [46] | | Species or species habitat may occur within area |

| Name | Status | Type of Presence |
|---|---|---|
| Sousa chinensis | | |
| Indo-Pacific Humpback Dolphin [50] | | Species or species habitat may occur within area |
| Stenella attenuata | | |
| Spotted Dolphin, Pantropical Spotted Dolphin [51] | | Species or species habitat may occur within area |
| Tursiops aduncus | | |
| Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418] | | Species or species habitat likely to occur within area |
| Tursiops aduncus (Arafura/Timor Sea populations) | | |
| Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900] | | Species or species habitat likely to occur within area |
| Tursiops truncatus s. str. | | |
| Bottlenose Dolphin [68417] | | Species or species habitat may occur within area |

## Extra Information

### Places on the RNE

[ Resource Information ]

Note that not all Indigenous sites may be listed.

| Name | State | Status |
|---|---|---|
| Natural | | |
| Coastal Margin Cape Preston to Cape Keraudren | WA | Indicative Place |
| Dampier Archipelago Marine Areas | WA | Indicative Place |

### Invasive Species

[ Resource Information ]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit,

| Name | Status | Type of Presence |
|---|---|---|
| Mammals | | |
| Felis catus | | |
| Cat, House Cat, Domestic Cat [19] | | Species or species habitat likely to occur within area |
| Oryctolagus cuniculus | | |
| Rabbit, European Rabbit [128] | | Species or species habitat likely to occur within area |
| Vulpes vulpes | | |
| Red Fox, Fox [18] | | Species or species habitat likely to occur within area |
| Plants | | |
| Cenchrus ciliaris | | |
| Buffel-grass, Black Buffel-grass [20213] | | Species or species habitat likely to occur within area |
| Parkinsonia aculeata | | |
| Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301] | | Species or species habitat likely to occur within area |
| Prosopis spp. | | |
| Mesquite, Algaroba [68407] | | Species or species habitat likely to occur within area |

# Coordinates

-20.74076 116.79874,-20.72979 116.87001,-20.74061 116.79889,-20.7301 116.86818,
-20.72964 116.86955

# Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

# Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium

-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

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Please feel free to provide feedback via the Contact Us page.


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# APPENDIX 5

## Land Capability and Geotechnical Assessment 2005 (Landform Research)

# LAND CAPABILITY and GEOTECHNICAL ASSESSMENT

# LOTS 10, 15, 16 and 17 FRANCISCO ROAD, DONGARA

JUNE 2005

Landform Research

# LAND CAPABILITY and GEOTECHNICAL ASSESSMENT

# LOTS 10, 15, 16 and 17, FRANCISCO ROAD, DONGARA

June 2005

Landform Research
Land Systems - Quarries - Environment
ABN 29 841 445 694

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## 1.0 INTRODUCTION

Dongara is a popular fishing, beach and holiday location, that is growing in popularity. The land north of Dongara is one of the areas that have been identified as suitable for a node of development.

The site (Lots 10, 15, 16 and 17) lies just inland from the coast, some 2 km north of Dongara.

### Methodology

Lindsay Stephens of Landform Research visited the area on 13 April 2005 during which traverses were made across the site, the geology and soils were investigated and the vegetation communities noted. During that study the soils were mapped to confirm soil type or gain information on the soils, the geology, and hydrology.

The site was also investigated by ARC Energy as part of their assessment for a 3D Seismic Survey conducted in early 2005. The ARC Assessment was subjected to Public Environmental Review through the Environmental Protection Authority and covered, in particular, the environmental issues associated with that survey, particularly disruptions to soils an vegetation.

Soils have also previously been assessed as part of the Geraldton Region, Land Resources Survey, (Rogers, 1996).

### Site Description

The site straddles a zone of coastal dunes extending from the coastal Quindalup Dunes to the older Tamala Dunes in the east.

The eastern part (Tamala) dunes are cleared and used for rural activities with the more hilly western dunes generally remaining covered by coastal vegetation.

## 2.0 EXISTING ENVIRONMENT

### 2.1 Geology and Geomorphology

The coast at this location consists of a series of old sand ridges ranging from those developed at various time in the Pleistocene and Recent. The oldest are the limestone ridges to the east of the Greenough Flats, well to the east of the study site.

The site straddles a portion of Pleistocene Tamala Limestone and soil system in the east which is an interdunal swale of degraded older dunes, and portion of the younger coastal Quindalup Dunes in the west, which rise some 20 to 30 metres above the eastern portion of the site. The eastern portion of the site is gently sloping dropping slightly from a low ridge along the eastern edge of the site towards the centre and to the eastern boundary.

The Older eastern Tamala dunes are part of an older coastal dune sequence of calcareous sands that has been lithified and weathered to form limestone with associated brown sands.

The dunes are formed from quartz or calcium carbonate in the form of shell fragments or foraminifer skeletons and marine organism skeletal remnants such as sponge spicules.

Superimposed on this older system of dunes is a younger set of dunes. The younger dunes parallel the pre existing dunes as a series of stabilised dunes formed at a time when the beach was accreting (having sand added to it).

Over time the calcium carbonate is dissolved leading to hardening of the underlying dunal materials and thus the older the dunes the more cemented and rock like the underlying sediments are. The "Tamala" Dunes along the eastern edge have limestone (calc-arenite) bases which can be seen protruding up through the soil on the low eastern ridge.

The dunes in the west are younger but are the oldest of the Quindalup system. They consist of brown coloured sands with variable amounts of silica and calcium carbonate. With exposure to the atmosphere, rainwater percolates down through the sands dissolving the calcium carbonate through the action of weak acids derived from organic matter and depositing the calcium carbonate lower in the profile. The deposition of the calcium carbonate forms cemented deposits in the base of these dunes.

**Dune Stability**

The lithified Tamala dunes and brown sands are underlain by limestone and are stable.

The Quindalup dunes are younger and less lithified and are therefore less stable than the Tamala dunes. The dune on the western side of the site is the oldest of the Quindalup Dune System and has therefore been stabilised by soil formation processes to be stable particularly in the swales. They are much more stable than new coastal sands being deposited at the rear of the current beaches, with the only areas of likely instability being the two high ridges in the south.

## 2.2 Soils

General information on the soil and land units can be found in Rogers, 1996.

Soils developed on the western Quindalup Dunes are sandy but have grey quartz rich surface horizons stained by organic matter. The age of the soils has an impact on the colour of the soils. The older the soils the more grey and brown they become, with the grey being due to accumulation of organic matter in the upper soil horizons and the brown due to goethite (a form of iron oxide) coating sand grains in older soils and originating from a break down of heavy minerals in the sands. A small amount of clay may also be present in the subsoils of older dunes due to a break down of feldspar grains.

As the Quindalup Dunes on site are the oldest of the system the sand is brown to cream brown sand containing minor clay and calcareous material, makes the soil stable. Existing tracks have cut down due to the impact of vehicles but have not eroded significantly.

The older Tamala system soils are brown sands grading to earthy sands and overlying limestone at variable depth. There has been little bleaching of the sand in the A horizon and minor accumulation of humus. In general the porous nature of the sand allows the humus to be broken down and clay to be washed down to lower levels in the soil profile.

**Phosphate Retention**

The goethite coatings of the sand grains in the older dunes has capability for absorbing phosphate, as does the calcium carbonate content of the soils.

Phosphate Retention Index (PRI) tests can frequently be misleading because all materials greater than 2 mm are sieved from the sample prior to testing. This means that a coarse sand for example will have the larger phosphate retaining particles removed from the sample prior to testing.

On the other hand the calcareous sand may have a better PRI, but in the field water movement may be so fast that the grains have little opportunity to adsorb nutrients.

Phosphate retention therefore cannot be considered in isolation, because the type of land use, type and placement of nutrients, flow paths and distances all contribute to variations in the behaviour of nutrients.

The phosphate retention (PRI) of the brown eastern Tamala System sands in the eastern half of the site is similar to Spearwood Sands which are rated at 5 - 20 during research by the Chemistry Centre. The soils on the eastern portion of the site would have similar PRI and the whole soil profile will be highly phosphate adsorption when the whole soil profile is taken into account and the flow paths of water are considered.

The soils western half consist of brown sands with variable composition of quartz or calcium carbonate in the form of shell fragments or foraminifer skeletons and marine organism skeletal remnants such as sponge spicules. The phosphate retention of soils such as this can normally vary from 2 - 5 (PRI) but can go higher when more lime is present. Sorption by calcareous soils is dominated by precipitation and sorption reactions with calcium carbonate and the formation and precipitation of minerals such as di-calcium phosphate, $CaHPO_4.2H_2O$.

Permeability and porosity of the soils is moderate to high, reduced slightly by non wetting and the small clay content, but microbial purification is high because of the depth of sand above the water table.

The generalised soil properties are summarised below.

| **Soil Characteristics** | **Brown Sand over Limestone (Tamala)** | **Grey Coastal Sands over Limestone (Quindalup)** |
|---|---|---|
| Location | Eastern portion of site | Western portion of site |
| Topsoil Texture | Brown sand | Grey calcareous sand |
| Subsoil Texture | Brown medium grained silica sand that becomes earthy and loamy on the lower elevation | Light brown to cream medium grained silica and calcareous sand with up to 80% calcareous sand grains. |
| Stone | Low apart from some patches of weathered weakly lithified limestone that occurs on the ridge in the east | Nil |
| Depth to Bedrock | Limestone (calc-arenite) from 1 to perhaps 5 metres | Weakly lithified limestone is possibly present to depths greater than 10 metres |
| Hardpan | No evidence in the soils apart from underlying limestone and some compaction effects in the more loamy soils | No evidence in the soils |
| pH | Neutral to alkaline | Alkaline |
| Salinity | Low | Low |

| | | |
|---|---|---|
| Soil Permeability | High | High |
| Soil Shrinkage | Very low | Minor compaction possible |

| **Land Qualities** | **Brown Sand over Limestone (Tamala)** | **Grey Coastal Sands over Limestone (Quindalup)** |
|---|---|---|
| Slope | Gentle to moderate on localised dune slopes | Gentle to steep localised dune slopes |
| Slope Stability | High | Moderate. There are two ridge areas that have potentially unstable soils but the remainder have brown sands that are relatively stable |
| Rock/Gravel | Present on ridge in the east | Not obvious but may be present as weakly lithified limestone generally below 500 mm |
| Wind Erosion Risk | Moderate to high if the vegetation is removed and the soils are exposed to wind | Moderate to high if the vegetation is removed and the soils are exposed to wind. There are two potentially unstable areas on steeper ridges. |
| Water Erosion Risk | Low, but as the sands can be non wetting summer storm events can cause minor water erosion rills on sloping dune sands that have no vegetation cover. The extent of this is minimal. | Low, but as the sands can be non wetting summer storm events can cause water erosion rills on steeply sloping dune sands that have no vegetation cover. The extent of this is minimal. |
| Drainage | Rapid to water table | Rapid to water table |
| Moisture Availability | Moderate to low | Low |
| Water Logging | Nil | Nil |
| Wetability | Moderate to high. Non wetting behaviour depending on the season | Moderate to low. Non wetting behaviour depending on the season |
| Flood Risk | Nil | Nil |
| Surface Water - Availability/Quality | Nil | Nil |
| Ground Water - Availability/Quality | Groundwater is present at about 3.0 metres below the lowest elevation. Quality varies from 1925 mg/L to 3 575 mg/L | Groundwater is present at about 3.0 metres below the lowest elevation. Quality varies from 1925 mg/L to 3 575 mg/L |
| Salinity Risk | Nil | Nil |
| Microbial Purification | High based on the depths of sand and depth to the water table. Higher elevations have longer travel distances and therefore better purification ability. | High based on the depths of calcareous sand and depth to the water table. Higher elevations have longer travel distances and therefore better purification ability. |
| Water Pollution Risk | Moderate. Design and management can reduce the potential for water pollution risk | Moderate. Design and management can reduce the potential for water pollution risk |
| Soil Profile; Phosphate absorption | High based on the proportion of calcium carbonate, minor clay, sesquioxides, porosity and permeability and distance of water travel. | Moderate based on the proportion of the calcium carbonate depth of soils, travel distances, porosity and permeability<br>Can be improved by use of an alternative waste water treatment system. |
| Soil Profile; Nitrogen Removal | High based on the travel distances | Moderate based on the travel distances. Can be improved by use of an alternative waste water treatment system. |
| Degradation | Low, but cleared | Low, uncleared apart from strategic fire breaks. |

### 2.3 Climate

Weather data is recorded at the Geraldton Airport which is slightly inland. Onsite temperatures can therefore be expected to have slightly lower summer maxima and slightly higher winter minima than Geraldton.

Geraldton averages show maxima of 32 degrees C. in summer, down to an average of 19 degrees C. in winter. Minima range from 18 degrees C. to 9 degrees C.

Rainfall averages 472 min per annum at Geraldton and 462 at Dongara.

9.00 am wind data shows a predominantly east to south east direction in summer and lighter north easterly directions in winter. At 3.00 pm there is a predominance of south westerly sea breezes which exceed 30 km/h for over 30% of the time. Strong northerly winds can occur ahead of cold fronts in autumn to spring and can be significant but short term events.

Swell directions are predominantly from the south west with storms from the north west in winter and occasional cyclonic storms from the decaying remnants of cyclones in late summer.

### 2.4 Vegetation

The vegetation was assessed briefly on 13 April 2005.

The eastern half of the site is cleared apart from *Acacia rostelfifera* regrowth that is now coming back on the limestone ridge.

The western portion has been previously cleared in the swales for grazing but is regrowing strongly as *Acacia rostellifera* Thicket. The tops of the ridges and the steeper slopes have largely been uncleared although grazed in the past. They are also regrowing.

The vegetation is dominated by *Acacia rostellifera* Ticket.
The species are typical of the older Quindalup Dunes, grading to more coastal species towards the west .

Common Species are;

*Acacia rostellifera* predominates, particularly in regrowth over previously cleared areas.

Additional species generally as understorey include *Acacia cyclops, Acanthocarpus praise, Alyxia buxifolia, Anthoceris littorea, Atriplex cinerea, Atriplex isatidea, Beyeria viscosa, Nitraria billardierei, Olearia axillaris, Rhagodia baccata, Desmocladus flexuosa, Leucopogon parviflorus, Cassytha racemosa, Alyogyne* spp, *Exocarpus sparteus, Tetragonia decumbens, Dianella divaricata, Westringia dampieri,* some *Melaleuca systena and Templetonia retusa.* Some *Melaleuca huegelii* is added to the communities of the ridge tops.

*Eucalyptus decipiens* occurs on site in scattered locations, and one plant *of Eucalyptus obtusifolia* was observed in the north.

A stable swale area in the north has a stand of *Melaleuca lanceolata* that is worthy of preservation.

Towards the coast the vegetation remains predominantly *Acacia rostellifera* Thicket but more coastal species are added to the communities with a higher component of *Spinifex longifolius, Myoporum insulare, Scaevola crassifolia , Acanthocarpus preissi Olearia axillaris, Carpobrotus virescens, Alyxia buxifolia, Anthoceris littorea, Salsola kali, Atriplex cinerea, Atriplex isatidea, Beyeria viscosa, Cassytha racemosa Exocarpus sparteus, Leucopogon parviflorus, Ozothamnus cordatus, Ficina nodosa, Dianella divaricata Scaevola anchusifolia, Nitraria billardierei, Rhagodia baccata* and *Tetragonia decumbens*.

**Rare and Priority Species**

It was the wrong time of year to search for Rare or Priority species, and a definitive search was therefore not possible. However the chances of recording any Priority or Declared species in these coastal vegetation communities is low because the species are widespread and common.

ARC Energy investigated the Declared Rare and Priority Species and made a list of the species likely to occur within their seismic area which covered the subject land, but also included large areas of land to the south of Dongara and different inland soil types. The Declared Rare and Priority species are listed in Table 4.14 of their report. None of the species is likely to occur in coastal dunes.

Therefore there is regarded to be a very low chance of there being any Declared Rare and Priority Species occurring on the subject land.

**Dieback**

CALM generally recognises that Dieback is less likely to impact on vegetation on limestone and Spearwood/Cottesloe Land Systems, Podger F D and K R Vear, 1998, *Management of Phytophthora and disease caused by it*, IN *Phytophthora cinnamomi* and the disease caused by it - protocol for identifying protectable areas and their priority for management, EPA 2000.

There are, however, other plant diseases caused by fungus such as *Armillaria* that can cause dieback symptoms.

No evidence of significant plant diseases was observed during the brief traverses.

**Vegetation Condition**

The vegetation of the majority of the western portion of the site appears to have been cleared in the swales and or significantly grazed. It is however regrowing as *Acacia rostellifera* Regrowth Thicket. Its condition ranges from small areas of Completely Degraded to Degraded - Good.

The vegetation condition is improving as stock remain excluded from the vegetation

The small high ridges in the south east are covered by vegetation in better condition, probably because of the steeper slopes. This vegetation appears to range from locally Degraded to Very Good with the majority above Good. The condition scale is taken from Bush Forever 2000.

### 2.5 Surface and Groundwater

There is no surface drainage on the site with all infiltration moving vertically downwards to the water table.

Two bores are located on site with water available at 14 metres depth in the north and 6.5 metres in the south, making the water table at about 2 metres AHD.

These bores are associated with the cleared land. The water quality is 2475 mg/L in the north and 1705 mg/L in the south. The water is suitable for stock and some more hardy plants but is not generally suited to horticulture.

The quality was apparently better in the past and may have decreased due to reduced rainfall in recent years or mixing with a more saline water body, perhaps by general overpumping in the Dongara area.

The quality is, however, well suited to stock on small rural holdings.

## 3.0 HYDROLOGICAL ASSESSMENT - WATER AVAILABILITY

Bore water on site is suitable for stock but is not potable.

Potable water can therefore be provided by scheme water, tanks or desalination and/or bore water combined with a UV steriliser.

## 4.0 ALTERNATIVE LANDUSES

The site is adjacent to special rural lots and the eastern portion of the site is well suited to that purpose. The western area of higher dunes is suited to rural residential whilst retaining the significant amounts of vegetation to maintain soil cover and managing the fire risk

Alternatively the site is suited to urban development on smaller lots and is no different to many areas that have been developed in coastal towns. The same vegetation community is retained on the coastal reserve.

The Local Planning Strategy has identified Lot 10 as suitable for rural residential with the balance being urban.

Some management of the less stable soils and steeper slopes is recommended.

## 5.0 GEOTECHNICAL FACTORS

### 5.1 Foundation Stability

The eastern area is deep silica sand over limestone. These soils provide good foundation stability. According to AS 2870, Site Class A to S would probably apply to the silica sands. Site Class P will apply when slopes require > 800 mm sand fill, particularly on filled sites where differential levels of fill are required or a section of dwelling is located on limestone.

There are however situations on the limestone ridge where some care needs to be taken. See points 5 and 6 below.

The western portion of he site is underlain by calcareous coastal dunes which include some steeper slopes. This can raise some foundation issues that can be addressed at the time of dwelling construction. Constructions on these sands will vary from AS 2870 Site Class S to P. Site Class P will apply when slopes require > 800 mm sand fill, particularly on filled sites where differential levels of fill are required or a section of dwelling is located on limestone after cut.

The main issues with foundation stability on the calcareous sands are;

1. Calcium carbonate sands can crush or settle under load. For example where one corner of a dwelling is located on limestone at shallow depth and another corner is located on calcareous sand fill.

2. Calcium carbonate can dissolve in acidic garden conditions or acidic waste water conditions.

3. Underlying limestone may be less competent.

4. Earthworks should be sympathetic to any potential to destabilise sand. For example roads and paths should be located in areas where wind erosion is less likely and or the verges, revegetated or covered to minimise the risks.

5. There is potential for a dwelling on a concrete slab to be located with one portion of the slab located on limestone, with less potential for settlement, and other portions of the slab on calcareous sands which can settle. This might lead to differential settlement of the slab and the potential for cracking.

6. Calcareous sands can be non wetting and need to be treated appropriately to ensure adequate compaction.

7. When levelling a dune ridge for construction the original part of the dune is potentially more competent and compacted than the fill area, which should be filled and compacted and tested to ensure adequate compaction and a lack of potential for differential settling.

8. Undermining of footings during strong wind events or storms. There is also the risk of local undermining of isolated piers such as a carport through excessive stormwater from roof drainage. This should be managed by sympathetic disposal of stormwater away from the footings and maintaining good groundcover at all times.

**Management Actions** that may be used to improve foundation stability could include management of the points above and following.

Other techniques that can be of assistance are

- Provide retaining walls and structures for fill.
- Retain shrubs and deeper rooted vegetation on slopes.
- Consider the use of flexible or split level structures

- Design for lateral creep pressures on slopes.
- Ensure adequate compaction of all areas and to depth.
- Use rows of piers or strip footings orientated up slope on sloping ground.
- Minimise the potential for acidic water loading of footings.
- Prevent undermining and removal of sand from around or from under constructions, particularly on exposed steeper slopes in the western portion.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.1.1 | Foundation stability | • See the above Management Actions for some methods of reducing potential foundation limitations on calcareous soils and dune ridges.<br>• Each dwelling site will need to be individually assessed at the time of design and construction to determine any potentially deleterious conditions and to incorporate methods to mitigate them.<br>• AS 2870 Site Class S - P depending on the location of the potential dwelling from a low sand swale to a steep calcareous sand ridge.<br>• The adequate ground cover is recommended to minimise the risk of undermining structures. |

- Site Class P may apply. For example constructions requiring more than 400 mm natural fill and/or 800 mm sand should be classified as Site Class P to ensure adequate compaction to prevent differential settling.
- Individual site assessment may be required for any dwelling or development because of lateral and vertical soil changes that may be present and because of previous soil disturbance that cannot be detected by visual assessment.

## 5.2 Drainage and Flood Risk

Almost the whole site is well drained with no risk of inundation or flooding. The exception is a small area in the central south where heavy rainfall can cause pools of water on the surface for a short time.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.2.1 | Inundation | • Some consideration of surface water may need to be made in the area marked on the aerial photograph. This can be through drainage or fill. |
| 5.2.2 | Flood risk | • No issues. |

## 5.3 Capability for On Site Effluent Disposal

The critical issues in the design and placement of effluent disposal systems is to ensure adequate microbial purification and adequate protection from bores. The soils are very permeable.

Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974, require 1.2 metres of free draining soil under a waste water disposal system and a location not closer than 30 metres to a bore. Normal practice is to allow 5 metres of sand travel for adequate microbial purification.

The separation distances between the water table, at about 2.0 metres AHD, is 4 - 5 metres at the small low point on the site in the central south. The separation then increases to 8 metres in the east and to over 35 metres in the west. This would comply for lot sizes down to 2 000 $m^2$. Smaller lot sizes in the future would require connection to sewerage.

There are only two bores, and waste water systems can be located over 30 metres from any bore. This would particularly apply to any bore used for a domestic supply. Water from such a bore that is closer than 30 metres could be sterilised using an in line UV steriliser.

Under land systems such as this the main nutrient loss is nitrate, with phosphorous being taken up by the iron oxides and calcium carbonate in the calcareous sands and basal limestone. This is discussed in 2.2 Soils.

The soils comply with the Government Country Sewerage Policy, the Health Act Regulations (1974) and Health Department Guidelines for the installation of both conventional septic systems and, alternative waste water systems and the Greywater Disposal Guidelines.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.3.1 | Site Capability for Effluent Disposal | • Conventional septic systems or alternative waste water systems are acceptable and comply with the Health Regulations 1974 and the Country Sewerage Policy.<br>• Alternative effluent system disposal areas are to be sized at $10L/m^2$ .<br>• Appropriate setbacks are recommended from domestic bores of at least 30 metres. |

## 5.4 Landslip Risk

Whilst the steeper slopes are sandy they are more susceptible to having structures undermined by wind if unprotected rather than slippage. Undermining could lead to unacceptable movements if allowed to occur. The only risk to structures is from foundation stability.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.4.1 | Landslip Risk | • Covered by the considerations in 5.1 Foundation stability. |

## 6.0 ENVIRONMENTAL MANAGEMENT

The following items are identified as the most likely to impact on the environment. These items can be managed by the implementation of the management recommendations. Other items are unlikely to impact or the impact is regarded as small.

### 6.1 Aesthetics

The aesthetics depend on the level of visibility that can be obtained of dwellings and other developments, particularly from the beach, Brand Highway and other dwellings. The use of Lot 10 for rural residential will provide a buffer to Brand Highway.

The site has setbacks and reserve land separating it from the beach. It is unlikely that few dwellings will be able to be seen from ground level from the beach because of coastal dunes and vegetation, even though the dwellings may well have ocean views. Some may be able to be seen from the ocean.

The low ridge in the east protects a significant portion of the site from Brand Highway. In addition trees are normally planted on smaller rural lots and lifestyle lots. Retention of vegetation in the west can be addressed as part of the subdivision approval process.

The colour, height and style of dwellings and other structures should be visually compatible with the area and to this end developments should be coloured, painted or colour bond sheeting used where applicable. The use of grey galvanised or zinc/alum sheeting should be avoided unless as an integral part of a development such as a roof on a "country style" home or shielded from key sight lines.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.1.1 | Remnant vegetation | • The identification of areas of vegetation to be retained can be established as part of the subdivision approval process.<br>• The eastern portion of the site is cleared and all the swale areas on the western half were previously cleared and are now occupied by regrowing *Acacia rostellifera* Thicket.<br>• Dongara townsite is growing and the subject land is a logical extension of urban and rural living lots to the south. |
| 6.1.2 | Dwellings, fences and other developments are to be aesthetically compatible with the area. | • The Shire of Irwin can place restrictions on the use of visually non compatible materials at the time of Development Approval.<br>• Appropriate conditions can be placed during the Subdivision approval process. |

### 6.2 Preservation of Agricultural Land

The western half is substandard agricultural land only suited to grazing in the swales. The cleared land in the east is cropping and grazing land, but is dissected by the limestone ridge. A portion was used for horticulture in the past but the bore water has become brackish to the point where it is not suitable for sensitive crops.

The amount of agricultural land that will be lost is small and offset by an extension to the Dongara townsite.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.2.1 | Protection of agricultural land | • A small area of agricultural land will be impacted on. |

## 6.3 Land Use Buffers

As the use of the site is proposed to be rural living, and possibly for future urban development, no particular buffers are required, The land adjoins reserve land and is bordered on the east by the Brand Highway.

The buffer to the coast is a minimum of 450 metres at its closest point. Management actions are suggested to minimise impacts on the coastal reserves in 6.8 Stormwater, Erosion Potential and Soil Management. It is suggested that the western boundaries of lots be fenced and that there only be one permitted and defined track to the beach from the subject land. Uncontrolled access could lead to destabilisation of some coastal reserve land.

The other potential issue is the dumping of garden waste over the back fences. This can lead to significant weed issues, but is little different to other areas. The best means of managing this is to have a hard paved surface separating the lots from the coastal reserves. This tends to discourage the dumping of weeds and provides a better opportunity for management, including access.

A hard surface track along the western boundary will also provide fire access.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.3.1 | Rural land | • No particular buffers are required. |
| 6.3.2 | Buffers to Agriculture | • Buffered by reserve land and Brand Highway. |
| 6.3.3 | Buffers to Coast | • Buffered by reserve land, fences and defined pathways.<br>• See recommendations in 6.8 Stormwater, Erosion Potential and Soil Management. |

## 6.4 Flora and Fauna

### Flora

The vegetation was assessed briefly on 13 April 2005.

The eastern half of the site is cleared apart from *Acacia rostelfifera* regrowth that is now coming back on the limestone ridge. This has minimal to generally no understorey species.

The western portion has been previously cleared in the swales for grazing but is regrowing strongly as *Acacia rostellifera* Thicket. The tops of the ridges and the steeper slopes have largely been uncleared although grazed in the past. They are also regrowing.

The vegetation of the western portion is dominated by *Acacia rostellifera* Thicket as discussed in 2.4 Vegetation. The same vegetation communities occur along much of the Western Australian coastal dunes and is generally well reserved.

The species are typical of the older Quindalup Dunes, grading to more coastal species towards the west.

ARC Energy investigated the Declared Rare and Priority Species and made a list of the species likely to occur within their seismic area which covered the subject land, but also included large areas of land to the south of Dongara and different inland soil types. The Declared Rare and Priority species are listed in Table 4.14 of their report. None of the species is likely to occur in coastal dunes and therefore none are expected to occur on site.

**Fauna**

The fauna was not assessed and is related to habitat. The more remnant vegetation remaining the greater the amount and chances of fauna. The adjoining land to the west and south are reserves, Reserve 25581, 23600 and 45038.

The best means of minimising impact on fauna is to retain habitat and minimise disruptions to fauna usage by fences and tracks. However the site is a logical extension of the Dongara townsite and this has to be balanced against the need for urban and rural living properties and town expansion.

The amount of habitat to be retained will be determined as part of the subdivision approval process.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.4.1 | Flora | • Some remnant vegetation to link the existing reserves to the north and west and the remnant vegetation along the eastern boundary is desirable.<br>• Fire breaks and fuel reduction zones will apply to the western edge of the site and could be formed on existing cleared/slashed areas and existing tracks. This can be determined as part of a Fire Management Plan to be prepared.<br>• Onsite firebreaks could be located in already cleared or disturbed areas and existing tracks.<br>• The better vegetation on the steeper south eastern corner could be considered when allocating public open space.<br>• The same vegetation community is retained in the coastal reserve. |
| 6.4.2 | Fauna | • Fauna depends on the retention of habitat and providing habitat linkages and corridors. See 6.5.1 above. |

### 6.5 Nutrient Management

The main issues with nutrient impacts is from waste water disposal and the potential for increased nutrients on the cleared land of the eastern half.

Phosphorous is the main nutrient implicated in algal blooms in waterways. Nitrates are normally taken up by vegetation, denitrified by bacteria under anoxic soil conditions or lost through volatilisation of ammonia. Microbial material is normally deactivated by soil micro-organisms.

Phosphorous will be taken up by the iron oxides and calcium carbonate in the calcareous sands and basal limestone. The soils of the site are coloured sands over limestone which together have sufficient phosphate retention capability to minimise phosphorous export. Sorption by calcareous soils is dominated by precipitation and sorption reactions with calcium carbonate and the formation and precipitation of minerals such as di-calcium phosphate, $CaHPO_4.2H_2O$.

Nitrogen and microbial material are dealt with during travel through the subsoils.

The depth to groundwater is a minimum of 4 - 5 metres in a small area in the central south with the majority of the site having a separation of 5 to 15 metres in the eastern half and 15 plus metres in the western half.

Phosphate Retention Index (PRI) is a measure of the potential adsorption of phosphorous by soils. At a low PRI of 2 each cubic metre of soils and limestone can adsorb 3.0 kg phosphorous. At a PRI of 5 the potential adsorption is 12 kg. This provides for substantial adsorption capability for the soils, even at the lowest PRI.

A typical septic system loses at least half the nitrogen through denitrification in the two tanks. This brings the concentration down to 10 - 40 mg/L. Conventional septic systems release 5 - 6 kg phosphorous per year. As such all the phosphorous will be adsorbed within 1 metre of a standard dual 9 metre leach drain system for a period of 33 years at a soil PRI of 2.

Further denitrification occurs in moist sands in the presence of organic matter. Therefore it is also unlikely that nitrogen will either reach the coast or reach it in significant concentrations.

Considering the travel distances to the water table and coast it is most unlikely that phosphorous will be exported to the marine environment, or the concentration will be below significant levels. The closest corner of the site to the ocean is 450 metres and the majority of the site is 10 to 15 plus metres to the water table.

On reaching the coast there will be additional very large dilution by the ocean.

**Change of landuse**

The eastern portion of the site is currently used for broad acre cropping and grazing.

With a current average stocking rate on the eastern half of 5 DSE, the estimated nutrient loading when fully stocked with sheep or equivalent numbers of stock could be 53 kg/N/ha/year and 7.3 kg/P/ha/year.

The use of nutrients on broad acre crops is not dissimilar to these levels, but will vary depending on the existing nutrient status of the soils and the type of crop grown, for example if a legume or green manure crop had been used in rotation and if stubble is retained. Phosphorous rates could be 10 - 30 kg P/ha (20 kg requires 220 kg superphosphate). Nitrogen requirements can be 100 to 200 kg/ha depending on the quality and protein content of the cereal crop. These fertiliser application rates are discounted for stubble retained (eg 40 kgN), and the existing retained soil levels from past cropping, and thus the actual application rates can be substantially less, particularly in the case of nitrogen.

Lantzke and Summers, 2005, state that the measured nutrient inputs for various land uses near Bunbury for cereal cropping was 30 kg/N/ha/year and 30 kg/P/ha/year.

With rural living the behaviours of nutrients is influenced by denitrification, volatilisation of ammonia, recycling, uptake by vegetation and phosphate absorption by sesqui-oxides.

To gain some idea of nutrient changes a typical conventional septic system releases 5.5 kg P year and 18 kg N/year. However allowing for six chickens, a dog and cat and a 250 $m^2$ area of fertilised gardens, a further loading of 12.3 kg N/year and 5.2 kg P/year can be added for the dwelling area. (Data from Select Committee on Metropolitan Development and Groundwater Supplies, Legislative Assembly 1994 and Nitrate management in the Jandakot UWPCA, Dames and Moore, undated).

One horse is estimated at 60 kg/N/year and 11 Kg/P/year, and one sheep 10.06 kg/N/year and 1.47 Kg/P/year. Data for cattle from Select Committee on Metropolitan Development and Groundwater Supplies shows cattle as 57.4 kg/N/year and 17.6 kg/P/year. The value for phosphorous may be too high for cattle not fed introduced feed.

Data for typical land uses listed below, which might be used at some stage in the future, show that overall nutrient loading is unlikely to rise with changes in land use, and with continued grazing there will also be no change.

For the western areas covered by remnant vegetation the inputs are likely to be less because a substantial portion of the existing vegetation is likely to be retained and stock reduced or excluded. For example a horse can release double the phosphorous of a conventional septic tank and three times the nitrogen when fed introduced feed. This is normally spread across paddocks but can be concentrated at a point source when a horse is stabled.

For smaller or urban lot sizes stock are normally removed, sewerage is provided and therefore the input rates of nutrients reduce.

**Typical nutrient loadings of some land uses**

| Possible lot size and activity | Nitrogen loading per hectare | Phosphorous loading per hectare | Likely nutrient scenario |
|---|---|---|---|
| Estimated average current stocking rate over the whole property 5 DSE per hectare | 53 kg/N/ha/year | 7.3 kg/P/ha/year | Possible nutrient loss through washing of dung down slope during waterlogged conditions and during storms. |
| Cereal cropping | 30 kg/N/ha/year | 30 kg/P/ha/year | |
| 2 hectare rural residential property, conventional septic system, garden, dog and cat as listed above and 1 horse | 45.2 kg/N/ha/year | 10.9 kg/P/ha/year | Unlikely to be nutrient export when correctly established. |
| 0.5 hectare rural residential property, conventional septic system, no stock, but garden and dog and cat as listed above | 60.6 kg/N/ha/year | 21.4 kg/P/ha/year | Unlikely to be nutrient export when correctly established. |

| | | | |
|---|---|---|---|
| 0.1 hectare urban lot with reticulated sewerage, 250 $m^2$ high nutrient garden and 50% of lots having a dog and cat as listed above | 60.0 kg/N/ha/year | 27.0 kg/P/ha/year | Unlikely to be nutrient export when correctly established. |

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.5.1 | Effluent disposal | • Interpretations of the groundwater movement, input of nutrients and soils suggest that it is unlikely that there will be any or minimal export of phosphorous or nitrogen to the coast. Any concentrations arriving there are likely to be insignificant and readily diluted by sea water. |

## 6.6 Salinity

There is no evidence of salinity on site and, with the free draining soils, salinity is not regarded as a significant issue.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.6.1 | Salinity | • Unlikely to be any significant changes to the current regime. |

## 6.7 Stormwater, Erosion Potential and Soil Management

The potential for wind erosion of the site is high in soils such as this.

Potential water erosion is minimal and confined to storm events when the soils are non wetting.

Some site conditions and management activities that will minimise the potential for wind erosion and prevent further dune degradation are;

- Constructing roads, fences and firebreaks in locations which are less likely to lead to soil erosion.
- The swales of the western areas have lower wind erosion risk. The two high sand ridges shown on the attached aerial photograph have higher risk and may require additional management.
- Existing roads in coastal areas such as Mulloway and Red Emperor Drive at Flat Rocks in the Greenough Shire demonstrate that construction of access is possible without leading to soil erosion.
- Unnecessary tracks can be closed with the exception of one track to allow public access to the beach.
- The access track to the coast should be defined by fencing, poles or some other mechanism where it is likely that the track will be breached or additional tracks formed.
- A perimeter fence along the lots, particularly in the west will minimise the incursions into the coastal vegetation.
- Some remnant vegetation on the remainder of the western portion of the site can be incorporated into the subdivision design.

- Firebreaks should be strategic and consist of low fuel zones through slashing rather than removal of vegetation.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.7.1 | Water erosion | • Runoff from roads is to the sand along the verges and drainage detention basins. |
| 6.7.2 | Wind erosion | • The management actions listed in the dot points above will be implemented. No special recommendations required. |

## 6.9 Fire Control

Fire Control falls under the Bush Fires Control Act (as amended) and the Shire of Irwin.

The remnant vegetation will pose a High risk, and fuel reduction zones between the vegetation and dwellings will be required.

The main issues with fire management are the reduction in fuel by slashing to minimise the potential for soil erosion.

A condition of subdivision could be for a tank holding at least 10 000 litres or a rainwater tank to at all times, or a standpipe facility to be available for fire fighting

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.9.1 | Fire Risk | • Dwellings could have adequate Building Protection Zones and be protected by a strategic fire break and/or fuel reduction zones.<br>• Access and fire management could be discussed with the relevant fire control officer and addressed in a Fire Management Plan.<br>• Guidelines in Planning for Bush Fire Protection, 2001 (FESA and DPI) and Shire of Irwin can be implemented.<br>• Provision of an emergency water supply is possible either through standpipe or similar mechanism or agreed to by the proponent and can be a condition of development or subdivision. |

## 7.0 CONCLUSIONS

The proposed development of Lots 10, 15, 16 and 17 Francisco Road, Dongara to rural residential or conventional residential development is sustainable.

The amount of land removed from agricultural production is small. Some vegetation in the west will require clearing, but this is typical coastal vegetation of which a substantial portion was previously cleared and is now regrowing to *Acacia rostellifera* Thicket.

Previous studies suggest that there are unlikely to be any Declared Rare or Priority species likely to be present. The coastal vegetation is common all along the coast and its taking of portion of an area such as this must be weighed against the planning consideration for the potential future expansion of the Dongara Townsite, this being the next closest land to the existing townsite.

The potential for nutrient export is assessed to be low either from rural living, special rural or urban lots.

The proposed subdivision is set well back from the coast at a minimum of 450 metres and is not likely to have significant impact on the coast, and may provide an opportunity to manage uncontrolled coastal access.

The use of Lot 10 for rural residential will provide a visual buffer between urban land and the Brand Highway.

There are no significant reasons why Lots 10, 15, 16 and 17 Francisco Road, Dongara cannot be rezoned to rural residential or at some point in the future, an expansion of the urban townsite.

**REFERENCES - BIBLIOGRAPHY**

Allen D G and R C Jeffery, 1990, *Methods for Analysis of Phosphorous in Western Australian Soils*, Chemistry Centre, Report on Investigation No 37.

ARC Energy - Origin Energy, 2004, *Denison 3D Seismic Survey*, Public Environemtnal Review.

ARMCANZ, ANZECC, September 1995, *Guidelines for Groundwater Protection in Australia,*

ANZECC, 2000, *Guidelines for Fresh and Marine Water Quality.*

Coles and Moore, 1998, *Runoff and Water Erosion*, in Soil Guide, WA Department of Agriculture, Bulletin 4343.

Dames and Moore, undated, *Nitrate management in the Jandakot UWPCA.*

Data from *Select Committee on Metropolitan Development and Groundwater Supplies*, Legislative Assembly 1994.

Dawes L and A Goonetilleke, 2001, *The importance of site assessment in designing effluent disposal areas*, Proceedings of the 2nd Australia and New Zealand Conference on Environmental Geotechnics - Geoenvironment, University of Newcastle, New South Wales.

Department of Environment WA, 2004A, *Stormwater Management Manual for Western Australia.*

EPA Guidance Number 26, *Management of Surface Runoff from Industrial and Commercial Sites* (draft) 1999.

Environmental Protection Authority Victoria/ Melbourne Water, undated, *Urban Stormwater, Best Practice Environmental Management Guidelines.*

FESA and WAPC, 2001, *Planning for Fire*, Fire and Emergency Services Authority of Western Australia.

Gerritse et al, 1995A, *Nitrogen Losses from a Domestic Septic Tank System on the Darling Plateau in Western Australia*, Wat. Res. Vol 29, No 9.

Gerritse et al, 1995B, *Retention of Nitrate and Phosphate in Soils of the Darling Plateau in Western Australia: Implications for Domestic Septic Tank Systems*, Aust. J. Soil Res. 33, 353-67.).

Gerritse R, 1993, *The influence of landuse and soil type on nutrient losses*, IN Swan River - The Future, Swan River Trust Report No 8.

Gerritse R G and J A Adeney, *Nutrient export from various land uses on the Darling Plateau in Western Australia CSIRO Report 92/41.*

Lantzke, 1997, *Phosphorous and nitrate loss from horticulture on the Swan Coastal Plain*, Agriculture WA

Podger F D and K R Vear, 1998, *Management of Phytophthora and disease caused by it*, IN *Phytophthora cinnamomi* and the disease caused by it - protocol for identifying protectable areas and their priority for management, EPA 2000.

Rogers L G, 1996, *Geraldton Region Land Resources Study*, Department of Agriculture, Land Resources Series Number 13.

*Select Committee on Metropolitan Development and Groundwater Supplies*, Legislative Assembly 1994.

# APPENDIX 6

**Bushfire Management Plan 2013 (York Gum Services)**

# Bushfire Management Plan

# Francisco Road Dongara

**Prepared by York Gum Services**

**November 2013**

(including minor modifications requested by Shire of Irwin 22 July 2014 Item P102-07/14, and clarification of dwelling setbacks and BAL rating requested by WAPC Modification 21)

# Bushfire Management Plan

## Francisco Road Dongara, Shire of Irwin WA

# 1. Introduction

## 1.1 General

This Bushfire Management Plan sets out the background, principles and commitments for minimising potential bushfire damage for a proposed residential development at Francisco Road Dongara, in the Shire of Irwin WA ("the property"). The plan is prepared on behalf of the proprietors (the "developer") of Lots 4, 5 and 10 at the corner of Brand Highway and Francisco Road (the "site") in the Shire of Irwin's (the "Shire") locality of Dongara by Roger Underwood of York Gum Services (the "consultant").

## 1.2 Purpose of this plan

The purpose of this Bushfire Management Plan is:

- To identify measures at the planning stage that will minimise the risk of bushfire damage to life, property and communal assets at the site;
- To address the requirements set out in the *Planning for Bushfire Protection Guidelines* (Western Australian Planning Commission and Fire and Emergency Services Authority, 2010) and the planning and bushfire requirements of the Shire of Irwin;
- To take into account the need to conserve environmental values including soil, flora and fauna and waterways;
- To identify the location of roads, fire breaks, fuels management, access and egress points;
- To describe proposed arrangements for water and power supply; and
- To identify standards, if necessary, to be adopted in the construction of homes.

In addition the developer recognises that some years could elapse before a subdivision plan is approved and development commences. For this reason, an interim fire management regime is proposed for the site.

The following underlying principles are adopted by the developer to underpin bushfire management at the site:

- Current and future bushfire threats will be identified and, as far as possible, mitigated;
- Planning will be undertaken in the light of an understanding of bushfire threats to human, economic and environmental/conservation values;
- Development will be in compliance with a formal bushfire management plan (this document) that must satisfy, as far as is practical, the bushfire management requirements of the Shire and the Department of Fire and Emergency Services (DFES).
- The developer will set out measures to be adopted to minimise the risk of bushfire damage at the site before development begins.

The developer also recognises a responsibility to the neighbours of the site, and further recognises that it will be important to ensure as far as possible that residents at the property maintain a high standard of bushfire preparedness. The developer undertakes to do this through education at the point in time of the sale of a lot, including providing lot buyers with copies of this management plan, and encouraging lot buyers to support the Shire and the local volunteer bushfire brigades in maintaining high standards of bushfire preparedness.

## 1.3 Description of the proposed development

### 1.3.1 Location

The site is located immediately north of the town of Dongara, west of the Brand Highway and north of Francisco Road, and about 1.5 kilometres from the sea. Immediately to the west is cleared farmland and beyond that an area of coastal scrub. To the east is long-established farmland, to the south the town of Dongara and to the north an area of hobby farms with scattered bush and clearings.

The total area of the three lots on which the development will be located is 57.7 hectares

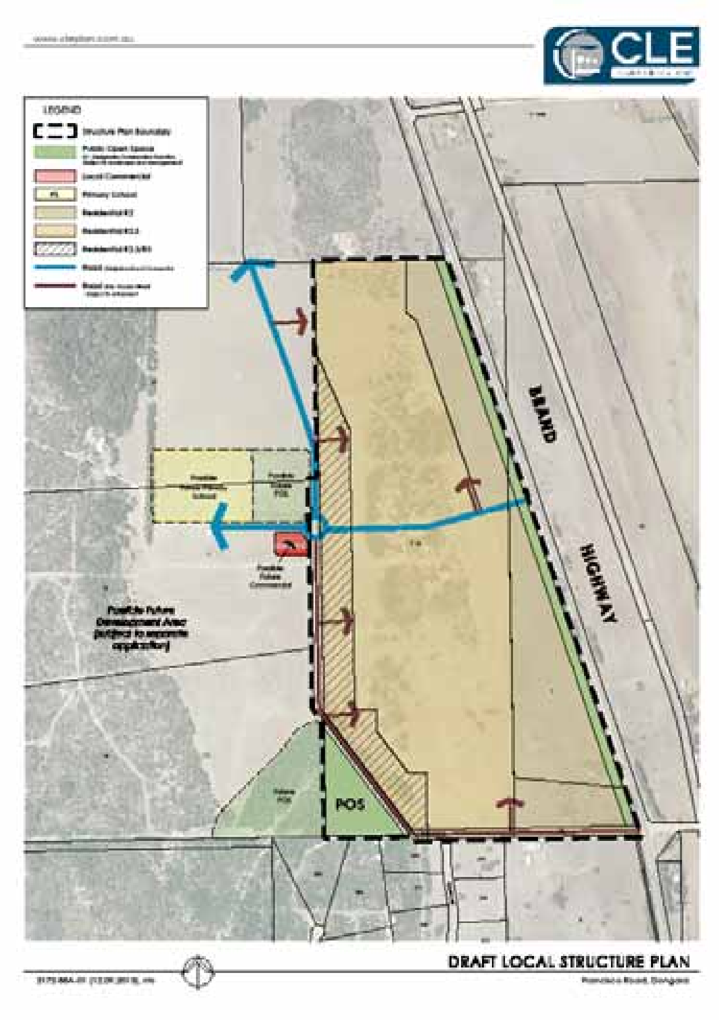



**Figure 1: Location and context**

### 1.3.2 District context

The site is readily accessed from (and new internal roads will be linked to) the Brand Highway and Francisco Road and from the north on planned future road link providing access over Lots 10 and 17 to Lot 1409.

Adjoining the property on its south-west corner is a small area of native bushland that will become public open space (POS), under the management of the Shire of Irwin.. Beyond that to the southwest is Nature Reserve 23600 which comprises coastal scrubland. This reserve is managed by the Department of Parks and Wildlife.The Dongara–Port Denison Volunteer Brigade station is located approximately 4 kilometres away. The property can be reached within 30 minutes by road by other fire brigades in the region.

Beyond the Dongara townsite the principal land-use is broad-acre farming. The farmers are generally well-organised and well-equipped and rapidly attend any bushfire that is threatening community or farm assets.

### 1.3.3 Zoning

The property is zoned 'Development" under the Shire's  Town Planning Scheme No. 5.


**Figure 2: Concept plan showing proposed lots and roads**

#### 1.3.4 Proposed lots

No formal subdivision plan has been prepared as yet, but the developer has foreshadowed that the property will be subdivided into 83 residential lots ranging in size from 4000 sq metres to 1.2 hectares, and has prepared a conceptual subdivision layout which accompanied the proposal to rezone the land from it's former rural zone to the current Development Zone.

In this layout, all lots will be serviced by fully constructed and sealed roads.

#### 1.3.6 Relationship of this Bushfire Management Plan to approval requirements

It is a requirement of the Development zone that a Structure Plan be adopted by both the Shire and the WA Planning Commission ("WAPC"). The Shire requires that a proposed structure plan be accompanied by a bushfire management plan that demonstrates how bushfire protection is to be planned and implemented at the site.

This Bushfire Management Plan is prepared to meet this requirement.

The developer undertakes to update this Bushfire Management Plan if, after a Structure Plan has been approved, there are any significant changes to the draft subdivision plan that has been foreshadowed in this Bushfire Management Plan.

#### 1.3.7 Existing Bushfire Management Plans impacting on the property

There is no existing Fire Management Plan covering the site.

# 2. Site Details

## 2.1 Climate

The climate of the region is Mediterranean, with cool wet winters and hot dry summers. Summer thunderstorms with lightning occur nearly every year. This climate is conducive to bushfire occurrence and fire spread, with hot days and low relative humidity for weeks at a time every summer.

The area experiences strong winds most summer days, especially the easterlies in the morning and a south-westerly sea breeze on most summer afternoons.

Under this climate bushland in the area will burn intensely in the height of summer when the vegetation is fully cured.

## 2.2 Topography

The site is gently undulating, rising to a high point in the northwestern corner. There is a north-south ridge running through the centre. There are no grades steeper than 1:10, and no dissected gullies or watercourses.

## 2.3 Rock outcrops and soil types

The bulk of the site comprises brown sand, but the north-south ridge comprises limestone caprock.

The small triangle of proposed POS on the south-west corner comprises a consolidated sand dune.

## 2.4 Vegetation

The site is about 75% cleared of it origainl native veagtation. The remainder, comprising the non-arable land along the capstone ridge, carries dense clumps of wattle scrub, mostly *Acacia rostellifera*. Lines of tuart (*Eucalyptus gomphocephela*) trees have been planted in three areas.

## 2.5 Existing water resources

Existing dwellings on the site are served by rainwater and/or bores.

The site sits over substantial reserves of underground water, located at a depth of about 10 metres.

## 2.6 Existing land use and improvements

The site has been used as farmland for many decades (principally grazing with sheep). The site has a boundary fence with locked gates.

There are three existing dwellings, located on the site. These existing dwellings may be incorporated into the future proposed development of the site.

# 3. Bushfire risk and threat

## 3.1 Bushfire history at the site

No data is available on the precise bushfire history at the site, although it is likely that fires have occurred in the area many times in the past.

## 3.2 Bushfire fuels

Current fuels over the bulk of the area of the site are light and while grazing continues will not carry a sever bushfire. The fuels are grass, Acacia scrub and exotic weeds, all of which have been heavily grazed.

There is a small patch of ungrazed bush on a steep dune in the south-west corner which is proposed to become POS. This portion of the site comprises heavy bushfire fuels.

## 3.3 Factors affecting the risk of a bushfire occurring

Fires are likely to be started by lightning, accident or arson. The likelihood of accidental or deliberate lighting of fires will increase as the population increases, but this can be counteracted by increased education and awareness.

Currently there are overhead powerlines on the site, and these represent a risk of a fire starting, but these will be replaced by underground power at the time of development. The site is adjacent to

Brand Highway, which could be a potential source of fire in the form of an accident or careless disposal of a cigarette butt or match.

## 3.4 Assessment of bushfire hazard

Using the methodology set out in *Planning for Bushfire Protection Guidelines*, bushfire hazard on the site is assessed as follows:

- Low Hazard: all areas of open cleared paddock, and grazed grassland
- High Hazard: clumps of dense coastal scrub on the central ridge including weed infestations

## 3.5 Values threatened by bushfire

The following values will be potentially threatened by a bushfire following development of the site:

- Human lives: approximately 250 people are expected to reside at the site or be present at the site on any day, following completion of development;
- Buildings and other personal assets, including sheds, gardens, vehicles, animals;

## 3.6 Assessment of Bushfire Attack Level (BAL)

Bushfire Attack Level (BAL) has been assessed according to the methodology set out in the *Planning for Bushfire Protection Guidelines* as follows:

There will be no bushland retained on the site other than in the POS in the south-west corner..

For proposed lots that will have no adjoining bushland the BAL is assessed as being Low, and no special housing construction standards are considered necessary.

For lots adjoining the bushland in the POS in the southwest corner:

- The bushland is classed as Low Open Forest (Class 4)
- The bushland will be uphill of any dwellings
- The distance from bushland to lot will be at least 20 metres;
- A 15m front setback applies to dwellings zoned Residential R2.5 providing additional seperation between bushland and dwelling;
- This indicates a BAL of 19 (which would typically require minimum 31m separation)
- Lots with a BAL of 19 must have dwellings that comply with the construction standards set out in sections 3 and 6 of AS 3959-2009

.

## 3.8 Summary of potential bushfire issues

That portion of the site proposed for development is either cleared pasture or low scrub that will be cleared during development. Following development and the construction of roads, houses and gardens the area is, therefore, unlikely to carry a running bushfire.

Dwellings in the south-west corner will need to have special protection from fires that might start in the adjacent Conservation Reserve and burn into the small triangle of POS.

The principal bushfire threat to the site will be from fires starting in the coastal bushland to the west and driven by a strong south-westerly wind, or fires coming in from the north under the influence of a northerly wind. Such fires will be fast moving and will generate flying embers that could reach the dwellings on the site.

A range of precautions must therefore be adopted to minimize the threat of damage from a bushfire or from an ember storm entering the property

# 4. Bushfire Action Plan

## 4.1 Interim bushfire management

The developer acknowledges that some years might elapse between the issue of an approval to subdivide the site and the time when the site becomes fully developed with dwellings. In the interim, the developer undertakes to implement the following measures on the site:

- Continue to maintain a secure fence around the property to discourage illegal access;
- Continue to maintain the perimeter firebreak and existing access routes and to meet all requirements of the Shire of Irwin;
- Continue to maintain low bushfire fuels on the site by grazing or other measures; and
- Continue to support the local volunteer bushfire brigades.

## 4.2 Protection of human lives and property

The following measures are proposed to protect, as far as is possible, the lives of residents and their assets from bushfire damage if this development proceeds:

1. The developer will register, with the co-operation of the Shire, a Section 70A Transfer of Land Act 1893 (as amended) Notification on each lot stating as follows:

   *The Shire of Irwin advises that:*
   *a. a Fire Management Plan applies to this lot; and,*
   *b. dwelling construction on the lot is required to comply with sections three and six of Australian Standards AS3959-2009 ("Construction of Buildings in Bushfire-prone Areas");*
   *c. while any dwellings constructed on the lot are required to comply with AS3959:2009 ("Construction of Buildings in Bushfire-prone Areas") this in no way guarantees that the constructed dwelling will survive a bushfire attack.*

2. Each lot owner will be required to install and maintain a Building Protection Zone (free of flammable material) around any dwelling they construct on a lot.

3. Building Protection Zones (BPZ) are to be contained fully within the lot as indicated on an approved subdivision plan Each BPZ is to have the following characteristics:

   - width: 20 metres measured from the outermost external walls of the building;
   - location: within the boundaries of the lot on which the building is situated, unless this zone overlaps with a BPZ on an adjoining property or within a road reserve;
   - fuel load: reduced to and maintained at 2 tonnes per hectare;
   - any trees planted within the BPZ to be a minimum of 10 metres apart and trees low pruned at least to a height of 2 metres;
   - no native scrub to be located within 2 metres of a building (including windows) and no tree crowns are to overhang the building;
   - fences and sheds within the BPZ are to be constructed using non-combustible materials (e.g. colourbond iron, brick, limestone);
   - shrubs in the BPZ are to have no dead material within the plant and tall shrubs in the BPZ are not to be planted in clumps close to the building i.e. within 3 metres; and

BPZs are to be installed before houses are constructed.

4. The developer will recommend to the Shire, that the Shire impose as a condition on building permits that all dwellings constructed on any lot created within the site be secured against bushfire embers entering through rooftop facilities. This means that:

   (a) Rotary roof ventilators should be fitted with metal gauze spark screens with a minimum aperture size of 1.8 mm; and,

   (b) Roof-mounted evaporative air conditioners have the openings to the cooling unit fitted with metal gauze spark guards.

5. The area of Public Open Space in the south-west corner of the structure plan is to be maintained as 'parkland cleared' i.e. retain only large mature trees and replace understorey with irrigated, mown grass. The developer is to establish and maintain the area of Public Open Space as 'parkland cleared' until it is ceded to the Shire of Dongara. The Shire of Dongara will then be required to monitor and maintain the Public Open Space as 'parkland cleared' from that point onwards.

6. The developer will provide a copy of the Bushfire Management Plan and appropriate bushfire preparedness literature to each initial lot purchaser.

## 4.3 Bushfire risk mitigation

The developer will ensure (by providing initial lot owners with a copy of this Bushfire Management Plan at the time of sale of a lot) that initial lot owners are aware of the risk of fires starting in bushland to the west and north of this property under severe weather conditions, and will encourage initial lot owners to support the Shire's fire risk management protocols and the local bushfire brigades.

## 4.4 Access/egress and fire breaks

The draft subdivision plan for the site provides for high quality access/egress via sealed roads to every lot, permitting two-way movement of vehicles in an emergency and rapid ingress for fire appliances. Alternative egress will be possible from every lot east to the Brand Highway or south to Francisco Road.

At a future date, access/egress will also be available in the north-western section of the property. This will result from an integration of the road system for Lot 10 upon a future development of adjacent Lot 17 (as depicted on Map 2).

The current draft subdivision layout depicts one short battle-axe access to three lots adjoining the proposed new entry point to Brand Highway. This provides for safer access to these lots.

Lot owners will be required to meet the Shire's annual Fire Break Order (FBO) issued pursuant to Section 33(1) of the Bush Fires Act 1954 (the "Act").

Driveways to dwellings will be required to meet the same standards in terms of width and vertical clearance as firebreaks.

All lots will be fenced.

Any signage erected by the developer will meet standards set out by the Shire.

## 4.5 Water supplies

Every lot will be serviced by pressurised reticulated water supply, with the Water Corporation being the asset owner.

In addition, the developer will install a fire hydrant to the specifications of DFES every 200 metres along the internal road system.

Lot buyers will be advised (via this Bushfire Management Plan) that they should also consider the installation of rainwater tanks to provide a back-up water supply in the event of an emergency.

### 4.6 Power supply

The developer will arrange for all lots to be supplied with electric power. All power cables within the site will be installed underground. Existing overhead powerlines will be removed within the site.

### 4.7 Fire safer area

The developer will consult with the Shire in relation to the designation of a bushfire refuge, or "fire safer area", in the event that residents must be evacuated due to a large regional bushfire. All initial buyers of each lot will be notified of the location of the fire safer area, which will be signposted.

The author of this Bushfire Management Plan suggests that an appropriate area to be so designated is the football oval in Dongara, which is located approximately 10 minutes drive from the site.

### 4.8 Fire protection during stages of development

The developer will retain responsibility for bushfire protection measures on unsold lot/s as an ongoing owner, until ownership of such lot/s is transferred.

### 4.9 Public education and community awareness

The developer will provide to all initial lot buyers with a copy of this Bushfire Management Plan, plus a copy of the booklet *A Homeowner's Guide to Bushfire Safety* and bushfire literature from the Shire of Irwin. All initial lot buyers will be advised to familiarise themselves with an FBO (non-compliance with same being the subject of penalties under the Act).

The developer will advise (via this Busfire Management Plan) all initial lot purchasers that they should form a 'Bushfire Ready' group as outlined in the Department of Fire and Emergency Services 'Bushfire Ready' brochure.

### 4.10 Ongoing assessment of fire management risk

It is recomemded that the Shire should, following subdivision of the land, inspect the site at intervals which the Shire considers reasonable and appropriate and, having regard to this Bushfire Management plan and the provisions of the Act, issue any FBO's it considers to be appropriate.

## 5. Summary

### 5.1 Overall fire threat

The site is naturally susceptible to bushfires. This is because of the climate, the flammability of nearby bushland, and potential sources of fire such as lightning.

Following development, the site will contain values and assets that may be threatened by a bush fire, including life, property and community and the environment.

However, over most of the area of the site, the potential threat can be mitigated by sensible planning, and the institution of a number of critical measures, for example by utilising Building Protection Zones, constructing dwellings to ASA 3959-2009, installation of an adequate underground power and reticulated water supply (incorporating fire hydrants), providing good thoroughfare (both in to and out of the site), creating a reasonably well-educated community (being the measures prescribed in this Bushfire Management Plan).

## 5.2 Fire Management Plan

The developer has arranged for the preparation of a Bushfire Management Plan (this document) as a basis for mitigating the fire threat on the site.

This Bushfire Management Plan provides for measures that either must, or should be adopted by the lot purchasers and builders and makes commitments on behalf of the developer (limited to where the developer is lawfully able to make those commitments).

The developer undertakes to update this Bushfire Management Plan if changes are made to the development design during the preparation/approval of a subdivision plan following adoption of the Structure Plan.

## 5.3 Owners responsibilities

It will be the responsibility of lot owners to:

- Read and familiarise themselves with key documents, including this Bushfire Management Plan;
- Comply with an FBO or any other bushfire management requirement issued by the Shire or DFES under the Act;
- Install and maintain BPZ's (for all dwellings);
- Ensure houses are constructed to the appropriate ASA 3959-2009 standard where applicable as set out in this plan;
- Be familiar with evacuation routes and bushfire safer areas so as to be prepared in the event of a major regional bushfire;
- Support fire management operations by the Shire and volunteer bushfire brigades.

## 5.4 Developer's responsibilities

The developer undertakes to meet all of the commitments made by the developer in this Bushfire Management Plan.

## 5.5 Shire of Irwin responsibilities

The Shire will, when satisfied, approve an appropriate bushfire management plan for the site (this document), and ensure lot owners meet their responsibilities under the Act and its regulations in future years.

The Shire should also liaise with the Department of Parks and Wildlife to seek appropriate fire preparedness operations be undertaken on the conservation reserve nearby.

The Shire will monitor and maintain the area of Public Open Space in the south-west corner of the structure plan as ‘parkland cleared’ once the Public Open Space has been ceded to the Shire.

## 6.0 Disclaimer

The Consultant preparing this Bushfire Management Plan takes no responsibility for the impacts of a future bushfire on any values at the Francisco Road Dongara development described in this management plan. He has done his best in this strategy to alert residents to the threat of bushfires, and to suggest measures to minimise these threats and potential bushfire damage, but there may occur an unusual combination of events or human actions or lack of actions which could not reasonably have been expected at the time of preparing the Plan. The Consultant takes no responsibility for the standard of bushfire preparedness or damage mitigation undertaken by lot owners in the future.

## Appendix:

# Compliance checklist for performance criteria and acceptable solutions

### Based on Appendix 4 from *Planning for Bushfire Protection*

## Element 1: Location

Does the proposal comply with the performance criteria by applying acceptable solution A1.1?

Yes The site comprises land which is mostly classified as Low bushfire hazard, and, in addition, a Bushfire Management Plan has been adopted that specifies the installation of 20m wide Building Protection Zones and, where required by BAL analysis, the construction of homes to accord with ASA 3959 depending on the assessed BAL. These measures are prescribed in the Bushfire Management Plan and will become enforced upon lot buyers by the Shire.

## Element 2: Vehicular access

Does the proposal comply with the performance criteria by applying acceptable solution A2.1?

Yes Every lot will be serviced by a fully engineered and sealed road. There will be 2 alternative access/egress points to the property, all of which will be options that lot-owners can take in an emergency, or which can be used for entry by firefighters. A further access/egress point is foreshadowed if development of the adjoining Lot 17 proceeds.

Does the proposal comply with the performance criteria by applying acceptable solution A2.2?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A2.3?

Yes There are no cul-de-sacs in the proposal.

Does the proposal comply with the performance criteria by applying acceptable solution A2.4?

Yes There is one very short battleaxe entry, but this will not compromise bushfire operations.

Does the proposal comply with the performance criteria by applying acceptable solution A2.5?

Yes Constructed private driveways will be required to meet the same specifications as perimeter and internal firebreaks.

Does the proposal comply with the performance criteria by applying acceptable solution A2.6?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A2.7?

Not Applicable

Does the proposal comply with the performance criteria by applying acceptable solution A2.8?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A2.9?

Yes All lots must meet the firebreak requirements of the Shire of Irwin

Does the proposal comply with the performance criteria by applying acceptable solution A2.10?

Yes The Bushfire Management Plan specifies that compliance level and signs erected by the developer must meet the specifications laid down by the Shire of Irwin

## Element 3: Water

Does the proposal comply with the performance criteria by applying acceptable solution A3.1?

Yes Reticulated water supply will be provided

If no, please explain in writing how the proposal satisfactorily complies with performance criterion P3 for this area of non-compliance, and attach this explanation to the rear of this checklist.

Does the proposal comply with the performance criteria by applying acceptable solution A3.2?

Not applicable

Does the proposal comply with the performance criteria by applying acceptable solution A3.3?

Not applicable

If no, please explain in writing how the proposal satisfactorily complies with performance criterion P3 for this area of non-compliance, and attach this explanation to the rear of this checklist.

## Element 4: Siting of development

Does the proposal comply with the performance criteria by applying acceptable solution A4.1?

Yes Every dwelling constructed must have a Building Protection Zone. Dwellings on lots with a BAL of 19 are identified and must, as a minimum, meet the prescribed requirements in ASA 3959-2009. In addition the developer has recommended high standards of rooftop protection from ember attack for all dwellings.

Does the proposal comply with the performance criteria by applying acceptable solution A4.2?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A4.3?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A4.4?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A4.5?

Not applicable. No shielding is proposed.

## Element 5: Design of development

Does the proposal comply with the performance criteria by applying acceptable solution A5.1?

Yes The design of the development in terms of building protection, hazard/fuel reduction, standard of construction, fire breaks, water supply, access/egress and education of lot buyers will ensure that the bushfire threat on the property is minimised, provided all of the provisions in this plan are instituted and maintained.

Does the proposal comply with the performance criteria by applying acceptable solution A5.2?

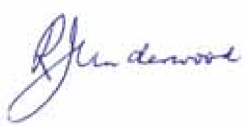
Not applicable

## Applicant Declaration

I declare that the information provided is true and correct to the best of my knowledge.

Full name: Roger Underwood

Applicant signature:



Date: November 25th 2013

# APPENDIX 7

## Acoustic Assessment 2015 (Herring Storer)

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## CLE TOWN PLANNING AND DESIGN

# LOT 4, 5 AND 10 BRAND HIGHWAY, DONGARA

STRUCTURE PLAN

ACOUSTIC ASSESSMENT

JANUARY 2015

OUR REFERENCE: 18772-3-15031

DOCUMENT CONTROL PAGE

# ACOUSTIC ASSESSMENT
DONGARA

Job No: 15031
Document Reference: 18772-3-15031

FOR

## CLE TOWN PLANNING AND DESIGN

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| 4. | TRAFFIC NOISE ASSESSMENT | 5 |


## APPENDICIES


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| B | Noise Contour Plot |
| C | Quiet House Design Guidelines |

# EXECUTIVE SUMMARY

Herring Storer Acoustics was commissioned by CLE to undertake an acoustical assessment of noise that would be received at proposed development from road traffic noise associated with the future Brand Highway.

Under the Western Australian Planning Commission (WAPC) Planning Policy 5.4 "Road and Rail Transport Noise and Freight Considerations in Land Use Planning" (SPP 5.4), the appropriate criteria for assessment for this development are:

**EXTERNAL**

$L_{Aeq(Day)}$ of 60 dB(A);
$L_{Aeq(Night)}$ of 55 dB(A).

**INTERNAL**

$L_{Aeq(Day)}$ of 40 dB(A) in living and work areas; and
$L_{Aeq(Night)}$ of 35 dB(A) in bedrooms.

Additional to the above, noise received at an outdoor area should also be reduced as far as practicable, with an aim of achieving an $L_{Aeq}$ of 50 dB(A) during the night period.

For this development, the difference between the $L_{Aeq(16hr)}$ and the $L_{Aeq(8hr)}$ would be less than 5 dB(A). Therefore, if compliance with the night period noise limit is achieved, then compliance with the day period noise limits would also be achieved.

The results of the acoustic assessment indicate that without any noise amelioration, noise received at the residences in the future would exceed the "Noise Limits" as outlined in the Western Australian Planning Commission (WAPC) Planning Policy 5.4 "Road and Rail Transport Noise and Freight Considerations in Land Use Planning" by up to 5 dB(A).

For residential developments, the possible noise amelioration options that are normally considered are:

- Noise bunds and / or barriers.
- "Quiet House" design applied to the first row of residences.

Due to lots sizes proposed for this development and the character and context, walls / barriers are not practical. As the Lot sizes are larger than average, there is an opportunity to have building envelopes set to the criterion (55 dB(A) contour line). This setback, which is approximately 48 metres from the road, would provide sufficient distance to comply. If residential building were required within this distance (less than 48 metres) then specific acoustic advice would be required, likely in the form of Package B.

Therefore, to comply with the Policy, the following options have been provided:

- Quiet House Design Package A to B.
- Building envelopes (setbacks)

We note that under the Planning Policy, as noise received within the proposed development would exceed the "Noise Target", notification on Titles is required for the identified Lots.

The above advice is based on the Local Structure Plan. Once final design (Sub Division) is known, a more detailed acoustical assessment can be provided for individual building requirements. Alternative construction would be possible if a suitably qualified acoustical consultant assessed the individual building requirements at the time of building licence approval.

# 1. INTRODUCTION

Herring Storer Acoustics were commissioned by CLE Town Planning and Design to carry out an acoustical assessment of noise received at the initial Structure Plan stage of the residential development located at Lot 4, 5 and 10 Brand Highway, Dongara.

As part of the study, the following was carried out:

- Determine by noise modelling the noise that would be received at proposed residences within this stage of the structure plan from vehicles travelling on the roadway (Brand Highway) for the future.

- Assess the predicted noise levels for compliance with the appropriate criteria.

- Provide detailed information as to noise control requirements such as quiet house design, noise wall and notification on titles.

# 2. CRITERIA

The WAPC released on 22 September 2009 State Planning Policy 5.4 *"Road and Rail Transport Noise and Freight Considerations In Land Use Planning"*. Section 5.3 – Noise Criteria, which outlines the acoustic criteria, states:

"5.3 - NOISE CRITERIA

*Table 1 sets out the outdoor noise criteria that apply to proposals for new noise-sensitive development or new major roads and railways assessed under this policy.*

*These criteria do not apply to—*

- *proposals for redevelopment of existing major roads or railways, which are dealt with by a separate approach as described in section 5.4.1; and*
- *proposals for new freight handling facilities, for which a separate approach is described in section 5.4.2.*

*The outdoor noise criteria set out in Table 1 apply to the emission of road and rail transport noise as received at a noise-sensitive land use. These noise levels apply at the following locations —*

- *for new road or rail infrastructure proposals, at 1 m from the most exposed, habitable façade of the building receiving the noise, at ground floor level only; and*
- *for new noise-sensitive development proposals, at 1 m from the most exposed, habitable façade of the proposed building, at each floor level, and within at least one outdoor living area on each residential lot.*

*Further information is provided in the guidelines.*

*Table 1: Outdoor Noise Criteria*

| *Time of day* | *Noise Target* | *Noise Limit* |
|---|---|---|
| *Day (6 am–10 pm)* | $L_{Aeq(Day)}$ = 55 dB(A) | $L_{Aeq(Day)}$ = 60 dB(A) |
| *Night (10 pm–6 am)* | $L_{Aeq(Night)}$ = 50 dB(A) | $L_{Aeq(Night)}$ = 55 dB(A) |

*The 5 dB difference between the outdoor noise target and the outdoor noise limit, as prescribed in Table 1, represents an acceptable margin for compliance. In most situations in which either the noise-sensitive land use or the major road or railway already exists, it should be practicable to achieve outdoor noise levels within this acceptable margin. In relation to the Lot 9000 sites, however, there is an expectation that the design of the proposal will be consistent with the target ultimately being achieved.*

*Because the range of noise amelioration measures available for implementation is dependent upon the type of proposal being considered, the application of the noise criteria will vary slightly for each different type. Policy interpretation of the criteria for each type of proposal is outlined in sections 5.3.1 and 5.3.2.*

*The noise criteria were developed after consideration of road and rail transport noise criteria in Australia and overseas, and after a series of case studies to assess whether the levels were practicable. The noise criteria take into account the considerable body of research into the effects of noise on humans, particularly community annoyance, sleep disturbance, long-term effects on cardiovascular health, effects on children's learning performance, and impacts on vulnerable groups such as children and the elderly. Reference is made to the World Health Organization (WHO) recommendations for noise policies in their publications on community noise and the Night Noise Guidelines for Europe. See the policy guidelines for suggested further reading.*

*<u>5.3.1 Interpretation and application for noise-sensitive development proposals</u>*

*In the application of these outdoor noise criteria to new noise-sensitive developments, the objective of this policy is to achieve –*

- *acceptable indoor noise levels in noise-sensitive areas (for example, bedrooms and living rooms of houses, and school classrooms); and*
- *a reasonable degree of acoustic amenity in at least one outdoor living area on each residential lot[1].*

*If a noise-sensitive development takes place in an area where outdoor noise levels will meet the noise target, no further measures are required under this policy.*

*In areas where the noise target is likely to be exceeded, but noise levels are likely to be within the 5dB margin, mitigation measures should be implemented by the developer with a view to achieving the target levels in a least one outdoor living area on each residential lot[1]. Where indoor spaces are planned to be facing any outdoor area in the margin, noise mitigation measures should be implemented to achieve acceptable indoor noise levels in those spaces. In this case, compliance with this policy can be achieved for residential buildings through implementation of the deemed-to-comply measures detailed in the guidelines.*

*In areas where the outdoor noise limit is likely to be exceeded (i.e. above $L_{Aeq(Day)}$ of 60 dB(A) or $L_{Aeq(Night)}$ of 55 dB(A)), a detailed noise assessment in accordance with the guidelines should be undertaken by the developer. Customised noise mitigation measures should be implemented with a view to achieving the noise target in at least one outdoor living or recreation area on each noise-sensitive lot or, if this is not practicable, within the margin. Where indoor spaces will face outdoor areas that are above the noise limit, mitigation measures should be implemented to achieve acceptable indoor noise levels in those spaces, as specified in the following paragraphs.*

1 For non residential noise-sensitive developments, (e.g. schools and child care centres) consideration should be given to providing a suitable outdoor area that achieves the noise target, where this is appropriate to the type of use.

*For residential buildings, acceptable indoor noise levels are $L_{Aeq(Day)}$ of 40 dB(A) in living and work areas and $L_{Aeq(Night)}$ of 35 dB(A) in bedrooms[2]. For all other noise-sensitive buildings, acceptable indoor noise levels under this policy comprise noise levels that meet the recommended design sound levels in Table 1 of Australian Standard AS 2107:2000 Acoustics—Recommended design sound levels and reverberation times for building interiors.*

*These requirements also apply in the case of new noise-sensitive developments in the vicinity of a major transport corridor where there is no existing railway or major road (bearing in mind the policy's 15-20 year planning horizon). In these instances, the developer should engage in dialogue with the relevant infrastructure provider to develop a noise management plan to ascertain individual responsibilities, cost sharing arrangements and construction time frame.*

*If the policy objectives for noise-sensitive developments are not achievable, best practicable measures should be implemented, having regard to section 5.8 and the guidelines."*

The Policy, under Section 5.7, also provides the following information regarding "Notifications on Titles" :

"5.7 - NOTIFICATION ON TITLE

*If the measures outlined previously cannot practicably achieve the target noise levels for new noise-sensitive developments, this should be notified on the certificate of title.*

*Notifications on certificates of title and/or advice to prospective purchasers advising of the potential for noise impacts from major road and rail corridors can be effective in warning people who are sensitive to the potential impacts of transport noise. Such advice can also bring to the attention of prospective developers the need to reduce the impact of noise through sensitive design and construction of buildings and the location of outdoor living areas.*

*The notification is to ensure that prospective purchasers are advised of –*

- *the potential for transport noise impacts; and*
- *the potential for quiet house design requirements to minimise noise intrusion through house layout and noise insulation (see the guidelines).*

*Notification should be provided to prospective purchasers and be required as a condition of subdivision (including strata subdivision) for the purposes of noise-sensitive development as well as planning approval involving noise-sensitive development, where noise levels are forecast or estimated to exceed the target outdoor noise criteria, regardless of proposed noise attenuation measures. The requirement for notification as a condition of subdivision and the land area over which the notification requirement applies, should be identified in the noise management plan in accordance with the guidelines.*

*An example of a standard form of wording for notifications is presented in the guidelines."*

2 For residential buildings, indoor noise levels are not set for utility spaces such as bathrooms. This policy encourages effective "quiet house" design, which positions these non-sensitive spaces to shield the more sensitive spaces from transport noise (see guidelines for further information).

# 3. MODELLING

To determine the requirements of any noise amelioration, acoustic modelling was carried out using the computer program 'SoundPlan'. Acoustic modelling was carried out for road traffic flows 20 years in the future.

**TABLE 4.1 - NOISE MODELLING INPUT DATA**

| Parameter | Value |
|---|---|
| Traffic flows (future) | 4,660 vpd |
| Heavy Vehicles (%) | 20.3 |
| Speed Limit (km/hr) | 80 (110) |
| Road Surface | Chip Seal |
| Façade Correction | +2.5 dB(A) |

( ) Current speed limit, with expectations for this to be reduced to 80km/hr in the future, due to residential expansion of Dongara.

From noise monitoring of similar projects on the same road system, it has been assumed that the difference between the $L_{A10,18hour}$ and $L_{Aeq,8hour}$, and the $L_{Aeq10,18hr}$ and $L_{Aeq,16\ hr}$ is -7 and -3 dB. As the difference between day and night $L_{Aeq}$ noise levels is less than 5 dB(A) (i.e. 4 dB(A)), the night period is the critical period for compliance. Therefore, only modelling for the night period was undertaken.

Noise modelling was carried out for noise received within the development for future traffic volumes.

# 4. TRAFFIC NOISE ASSESSMENT

Under the WAPC State Planning Policy 5.4, for this development, the Noise Limits as listed in Table 1 are the appropriate noise levels for to be achieved. From previous noise monitoring, we believe that the difference between the $L_{Aeq(16hr)}$ and the $L_{Aeq(8hr)}$ would be less than 5 dB(A). Therefore, if compliance with the night period noise limit is achieved, then compliance with the day period noise limits would also be achieved. The policy states that the outdoor criteria applies to the ground floor level only, however, it also states that noise mitigation measures should be implemented with a view to achieving the target levels in least one outdoor living area.

For residential premises, the Policy states that residence should be designed to meet the following acceptable internal noise levels:

| | |
|---|---|
| Living and Work Areas | $L_{Aeq(Day)}$ of 40 dB(A) |
| Bedrooms | $L_{Aeq(Night)}$ of 35 dB(A) |

The results of the acoustic assessment indicate that noise received at the ground floor level of residences located adjacent to Brand Highway, could exceed the above acoustic criteria. In the worst case location, the level of exceedance would be approximately 5 dB(A). However, compliance would be achieved at the distances listed in Table 5.1.

**TABLE 5.1 – DISTANCE TO COMPLY WITH "NOISE LIMITS"**

| Road | Distance* (m) |
|---|---|
| Brand Highway | 48 |

* Distance from Edge of Nearest Carriageway

For information the noise contour for the night period is contained in Appendix B, with the red, 55 dB(A) contour line being the limit criterion.

Therefore, to comply with the Policy, the following options have been provided:

- Quiet House Design Package A to B.
- Building envelopes (setbacks)

For Brand Highway, we do not believe that it would be either practicable or desirable to construct noise barriers at the edge of the road reserve, between the road and the residence. As the Lot sizes are larger than average, there is an opportunity to have building envelopes set to the criterion (55 dB(A) contour line). This setback, which is approximately 48 metres from the road, would provide sufficient distance to comply. If residential building were required within this distance (less than 48 metres) then specific acoustic advice would be required, likely in the form of Package B.

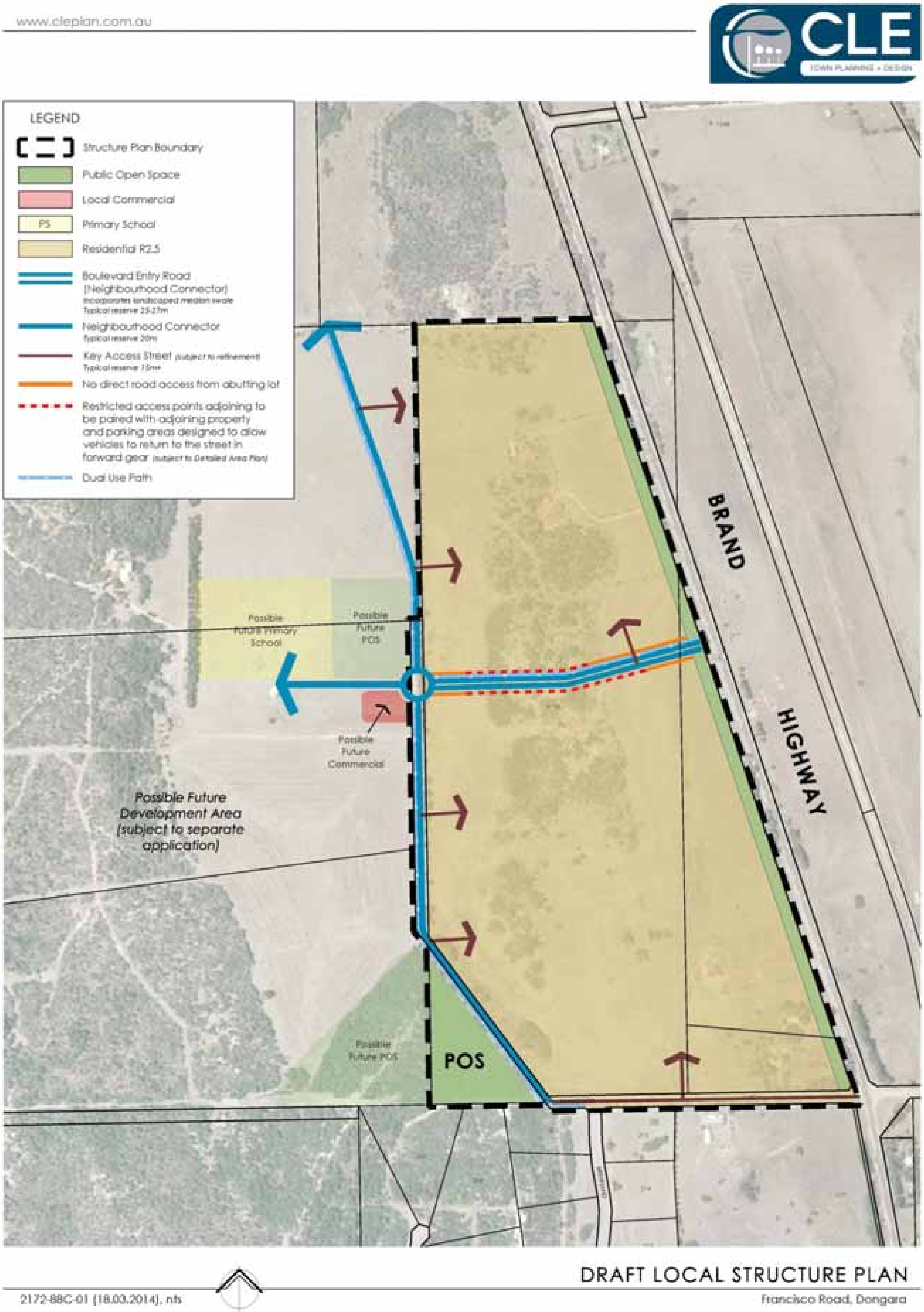
Noise received at the outdoor living areas would then comply with the "Noise Target" as required under SPP 5.4. Then along these frontages, "Quiet House Design" be developed for the first row of residence.

Preliminary information regarding "Quiet House" design guidelines are contained in Appendix C.

# APPENDIX A

FIGURE A1 – SITE LAYOUT

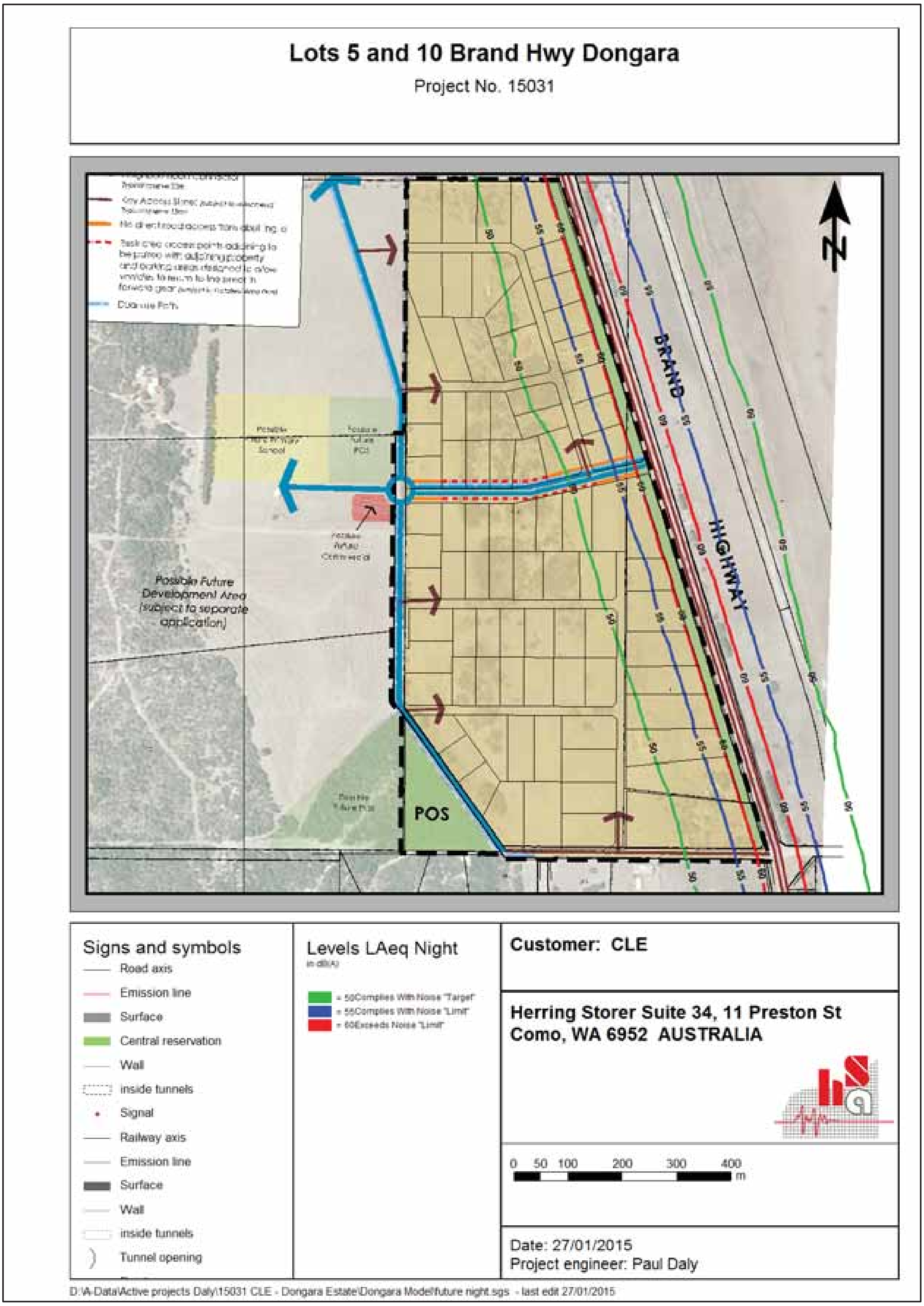
# FIGURE A1 – SITE LAYOUT



# APPENDIX B

NOISE CONTOURS PLOT

**Figure B1 - $L_{Aeq(Night)}$ Noise Contours No Noise Control**



# APPENDIX C

QUIET HOUSE DESIGN GUIDELINES

| Area | Orientation to road or rail corridor | Package A<br>$L_{Aeq}$,Day up to 60dB<br>$L_{Aeq}$,Night up to 55dB | Package B<br>$L_{Aeq}$,Day up to 63dB<br>$L_{Aeq}$,Night up to 58dB | Package C<br>$L_{Aeq}$,Day up to 65dB<br>$L_{Aeq}$,Night up to 60dB |
|---|---|---|---|---|
| Bedrooms | Facing | • Walls to $R_w$+$C_{tr}$ 45dB<br>• Windows and external door systems:<br>Minimum $R_w$+$C_{tr}$ 28dB (Table 6.4), total glazing area up to 40% of room floor area. [if $R_w$+$C_{tr}$ 31dB: 60%] [if $R_w$+$C_{tr}$ 34dB: 80%]<br>• Roof and ceiling to $R_w$+$C_{tr}$ 35dB (1 layer 10mm plasterboard)<br>• Mechanical ventilation as per Section 6.3.1 | • Walls to $R_w$+$C_{tr}$ 50dB<br>• Windows and external door systems:<br>Minimum $R_w$+$C_{tr}$ 31dB (Table 6.4),<br>total glazing area up to 40% of room floor area. [if $R_w$+$C_{tr}$ 34dB: 60%]<br>• Roof and ceiling to $R_w$+$C_{tr}$ 35dB<br>(1 layer 10mm plasterboard)<br>• Mechanical ventilation as per Section 6.3.1 | • Walls to $R_w$+$C_{tr}$ 50dB<br>• Windows and external door systems:<br>Minimum $R_w$+$C_{tr}$ 34dB (Table 6.4), total glazing area limited to 40% of room floor area [if 20% of floor area or less, $R_w$+$C_{tr}$ 31dB]<br>• Roof and ceiling to $R_w$+$C_{tr}$ 40dB<br>(2 layers 10mm plasterboard)<br>• Mechanical ventilation as per<br>Section 6.3.1 |
| | Side-on | •As above, except glazing Rw+Ctr values for each package may be 3dB less, or max % area increased by 20% | | |
| | Opposite | • No requirements<br>• As per Package A 'Side On'<br>• As per Package A 'Facing' | • No requirements<br>• As per Package A 'Side On'<br>• As per Package A 'Facing' | • No requirements<br>• As per Package A 'Side On'<br>• As per Package A 'Facing' |
| Indoor living and work Areas | Facing | • Walls to Rw+Ctr 45dB<br>• Windows and external door systems:<br>Minimum Rw+Ctr 25dB (Table 6.4),<br>total glazing area limited to 40% of<br>room floor area. [if Rw+Ctr 28dB: 60%]<br>[if Rw+Ctr 31dB: 80%]<br>• External doors other than glass doors<br>to Rw+Ctr 26dB (Table 6.4)<br>• Mechanical ventilation as per<br>Section 6.3.1 | • Walls to Rw+Ctr 50dB<br>• Windows and external door systems:<br>Minimum Rw+Ctr 28dB (Table 6.4),<br>total glazing area up to 40% of room<br>floor area. [if Rw+Ctr 31dB: 60%]<br>[if Rw+Ctr 34dB: 80%]<br>• External doors other than glass doors<br>to Rw+Ctr 26dB (Table 6.4)<br>• Mechanical ventilation as per<br>Section 6.3.1 | • Walls to $R_w$+$C_{tr}$ 50dB<br>• Windows and external door systems:<br>Minimum $R_w$+$C_{tr}$ 31dB (Table 6.4),<br>total glazing area up to 40% of room<br>floor area. [if $R_w$+$C_{tr}$ 34dB: 60%]<br>• External doors other than glass doors<br>to $R_w$+$C_{tr}$ 30dB (Table 6.4)<br>• Mechanical ventilation as per<br>Section 6.3.1 |
| | Side-on | • As above, except the glazing $R_w$+$C_{tr}$ values for each package may be 3dB less, or max % area increased by 20% | | |
| | Opposite | • No requirements | • As per Package A 'Side On' | • As per Package A 'Facing' |
| Other indoor areas | Any | • No requirements | • No requirements | • No requirements |
| Outdoor living areas | Any (Section 6.2.3) | • As per Package C, and/or<br>• At least one ground level outdoor living<br>area screened using a solid continuous<br>fence or other structure of minimum<br>2 metres height above ground level | • As per Package C, and/or<br>• At least one ground level outdoor living<br>area screened using a solid continuous<br>fence or other structure of minimum<br>2.4 metres height above ground level | • At least one outdoor living area located<br>on the opposite side of the building<br>from the transport corridor |

# APPENDIX 8

## Traffic Report 2014 (Jonathan Riley)

# FRANCISCO ROAD, DONGARA

# STRUCTURE PLAN TRAFFIC REPORT

January 2014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Perth WA 6831

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| | | | |
|---|---|---|---|
| Issued on | 13 January 2014 | Amendments | Date |
| Version | V2 | V1 published<br>V2 minor text edits | 18-11-13<br>13-01-14 |
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7.0 PEDESTRIANS, CYCLISTS AND PUBLIC TRANSPORT

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## 1.0 EXECUTIVE SUMMARY

Riley Consulting has been commissioned through CLE planning consultants to consider the traffic and transport impacts of developing 85 residential lots at land west of the Brand Highway, Dongara. The key findings of the traffic investigations are:

- The site can be expected to generate up to 850 vehicle movements per day once fully developed. A local road network in accordance with *Liveable Neighbourhoods* is proposed.

- Longer term planning may see additional land being developed to the west of the subject land. This traffic report is cognisant of the implications of this potential future development.

- Traffic generated by the subject site is not expected to result in a significant impact to existing adjacent streets.

- Access to the site will be taken from Brand Highway at a location already approved by Main Roads Western Australia. The full development of the subject land will require the provision of a fully channelised access intersection to Brand Highway.

- Analysis of the proposed access indicates that the warrants for the provision of turn lane pocket will not be met until 24 dwellings are occupied (based on the expected Brand Highway volume in 2025). It is considered therefore that an opportunity exists to develop 20 lots as a first stage with no turning pockets provided on the Brand Highway.

## 2.0 THE SITE AND SURROUNDING ROAD NETWORK

The subject land is located approximately 1.5km north of Dongara town adjacent to the Brand Highway. The location of the subject site is shown in Figure 1.

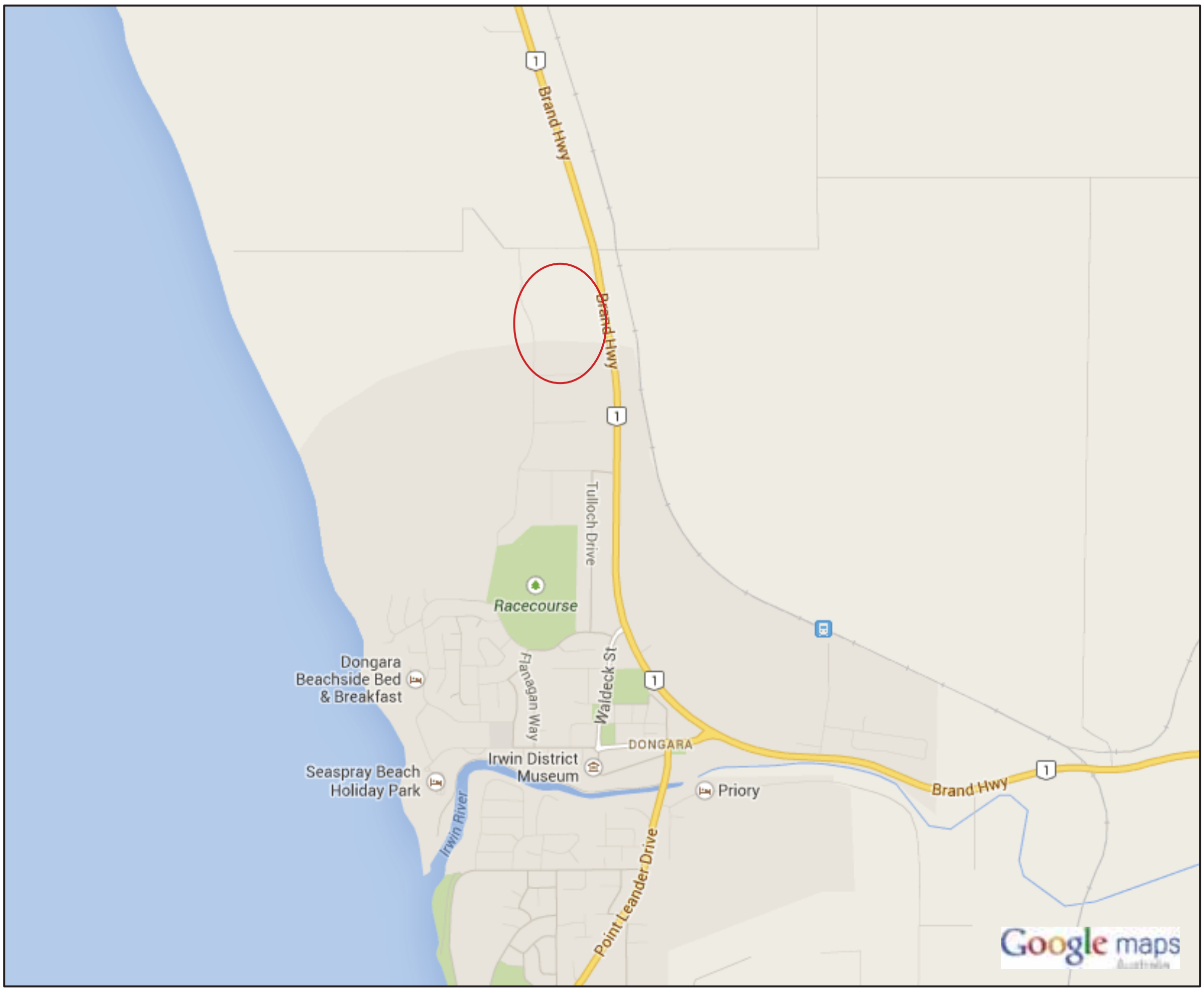



**Figure 1 Site Location**

Roads expected to be affected by the development of the site are considered below.

### 2.1 Brand Highway

The Brand Highway is a primary distributor road falling under the control of Main Roads Western Australia (MRWA). It provides significant regional access between Geraldton and Perth. The Highway is constructed as a two-lane single carriageway road for the majority of its length. Through the urban area of Dongara the speed limit is reduced, but to the north of Francisco Road returns to the national 110kph limit.

Traffic data provided by MRWA indicates a current average weekday volume of 3,140 vehicles per day (vpd) to the south of Matsen Road (about 10km north of the subject site). Traffic data recorded in 2013 to the west of Midlands Road (just south of Dongara) shows an average weekday flow of 2,722vpd with an evening peak period equating to 5.6% of the daily volume.

Historical data from 2007 recorded to the north of Waldeck Street, provides the following peak hour proportions and directional split.

- 8am – 9am 7.3% of daily flow - 38% north / 62% south
- 1pm – 2pm 7.4% of daily flow - 52% north / 48% south
- 4pm – 5pm 7.4% of daily flow - 53% north / 47% south
- 5pm – 6pm 6.9% of daily flow - 70% north / 30% south

It is not expected that a major change to the peak hour proportion or directional split would have occurred. Whilst more recent traffic data is available to the south side of Dongara, the peak hour proportions are lower than indicated by historical data.

### 2.2 Francisco Road

Francisco Road is a local access road currently unmade to the west of the Brand Highway. A four-way intersection is created at Brand Highway with the eastern leg sealed. Traffic data is not available for Francisco Road, but the current unmade status and access to 11 properties would suggest s daily flow of less than 100vpd.

Once sealed a speed limit of 60kph or 50kph may apply to Francisco Road.

### 2.3 Brennand Road

Brennand Road is a local access street and is constructed with a 7 metre wide pavement (approximately). The rural location of the road would suggest a posted speed of 60kph.

No traffic data is available for Brennand Road, but based on the current level of residential construction, it is estimated to carry less than 300 vehicles per day north of Philby Road.

### 2.4 Philby Road

Philby Road is a local access street providing an east-west link between Brennand Road and the Brand Highway. It has a standard 7 metre wide road pavement (approximately). It is rural in nature with no kerbs and has no footpaths.

No traffic data is available for Philby Road, but based on the current level of residential construction, it is estimated to carry about 470vpd east of Brennand Road and about 700vpd west of Brand Highway.

### 2.5 Tulloch Drive

Tulloch Drive is a local access street providing a north-south connection from Philby Road to the town. It is constructed with a standard 7 metre wide pavement (approximately). It is rural in nature with no kerbs and has no footpaths.

No traffic data is available for Tulloch Drive, but based on the current level of residential dwellings in its catchment, it is estimated to carry about 500 vehicles per day.

Figure 2 shows the draft local structure plan.

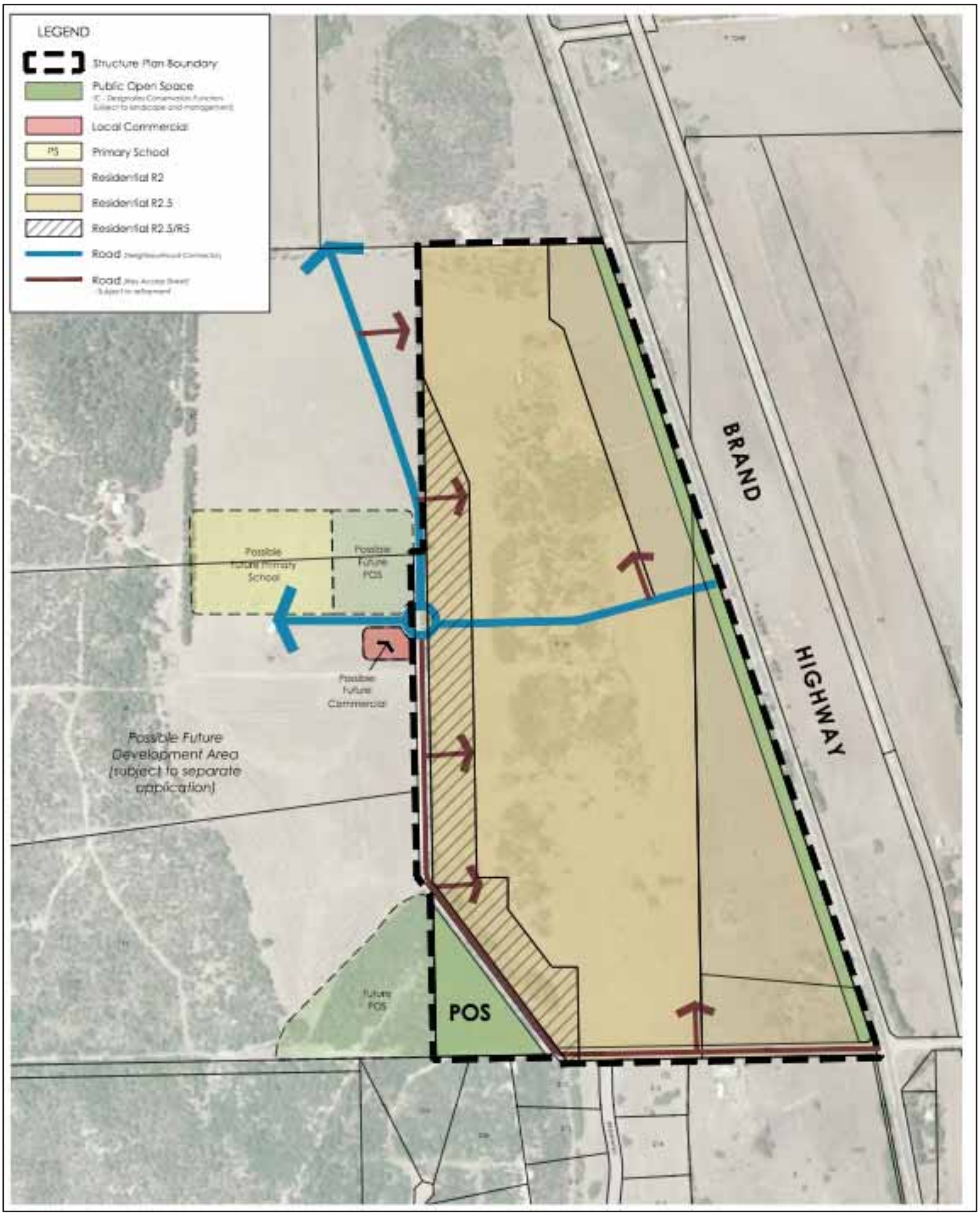



**Figure 2** **Draft Local Structure Plan** (refer CLE for detail)

## 3.0 TRAFFIC GENERATION AND DISTRIBUTION

The development of residential land at Dongara will provide for the growing population forecast for the region.

Reference to trip generation source documents suggests that the trip generation of a typical household can vary from 5 trips to 11 trips per dwelling per day. Traffic analysis of developments to the south of Geraldton identified a residential trip rate of 9 trips per dwelling per day based on local traffic counts. The trip rate is based on typical R20 density which is attractive to families. It can be expected that the subject land would generate a similar level of traffic.

For the purpose of assessing the potential traffic generation of the subject land, a trip rate of 10 trips per dwelling per day is used. The trip rate should result in an over-estimation of the future traffic movements, ensuring the road network is considered in a robust manner.

The subject land is expected to yield 85 residential lots and on the basis of 10 trips per lot, can be expected to generate (85 x 10) 850 vehicle movements per day.

### 3.1 Distribution

Traffic associated with the subject site is distributed to the road network based on trip purpose. Primary school trips are assigned to the local school based on the Education Department's expectations of 0.35 students per dwelling.

Table 1 shows the distribution assumptions by trip purpose used to assign traffic onto the external road network.

**Table 1 Dongara Distribution**

| Purpose[1] | North | South |
|---|---|---|
| Work Trips @ 29% | 70% | 30% |
| Home based Other @ 36% | 30% | 70% |
| Home Based Evening @ 21% | 20% | 80% |
| Non Home Based 14% | 70% | 30% |

[1] Trip purpose is based on the Perth Metropolitan Travel Survey 1986, factored to exclude education trips.

Figure 3 shows the forecast daily volumes associated with the subject land.

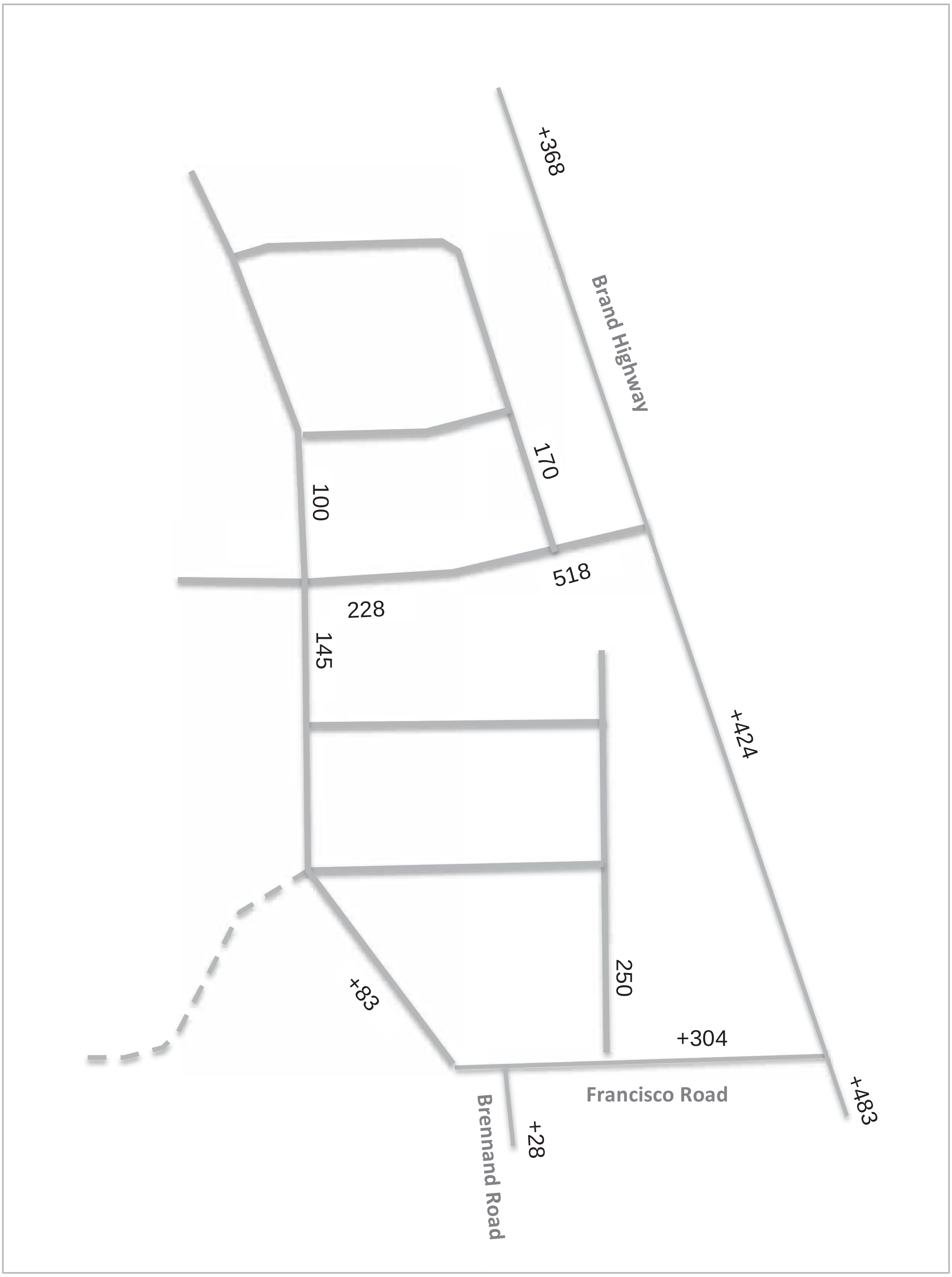



**Figure 3 Forecast Traffic Volumes**

### 3.2 Future Development

Land to the west of the subject site has also been identified for future residential development. An indicative lot yield of 1,500 dwellings has been suggested. Whilst this adjacent land area is not part of the current structure plan, traffic generated by future development will impact the structure plan road network and therefore needs to be considered.

Appendix A shows the draft structure plan for the locality and access to the west land parcels is provided almost solely through the subject site.

Figure 2 indicates a central neighbourhood connector linking land to the west to Brand Highway. It can also be expected that some traffic will filter through the southern access street to reach Brennand Road. Based on the potential of 1,500 lots, the adjacent land could generate (1,500 x 10) 15,000vpd. It could be expected that 80% of the generated traffic (12,000vpd) will leave the locality. Of this externalised traffic, potentially 20%, or 2,400vpd may use local roads to access Dongara.

- Ultimately the central neighbourhood connector could be expected to carry (9,600vpd + 518vpd) 10,118vpd.

- The link to Brennand Road may attract (2,400vpd + 145vpd) 2,252vpd

- Francisco Road may ultimately attract (2,400vpd + 304vpd) 2,704vpd.

The above forecast traffic demands are used to consider the road reservation requirements within the subject land.

## 4.0 DEVELOPMENT TRAFFIC IMPACTS

Based on the forecast traffic increases anticipated from the subject land, Table 2 shows the potential impacts to the road network in terms of Levels of Service (LoS). The Levels of Service by road type are shown as Appendix B.

**Table 2 Daily Traffic Volumes and Development Increase Impacts to LoS**

| Road | Daily Flow | LoS | Development | % | LoS |
|---|---|---|---|---|---|
| Brand Highway north | 3,140 | B | +368 | +12% | B |
| Brand Highway south | 3,140 | D | +483 | +15% | D |
| Francisco Road | <100 | A | +304 | +300% | A |
| Brennand Road | <300 | D | +28 | +9% | D |
| Philby Road | @470 | A | +28 | +6% | A |
| Tulloch Drive | @500 | A | +28 | +6% | A |

The LoS is based on Appendix A

In traffic engineering it is considered that traffic flow changes to the surrounding road network of +/-5% fall within the daily variation of traffic volumes and are considered to have no significant impact. It can be seen from Table 2 that the proposed development can be expected to increase current traffic flows by 6% up to 300% and such increases can be considered as significant.

When traffic flow increases are significant, it is appropriate to consider the operation of the affected roads. Table 2 provides an overview of the Level of Service that can be expected with various daily traffic flows by road type and is based on advice contained in Austroads *Guide to Traffic Engineering Practice*.

Table 2 indicates that the proposed development can be expected to have no impact to current Levels of Service. Whilst the traffic increases may be considered proportionately high, their impact will not result in a detriment to the operation of the surrounding road network. It is concluded therefore that the proposed development will have no detrimental impact.

***The proposed development will create no detrimental impact.***

## 5.0 ACCESS

Access to the subject site will be taken via a new road link to Brand Highway. It is understood that previous discussions with MRWA have identified the location of access shown in Figure 2 as being suitable. It is also understood that the location has been assessed in terms of achieving appropriate visibility to Austroads standards (MRWA).

Analysis of the future operation of the access intersection is undertaken for the proposed subject site. Long term operation may change as a result of future development to the west (if land is rezoned).

**Intersection Control**

The present day traffic demand on Brand Highway is in the order of 3,000vpd and with growth at a rate of 3%pa, by 2025 the Highway could be carrying about 4,000vpd. The subject site is shown to generate 850 trips per day, which can be expected to access Brand Highway in the medium term (access to Francisco Road will occur in later stages). Based on the forecast traffic demands, advice contained in Appendix C indicates that priority control would be appropriate.

Appendix D shows the expected traffic volumes in the year 2025 (10 year planning horizon) with full development of the subject site.

**Turn Lane Requirements**

Austroads provides advice in regard to intersection layouts and the provision of turning lanes. Ultimately Brand Highway may be subjected to a reduced speed, but in regard to the subject site, assessment of access to a 110kph road environment is required. Appendix E shows the turn lane warrants.

Based on the forecast demands in 2025, the following warrants are investigated:

Right turn lane $Q_R$ = 25 vehicles $Q_{T1} + Q_{T2} + Q_L$ = 340 vehicles

***Austroads indicates the warrants for a right turn lane will be met.***

Left turn lane $Q_L$ = 31 vehicles $Q_{TL}$ = 216 vehicles

***Austroads indicates the warrants for a left turn lane will be met.***

The deceleration lengths based on a posted speed of 110kph will be:

| | |
|---|---|
| Right turn lane | 185 metres (including diverge taper) |
| Left turn lane | 175 metres (including diverge taper) |

Analysis of the access intersection has been undertaken using SIDRA for the year 2025. Table 3 shows the summary of the analysis attached as Appendix E.

**Table 3 Brand Highway / Site Access 2025**

| Approach | V/C | Delay | LoS |
|---|---|---|---|
| **AM Peak** | | | |
| Brand Highway south | 0.07 | 0.8s | A |
| Site Access | 0.089 | 10.7s | A |
| Brand Highway north | 0.115 | 0.5s | A |
| **PM Peak** | | | |
| Brand Highway south | 0.123 | 1s | A |
| Site Access | 0.039 | 10.8s | A |
| Brand Highway north | 0.053 | 2s | A |

Where V/C = volume of capacity
Delay is average delay per vehicle
LoS = Level of Service

Table 3 indicates that the proposed access to Brand Highway will operate with excellent Levels of Service. Figure 4 shows the form of access intersection required.

**Figure 4 Form of Access** (subject to MRWA)

Due to the high-speed environment of Brand Highway it is recommended that the intersection be created as a painted treatment. Raised medians may introduce an un-necessary road safety hazard.

## 6.0 THE INTERNAL ROAD NETWORK

The proposed development of 85 residential lots is expected to generate about 850 vehicle movements per day and therefore all roads would be exected to operate as Access Streets. However, at some future time it has been indicated that development may occur to land to the west which has the potential to generate an additional 12,000vpd through the subject land.

The forecast traffic flows provide a basis to develop an internal road hierarchy. Table 4 reproduces the advice on road types recommended by *Liveable Neighbourhoods.*

**Table 4 *Liveable Neighbourhoods* Road Hierarchy**

| **Indicative Daily Traffic Flow*** | **Designation** | **Street Characteristics** |
|---|---|---|
| < 1,000 vpd | Access Street | Narrower access streets (5.5 to 6m) may be appropriate in locations further away from centres and activity where traffic flows are less than 1,000 vpd and a low on-street parking demand exists. |
| 1,000 vpd to 3,000 vpd | Higher Order Access Street | Wider access streets (7 to 7.5m) cater for higher traffic volumes and are located closer to neighbourhood centres. |
| 3,000 vpd to 7,000 vpd | Neighbourhood Connectors | Generally 2-lane undivided. These are 'special' streets and their design needs to have regard to context, function and adjacent land uses. |
| 7,000 vpd to 20,000 vpd | District Distributor Type B | Typically will have 1 clear lane of travel in each direction and a parking / manoeuvring lane. |
| 15,000 vpd to 35,000 vpd | District Distributor Type A | Typically have service roads and development frontage with ample on-street parking to support a mixture of land uses. Direct vehicle access from adjoining property should be limited where no service roads are provided. |

* Function of streets needs to be considered as well as traffic volume.

The road hierarchy considers those streets that have a connective function and assigns an appropriate classification based on volume and continuity of movement.

Figure 5 shows the internal road hierarchy.

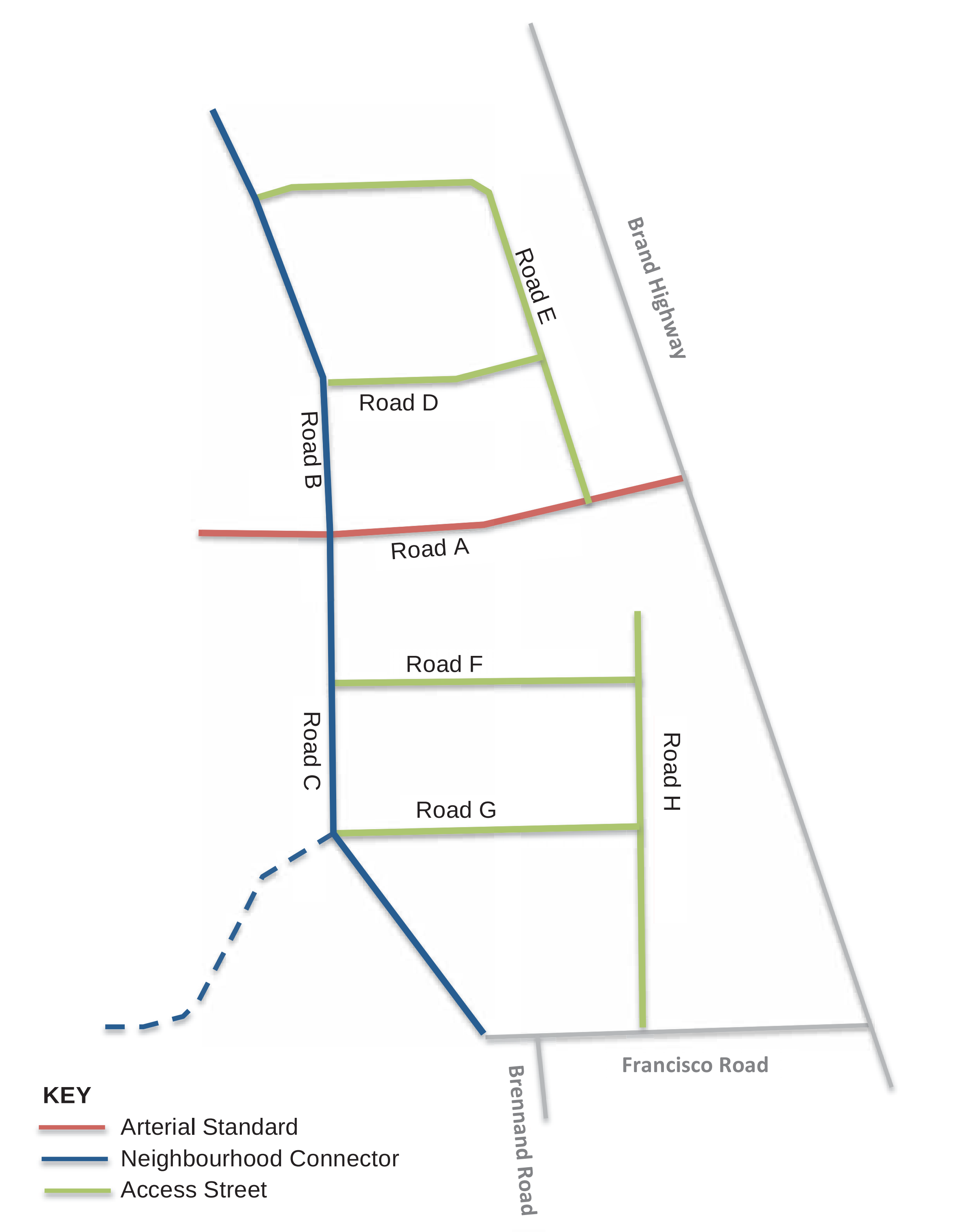



**Figure 5 Local Road Hierarchy**

## 6.1 Road A

Road A forms the main access to the subject land and has a forecast flow of less than 1,000vpd. It would be expected to be classified as an access street. However, it is acknowledged that land to the west, currently not zoned, may be developed to provide up to

1,500 new dwellings. The resulting traffic demands to Road A could potentially increase to about 10,120vpd. The traffic demand falls into the *Liveable Neighbourhoods* classification of Integrator Arterial and a minimum road reservation of 25.2 metres will be required.

Road A is shown to carry very low traffic flows and direct lot access is acceptable. However, in the long term if traffic flows exceed 5,000vpd, then direct lot access would not be acceptable. The road reservation at 25.2m will allow the provision of a 7.2m pavement and two one-way service roads of 4.1m (the Austroads minimum pavement width). The verge can provide a 2m median, a 4.1m one-way lane and a residual 3m verge. The road reservation will therefore be capable of accommodating the arterial status should land to the west be developed in the future. However, contemplation of the road reservation has determined that the first section from Brand Highway will be provided at 25 metres to the first intersection. All adjacent dwellings have an alternative form of access and direct access is not required. Beyond the first intersection a road reservation of 27 metres will be provided to allow the provision of one-way service lanes should future development occur.

***Road A will be provided with a 25m – 27m road reservation.***

### 6.2 Road B and Road C

Roads B and C provide a north-south connection between Francisco Road and possible future development located to the north. The forecast traffic flows on these roads are expected to be less than 500vpd and Access Street status would be expected. However, a classification of Neighbourhood Connector has been used to ensure robustness for future planning. A 20 metre road reservation is recommended for Road B and Road C.

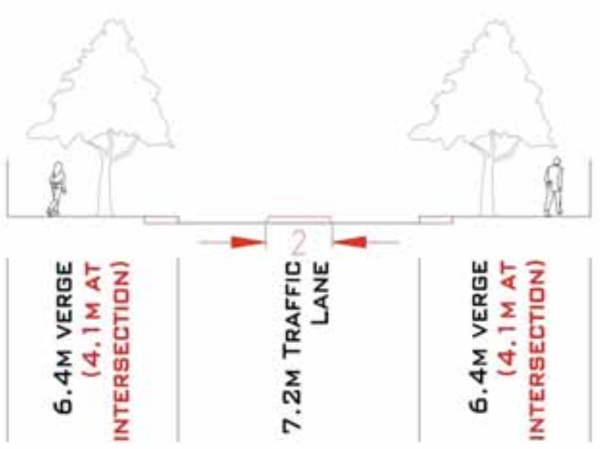



**Figure 6 20m Road Reserve**

Figure 6 shows a typical cross-section for a single carriageway road in a 20 metre road reservation. The reservation shown allows for the provision of 2 metre wide medians at intersections.

***Roads B and C are recommended to have a 20 metre road reservation.***

### 6.3 Roads D, E F, G and H

The remaining roads within the subject site will not provide for a through function and can be classified as Access Streets. It is recommended that the minimum carriageway width be provided to encourage a slower speed environment. Streets with 7.0+ metre carriageways and low-density lots frequently experience traffic speeds well in excess of the posted 50kph limit. A reduced carriageway width will assist in achieving a more appropriate 40kph typical travel speed.

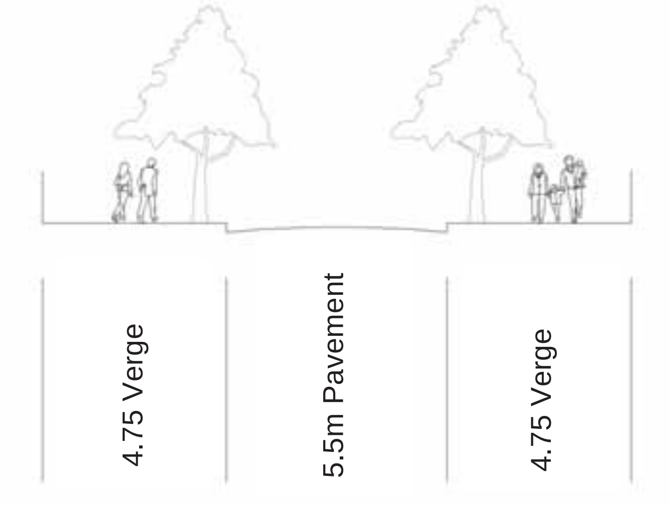



**Figure 7 15m Road Reserve**

All internal Access Streets have forecast traffic flows of less than 300vpd and will fall under the Access Street D classification in *Liveable Neighbourhoods*. A 5.5m – 6.0m road pavement width is considered appropriate for the forecast flows. Further, as larger lots are proposed, there is minimal need to cater for on-street parking. Figure 7 shows a typical cross-section suited to Roads D, E, F, G and H. A 6m pavement can be used and will provide a residual 4.5m verge.

***Access Streets are suited to a 5.5 metre pavement in a 15 metre road reservation.***

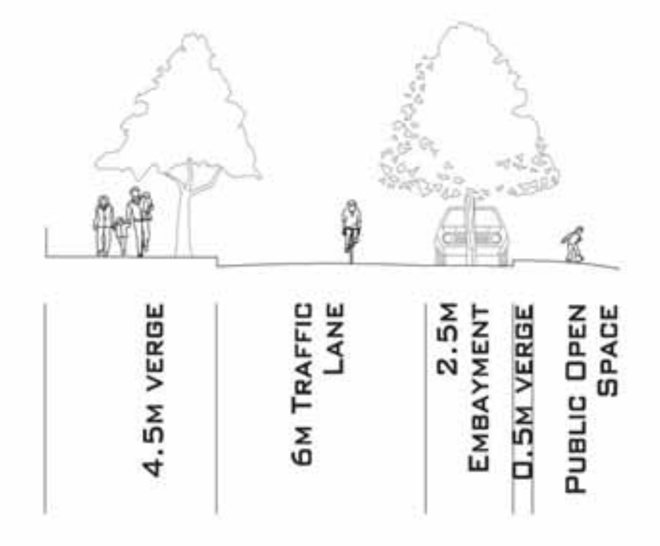



**Figure 8 Roads Adjacent to POS**

### 6.4 Roads Adjacent to Open Space

Where the road reservation abuts POS, bushland, golf courses etc, there is limited need to provide a verge. The verge may be reduced where parking and/or services are not required and should be considered at the time of subdivision. A minimum verge of 0.75 metres is advised by current road planning standards to accommodate street furniture.

Footpaths do not need to be adjacent to the road where POS is provided, but must be provided in a safe and appropriate manner. Figure 8 shows an example of a reduced road reservation adjacent to open space.

### 6.6 Four-way Intersections

Within the structure plan area daily traffic volumes are shown to be low and the use of four-way intersections is appropriate. Figure 9 shows an extract from Liveable Neighbourhoods on the preferred treatment of four-way intersections.

*Liveable Neighbourhoods* suggests that four-way intersections are an appropriate treatment at the meeting of two access streets and where daily flows through the intersection are less than 2,000vpd. Approach legs should be limited to a maximum length of 160 metres with some form of speed reducing feature where the length is greater than 80 metres.

Access streets meeting neighbourhood connectors and some arterial streets are considered acceptable, but will generally require a treatment as indicated in Figure 9. However, introducing four-way priority intersections on arterial streets is not recommended.

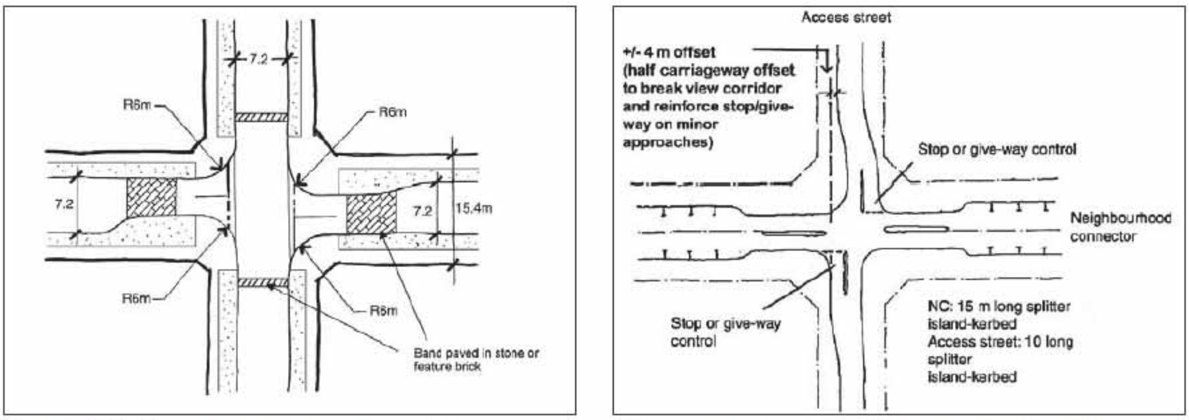



Figure 29A: Access street to access street with-four way and stagger.

Figure 31: Left-right minor offset four-way on neighbourhood connector (derived from Austroads Guide to traffic engineering, Part 5 Intersections, Figure 5-8).

**Figure 9 Liveable Neighbourhoods Four-way Intersections**

In the interim years the use of a four-way at the intersection of Road A and Roads B / C is an acceptable treatment. In the long term, should land to the west be developed, the intersection would require control by a roundabout. This will need to be addressed by any future structure plan for land to the west.

### 6.7 Corner Treatments

To reduce the opportunity for speeding it is recommended that corner radii advised by *Liveable Neighbourhoods* be used within the subdivision. The recommended radii are:

- 6.0 metres - access street / access street intersections
- 9.0 metres - access street / neighbourhood connector

Where larger vehicles are expected, such as buses accessing the school, larger radii may be required and should be considered at subdivision stage.

All streets are of relatively short lengths and high traffic speeds would not be expected. Further, the narrower carriageway widths proposed in low traffic residential streets will assist in reducing the attraction for speeding, making a safer environment for local children.

***No specific traffic management features are considered to be required.***

## 7.0 PEDESTRIANS, CYCLISTS AND PUBLIC TRANSPORT

Current planning guidelines suggest that all streets should be provided with a footpath wherever possible. Where traffic flows exceed 1,000 vehicles per day, a footpath to both sides of the road should be provided. Figure 10 shows those streets where a footpath is required to both sides.

### 7.1 Cycling

Cycling would be safe on the majority of local streets where traffic flows are less than 1,000 vehicles per day. On the neighbourhood connectors shared paths should be provided to provide a safe alternative to on-road cycling. Figure 10 shows the recommended cycle and footpath network. The figure aims to encourage cyclists and pedestrians to use Brennand Road rather than Brand Highway.

Off-street cycle routes are desirable to provide recreational cycling opportunities in the region and should be contemplated with structure planning of land to the west.

### 7.2 Public Transport

The rural locality of Dongara is likely to make the provision of public transport unviable. However, planning for a long term bus service should be considered and Road A is suited to cater for a future bus service.

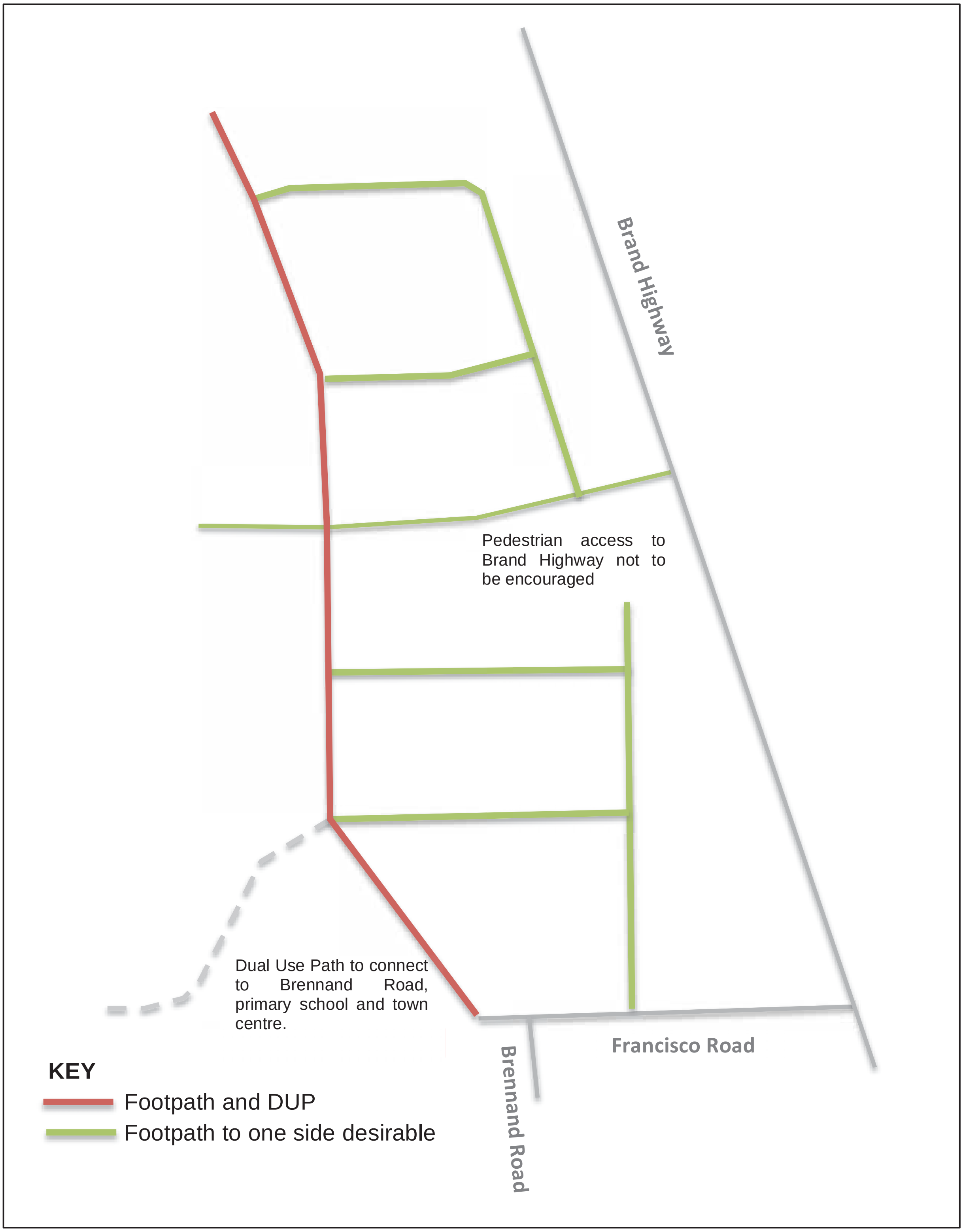



**Figure 10 Local Pedestrian and Cycle Paths**

## 8.0 DEVELOPMENT STAGING

The development of the subject land will occur in stages. It has been shown that ultimately the warrants will be met for a fully channelised intersection at Road A / Brand Highway to cater for the forecast traffic demands. The cost of constructing this intersection is significant and there is a strong desire to stage the implementation of the intersection.

Based on the traffic generation and distribution, it can be derived that peak hour turn movements equate to:

- Right turn (25 / 85) 1 movement per 3.4 dwellings
- Left turn (31 / 85) 1 movement per 2.7 dwellings

Using the forecast trafic volumes shown in Appendix E it is possible to derive at what stage of development the turn lane warrants will be met. The forecast flows on Brand Highway for the year 2025 are used to ensure robustness to the assessment. The level of turning traffic below the threshold of the turn lane provision will be (based on Appendix E) :

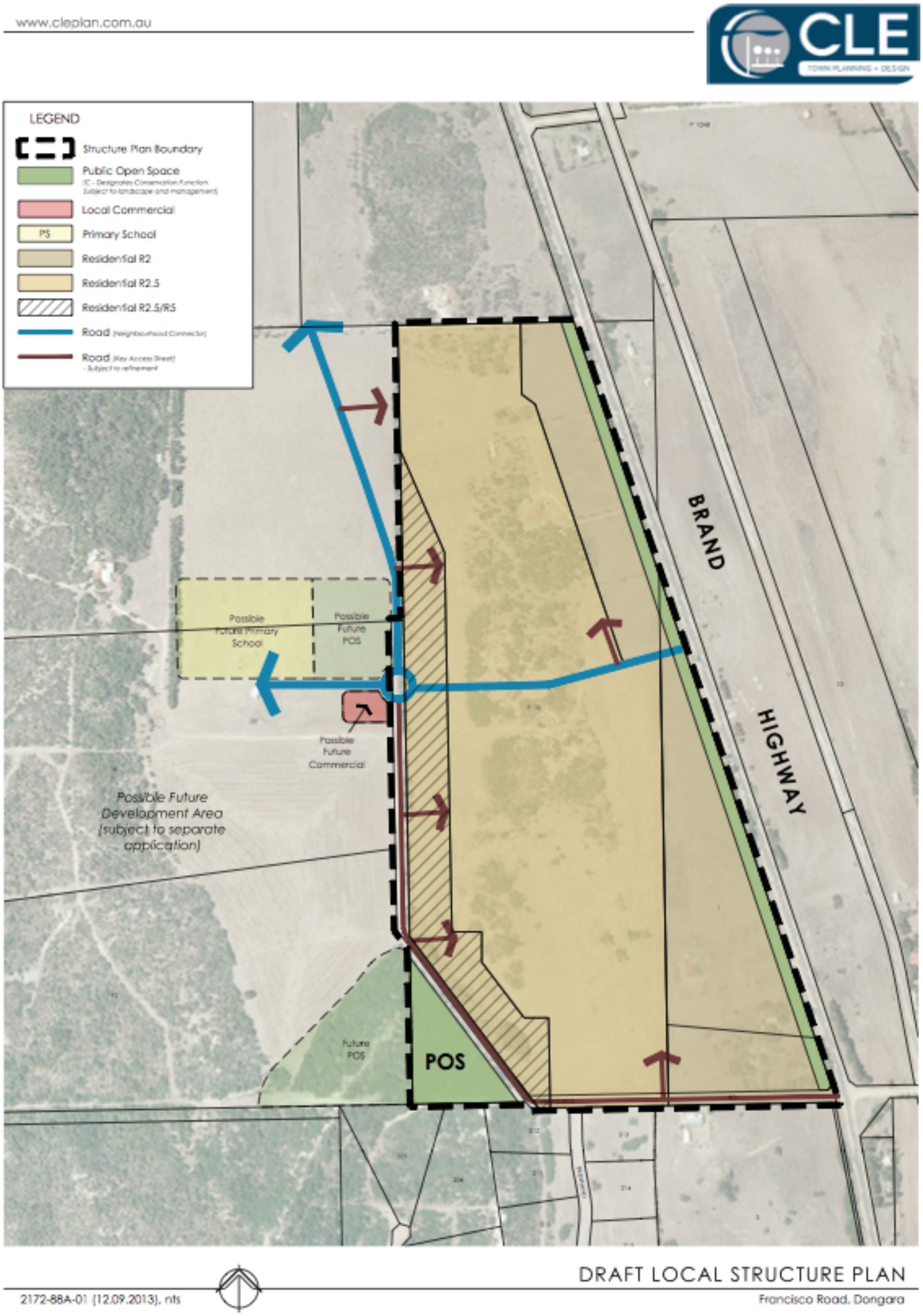
- Right turn lane $Q_{T1} + Q_{T2}$ = 309 vehicles $Q_R$ = 7 vehicles
- Left turn $Q_{TL}$ = 216 vehicles $Q_L$ = 18 vehicles

- Right turn of 7 movements = 23.8 dwellings
- Left turn of 18 movements = 48 dwellings

Thus it can be seen that the warrants to provide a right turn lane (full intersection) would not be met until 24 dwellings are occupied. It is recommended therefore that the first stage of development considers the creation of 20 lots and that development of stage 2 would be expected to provide the access intersection as indicated in Figure 4.

## APPENDIX A

### Draft Structure Pan



## APPENDIX B

**Table 1 Levels of Service by Road Type**

| LOS | Single Carriageway[1] | 2-Lane Boulevard[2] | Dual Carriageway (4-Lanes)[3] | Dual Carriageway (4-lane Clearway)[3] |
|---|---|---|---|---|
| A | 2,400vpd | 2,600vpd | 24,000vpd | 27,000vpd |
| B | 4,800vpd | 5,300vpd | 28,000vpd | 31,500vpd |
| C | 7,900vpd | 8,700vpd | 32,000vpd | 36,000vpd |
| D | 13,500vpd | 15,000vpd | 36,000vpd | 40,500vpd |
| E | 22,900vpd | 25,200vpd[4] | 40,000vpd | 45,000vpd |
| F | >22,900vpd | >25,200vpd[4] | >40,000vpd | >45,000vpd |

[1] Based on Table 3.9 Austroads - Guide to Traffic Engineering Practice Part 2
[2] Based on single carriageway +10% (supported by Table 3.1 Austroads - Guide to Traffic Engineering Practice Part 3) – Boulevard or division by medians.
[3] Based on RRR Table 3.5 - mid-block service flow rates (SF.) for urban arterial roads with interrupted flow. Using 60/40 peak split.
[4] Note James Street Guildford passes 28,000vpd.

## APPENDIX C

## Guide to Intersection Requirements (RTUA – UK)

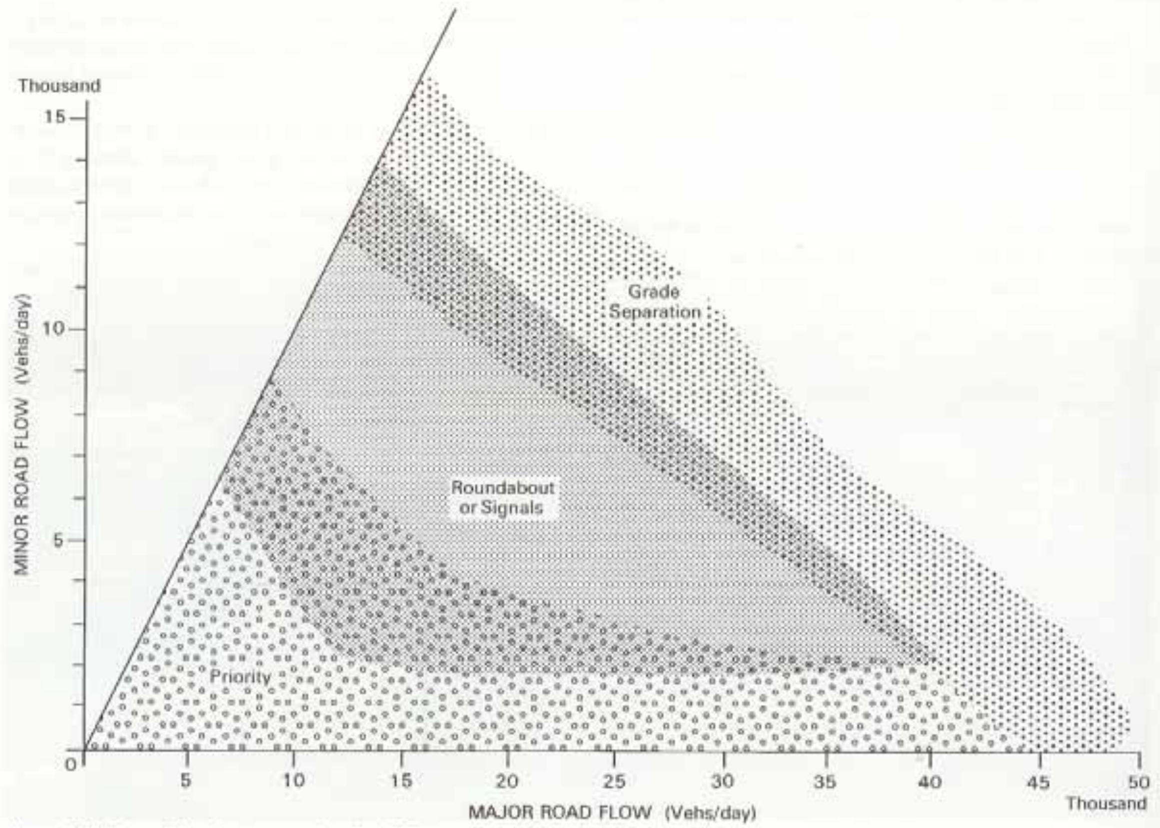
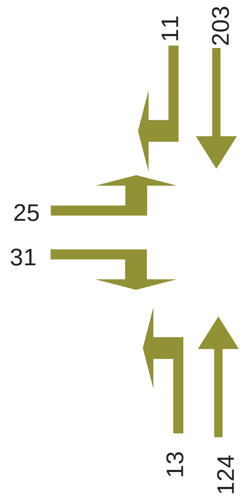


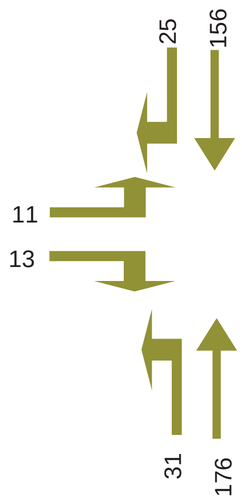

*Figure 38.1* Type of junction appropriate for different traffic flows

## APPENDIX D

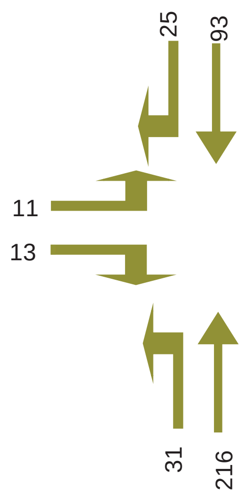
### Access Peak Hour Demand Volumes 2025




**AM Peak (8am – 9am)**




**PM Peak (4pm-5pm)**



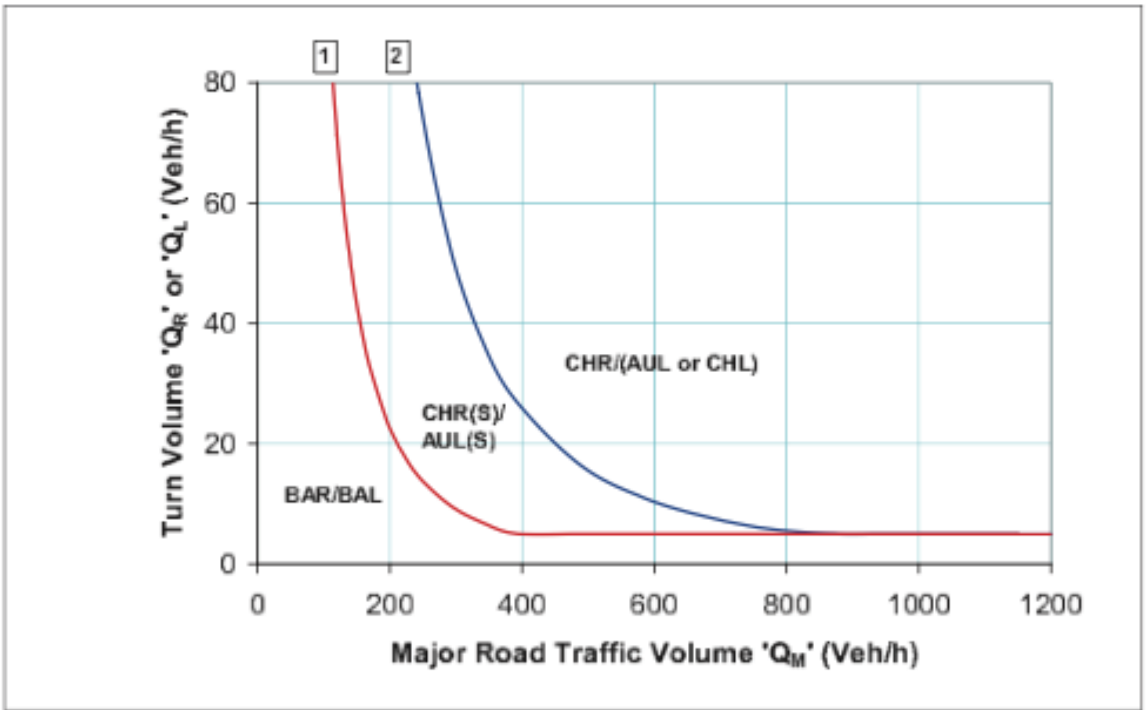

**PM Peak (5pm – 6pm)**

Note: Development flows based on 10% generation during peak periods.

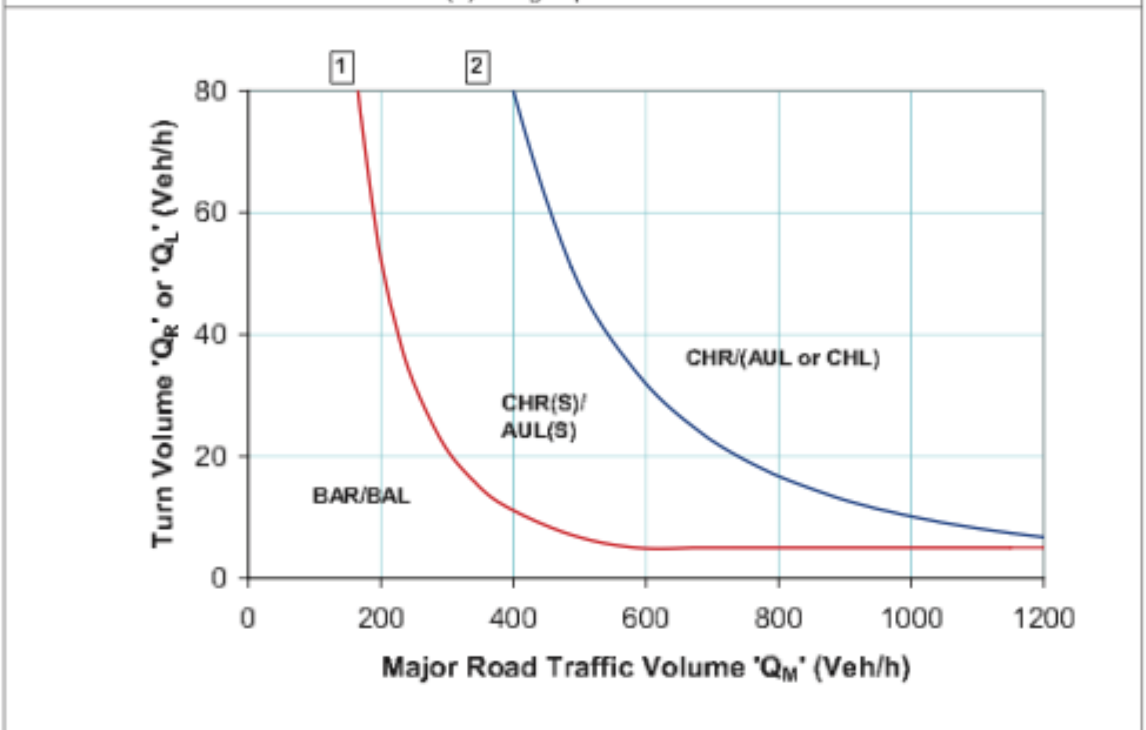
# APPENDIX E

## Austroads Turn Lane Warrants

Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections




(a) Design speed ≥100 km/h




(b) Design speed < 100 km/h

Source: Arndt and Troutbeck (2006).

**Figure 4.9: Warrants for turn treatments on the major road at unsignalised intersections**

# APPENDIX F

# BRAND HIGHWAY ACCESS ANALYSIS

Brand Highway / Site Access
Year 2025 Full Development
AM PEAK
Giveway / Yield (Two-Way)

**Movement Performance - Vehicles**

| Mov ID | Turn | Demand Flow | HV | Deg. Satn | Average Delay | Level of Service | 95% Back of Queue Vehicles | 95% Back of Queue Distance | Prop. Queued | Effective Stop Rate | Average Speed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | veh/h | % | v/c | sec | | veh | m | | per veh | km/h |
| South: Brand Highway South | | | | | | | | | | | |
| 1 | L | 14 | 0.0 | 0.007 | 8.2 | LOS A | 0.0 | 0.0 | 0.00 | 0.67 | 49.0 |
| 2 | T | 131 | 8.0 | 0.070 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| Approach | | 144 | 7.2 | 0.070 | 0.8 | LOS A | 0.0 | 0.0 | 0.00 | 0.06 | 58.7 |
| North: Brand Highway North | | | | | | | | | | | |
| 8 | T | 214 | 8.0 | 0.115 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| 9 | R | 12 | 0.0 | 0.009 | 8.8 | LOS A | 0.0 | 0.3 | 0.24 | 0.61 | 47.8 |
| Approach | | 225 | 7.6 | 0.115 | 0.5 | LOS A | 0.0 | 0.3 | 0.01 | 0.03 | 59.2 |
| West: Site Access | | | | | | | | | | | |
| 10 | L | 26 | 0.0 | 0.089 | 10.9 | LOS A | 0.4 | 2.9 | 0.37 | 0.63 | 46.2 |
| 12 | R | 33 | 0.0 | 0.089 | 10.6 | LOS A | 0.4 | 2.9 | 0.37 | 0.71 | 46.4 |
| Approach | | 59 | 0.0 | 0.089 | 10.7 | LOS A | 0.4 | 2.9 | 0.37 | 0.68 | 46.3 |
| All Vehicles | | 428 | 6.4 | 0.115 | 2.0 | NA | 0.4 | 2.9 | 0.06 | 0.13 | 56.9 |

Brand Highway / Site Access
Year 2025 Full Development
PM PEAK
Giveway / Yield (Two-Way)

**Movement Performance - Vehicles**

| Mov ID | Turn | Demand Flow | HV | Deg. Satn | Average Delay | Level of Service | 95% Back of Queue Vehicles | 95% Back of Queue Distance | Prop. Queued | Effective Stop Rate | Average Speed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | veh/h | % | v/c | sec | | veh | m | | per veh | km/h |
| South: Brand Highway South | | | | | | | | | | | |
| 1 | L | 33 | 0.0 | 0.018 | 8.2 | LOS A | 0.0 | 0.0 | 0.00 | 0.67 | 49.0 |
| 2 | T | 227 | 8.0 | 0.123 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| Approach | | 260 | 7.0 | 0.123 | 1.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.08 | 58.4 |
| North: Brand Highway North | | | | | | | | | | | |
| 8 | T | 98 | 8.0 | 0.053 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| 9 | R | 26 | 0.0 | 0.024 | 9.3 | LOS A | 0.1 | 0.8 | 0.34 | 0.64 | 47.4 |
| Approach | | 124 | 6.3 | 0.053 | 2.0 | LOS A | 0.1 | 0.8 | 0.07 | 0.14 | 56.8 |
| West: Site Access | | | | | | | | | | | |
| 10 | L | 12 | 0.0 | 0.039 | 11.0 | LOS A | 0.2 | 1.3 | 0.43 | 0.66 | 46.2 |
| 12 | R | 14 | 0.0 | 0.039 | 10.7 | LOS A | 0.2 | 1.3 | 0.43 | 0.70 | 46.3 |
| Approach | | 25 | 0.0 | 0.039 | 10.8 | LOS A | 0.2 | 1.3 | 0.43 | 0.68 | 46.2 |
| All Vehicles | | 409 | 6.4 | 0.123 | 1.9 | NA | 0.2 | 1.3 | 0.05 | 0.14 | 57.0 |

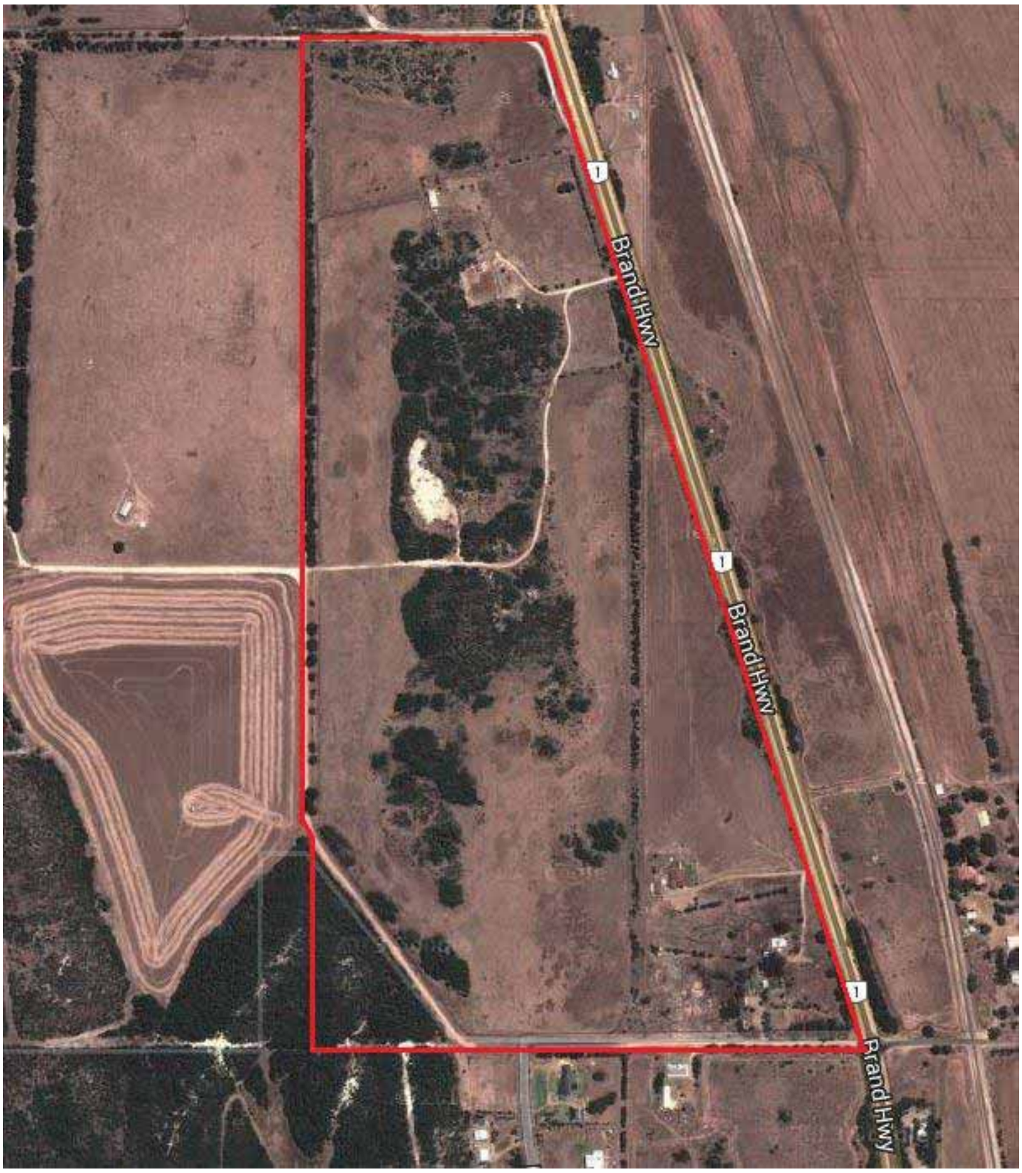
# APPENDIX 9

## Local Water Management Strategy 2014 (Civil Technology Pty Ltd)

# LOCAL WATER MANAGEMENT STRATEGY

## for the proposed subdivision of:

## Lots 4, 5 & 10 Francisco Road, Bonniefield

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*Revision 6: 3 September 2014*

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# 1 EXECUTIVE SUMMARY

The owners of Lots 4, 5 and 10 located on the corner of Brand Highway and Francisco Road, Bonniefield (located in the Shire of Irwin) have instructed Civil Technology to prepare a Local Water Management Strategy (LWMS) for a proposed Structure Plan prepared by CLE Town Planners and Design (refered to on the Structure Plan as a “Development Concept Plan”).

This LWMS has been prepared for the purpose of being submitted together with the proposed structure plan in accordance to clause 5.35.6.1 (f) viii of Amendment 15 of the Shire of Irwin Town Planning Scheme No. 5 which requires that a proposed structure plan should include a written report addressing the urban water management of the land the subject of the proposed structure plan.

The existing water environment involves stormwater discharging into the surrounding environment. Due to the topography of the site, stormwater flows to the west and east of the site and discharges into adjacent land.

This LWMS outlines the proposed approach in implementing a drainage design if development were to proceed in accordance with the structure plan and establishing that this can be done without any adverse impacts to the existing local water environments.

It is proposed that stormwater be transported to four discharge points via vegetated road side swales. This is to encourage ground infiltration of the stormwater runoff enroute to the discharge points enabling distributed groundwater recharge over the site.

As the topography of the site need not be altered to any great degree as part of any development, the location of the post development stormwater discharge points are identical to that of the pre development condition with similar flow rates. Due to potable water reticulation being able to be provided by the Water Corporation, which will reduce reliance on groundwater extraction, and coupled together with the stormwater hierachy being maintained, impacts on the groundwater environment are likely to be negligable.

This LWMS demostrates that there will be no adverse impacts on the environment as a result of implementing the subdisvion of the proposed structure plan.

# 2 INTRODUCTION

## *2.1 Subject Site Description*

The subject site is located in Bonniefield, 3 km north of the Dongara town centre, within the Shire of Irwin.

The site is bounded by Brand Highway to the east and local reserves to the south and west. The Indian Ocean is only approximately 1.5km away from the site boundary to the west. The locality of the site is shown in Figure 1.

The north boundary consists of General Farming lots while south boundary comprises Francisco Road and a conservation area. A small rural residential subdivision with lot sizes that range from 1 to 4 hectares is located directly south of the site along Brennand Road. Figure 2 shows a close-up of the subject site.

Total site is approximately 57 hectares in total area and consists of the following lots:

- Lot 4 Francisco Road, Bonniefield (Area 2.4103ha)
- Lot 5 Brand Highway, Bonniefield (Area 8.5761ha)
- Lot 10 Francisco Road, Bonniefield (Area 48.245ha)

Each of these lots has an existing dwelling or structure.

## *2.2 Design Objectives*

Total water cycle management, also referred to as integrated water cycle management, 'recognises that water supply, stormwater and sewage services are interrelated components of catchment systems and therefore must be dealt with using a holistic water management approach that reflects the principles of ecological sustainability' (Stormwater Management Manual for Western Australia, 2004-07, DoW).

The State planning policy 2.9: Water resources (WAPC, 2004), outlines the key principles of integrated water cycle management as:

- Consideration of all water resources, including wastewater in water planning;
- Integration of water and land use planning;
- The 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 human water use and natural water processes; and
- A whole of catchment integration of natural resource use and management.

The principles and objectives for managing urban water as stated in the Stormwater management manual for Western Australia (DoW, 2004-2007) are as follows:

- **Water quality**: to maintain or improve the surface and groundwater quality within the Development Areas relative to pre-development conditions.

- **Water quantity**: to maintain the total water cycle balance within the Development Areas relative to the predevelopment conditions.

- **Water conservation**: to maximise the reuse of stormwater.

- **Ecosystem health**: to retain natural drainage systems and protect ecosystem health.

- **Economic viability**: to implement stormwater management systems that are economically viable in the long term.

- **Public health**: to minimise the public risk, including risk from injury or loss of life, to the community.

- **Protection of property**: to protect the built environment from flooding and waterlogging.

- **Social values**: to ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

- **Development**: to ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

### *2.3 Planning Background*

The owners propose to subdivide the land into residential lots ranging in size from approximately 0.4ha to 1.4ha each.

The site was previously zoned “General Farming” under the Shire of Irwin’s Local Planning Scheme No. 5, and on 18th June 2013 was rezoned to “Development” as per Amendment No. 15 of the Shire of Irwin Town Planning Scheme No. 5.

### *2.4 Previous Studies*

The following studies have been carried out in relation to the subject site. Most have been conducted as desktop studies and outline the necessary elements required to support the application for the recent successful rezoning of the land to support subdivisional development. These include the following:

Land Capability and Geotechnical Assessment: Lots 10, 15, 16 and 17 Francisco Road, Dongara (June 2005). This report, prepared by Landform Research, covers various aspects of the existing environment including Geology and Geomorphology, water availability, alternative land uses, geotechnical factors, and environmental management.

Francisco Road Proposed Rezoning - Desktop Preliminary Engineering Services Review, Revision 3 (June 2012) was prepared by AECOM Australia, Geraldton office. The desktop study briefly addressed aspects of the larger subject site (including Lots 1409 Brand Highway, and Lots 15, 16 and 17 Francisco Road, Bonniefield) dealing with Earthworks and Topography, Drainage and Groundwater, Water Supply, Sewer, Power, Gas and Telecommunications.

Bushfire Management Plan: Francisco Road, Dongara (October 2013) was prepared by York Gum Services on behalf of the developer and addresses the bushfire risk and threat and an action plan.

# 3 PROPOSED DEVELOPMENT

## 3.1 Zoning and Structure Plan

A proposed structure plan has been prepared by CLE (see figure 3) and which is the subject of this Local Water Management Strategy (LWMS). This LWMS deals with the following land:

- Lot 4 Francisco Road, Bonniefield (Area 2.4103ha)
- Lot 5 Brand Highway, Bonniefield (Area 8.5761ha)
- Lot 10 Francisco Road, Bonniefield (Area 48.245ha)

The revised Structure Plan was lodged together with the application for rezoning from “General Farming” to “Development” as per The Shire of Irwin’s Town Planning Scheme No. 5, Amendment No. 15. The structure plan is yet to be formally adopted by the shire under the provisions of Amendment 15.

## 3.2 Existing Land Use

An examination of aerial photos (Figure 4) clearly indicates how the site has been extensively cleared and used for various rural / agricultural pursuits, namely cropping and grazing of livestock. Furthermore, each of the lots contains residential dwellings and associated outbuildings.

The aerial photos clearly depict the unmade road reserves and various driveways and tracks that traverse the landholdings.

## 3.3 Landscaping

As per the Structure Plan, it is proposed to have an adequate amount of landscaping elements incorporated into the design. Although there is no requirement to provide public open space within Rural Residential type subdivisions, the conical hill / landscape feature on the southern boundary is proposed to be retained as public open space (conservation purposes). This will link in with the existing conservation reserve to the south and coastal foreshore reserve to the west. The public open space which is approximately 5.1ha will be bordered by the proposed roads.

In addition to the public open space, the site will be enhanced with street scaping within the road reserves and tree planting and landscaping within the individual Rural Residential home sites.

# 4 DESIGN CRITERIA

The design criteria for this LWMS have been based on the design objectives outlined in the WAPC's Better Urban Water Management document (WAPC, 2008) and also the Shire of Irwin's draft District Water Management Strategy (GHD, 2012).

The following design criteria are to be used as a guide for development of the urban water management system for strategic planning, subdivision and development (unless other specific objectives have been defined in other approved water management plans/strategies).

**Water conservation — potable and wastewater**

*Objective*

Minimising total water use and ensuring that potable water is used as efficiently as possible by sustainable management of all aspects of the water cycle.

*Design criteria*

Consumption target for water of 100 kL/person/yr – as outlined in the *State Water Plan* (2007) – with an aspirational target of not more than 40–60 kL/person/yr scheme water, as provided in *Better Urban Water Management* (2008).

Minimising potable water use outside of buildings by substituting potable water with fit-for purpose water for all non-drinking uses.

Ensuring that all potable water is used as efficiently as possible by recommending all new fittings meet an efficiency rating of 5 stars or more.

Promoting the use of native plants to minimise water consumption

And also recommending rainwater tanks so that the water consumption targets can be achieved and also assist in the storage of stormwater on site.

**Water quantity management**

*Objective*

Post-development annual discharge volume and peak flow be maintained relative to pre-development conditions, unless otherwise established through determination of ecological water requirements for sensitive environments.

*Design criteria*

Ecological protection – For the critical 1-in-1-year ARI storm event, the post-development discharge volume and peak stormwater flow rates shall be maintained relative to predevelopment conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the Department of

Water. This will be done using rural style open road shoulder drains and vegetated swales during the subdivision phase of development and during the future domestic phase of development it will be achieved by using soakwells and rainwater tanks.

Serviceability of roads and infrastructure in minor ARI events (up to the 1 in 5 year ARI) – runoff from the entire catchment area generated by up to a 5 year ARI event will be managed using stormwater conveyance systems comprising of rural style open drains and, where road pavements intersect such drains, using piped culverts.

Flood management – Manage the stormwater catchment runoff for up to the 1-in-100-year ARI event within the development area to pre-development peak flows unless otherwise indicated in an approved water management strategy or as negotiated with the relevant drainage service provider.

## Water quality management

### *Objective*

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

### *Design criteria*

Contaminated sites – To be managed in accordance with the *Contaminated Sites Act 2003* (WA).

All other land – If the pollutant outputs of the development (measured or modelled concentrations) exceed catchment ambient conditions, the proponent shall achieve water quality improvements within the development area or, alternatively, arrange equivalent water quality improvement offsets within the catchment. If catchment ambient conditions have not been determined, the development should meet relevant water quality guidelines stipulated in the *National water quality management strategy* (AWWA, ANZECC & ARMCANZ, 1994).

Drainage – To ensure that all runoff contained within the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater management manual for Western Australia* (2004–07). Swales/vegetated bio-retention systems (also referred to as rain gardens) are to be sized at 2 per cent of the constructed impervious area from which they receive runoff. In addition, all outflows from subsoils should receive treatment prior to discharge to the stormwater system.

### *Stormwater modelling criteria*

If it is proposed to use a computer stormwater modelling tool to demonstrate compliance with design objectives, the following design modelling parameters are recommended.

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

## Disease vector and nuisance insect management

To reduce the health risk from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated within a time period not exceeding 96 hours.

Permanent water bodies are discouraged, but may be accepted by the Department of Water, where issues outlined in the *Interim position statement: Constructed Lakes* (2007) are adequately addressed. Any water body must be designed to maximise predation of mosquito larvae by native fauna.

# 5 PRE-DEVELOPMENT ENVIRONMENT

## *5.1 Site Conditions*

Based upon an examination of contours (derived by aerial mapping) and aerial photos available of the site, it is apparent that the land has undulating topography with open fields and hills. A substantial area in the middle of the site has been cleared for livestock grazing. These are the low lying areas which are generally flat or with gentle slopes.

The site levels range from a RL of 6 to 30. Adjacent to the open field is a steep ridge which runs from north to south, which has an average gradient of 1 in 6 and maximum gradient of 1 in 4.

Geological series maps (Surface Geology of Australia Map Cat. No. 73360 – Geoscience Australia, 2012) indicate that the site characteristics consist of dunes with calcareous and quartz sand, limestone and sandstone which is typical in much of the town of Dongara. Ground conditions are expected to consist of generally deep sand over Tamala Limestone. A small amount of clay may also be present in the subsoils of older dunes due to a breakdown of feldspar grains (Reference: *Land Capability and Geotechnical Assessment – Lots 10, 15, 16 and 17, Francisco Road, Dongara –* Landform Research (June 2005)).

It is anticipated that a desirable site grading suitable for subdivision can be achieved with some earthworks being applied to the site. The potential presence in some areas of limestone and small amounts of clay can be managed during the design and construction phases of the development.

Due to the amount of earthworks and clearing required, site stabilisation will be an important factor that will be considered at detailed design and construction stage to avoid dust nuisance and ground erosion principally from wind.

Figure 5 illustrates the site contour plan.

## *5.2 Climate*

The subject site is located in the mid-west region of Western Australia, where the climate transitions from Mediterranean to semi-arid. The climate is characterised by warm dry summers and mild wet winters. The nearest weather station is located in Mingenew which is approximately 55 km east from Dongara, however as Dongara is located directly on the WA coast the nearest weather station which would have a similar climate is located at Geraldton Airport approximately 65 Km to the north of Dongara. The mean recorded annual rainfall is 442.7mm. Figure A below shows the climatic data for the region. (BOM, 2014)

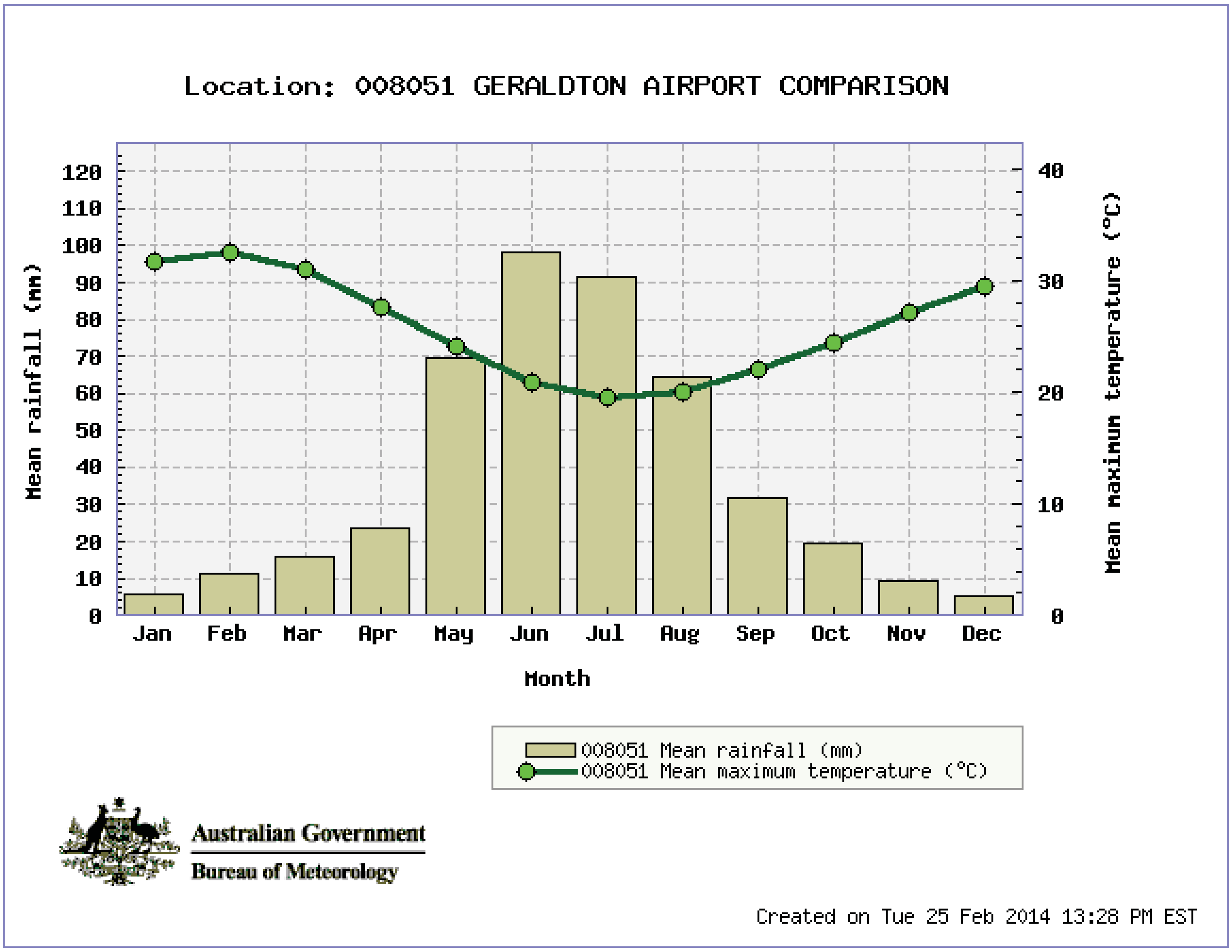



**Figure A: Climatic data of nearest relevant weather station (BOM, 2014)**

### *5.3 Geotechnical Plan*

As previously mentioned in Section 1.4 of this report, all relevant geotechnical information has been covered by the Land Capability and Geotechnical Assessment: Lots 10, 15, 16 and 17 Francisco Road, Dongara (June 2005). This report, prepared by Landform Research, covers various aspects of the existing environment including Geology and Geomorphology, water availability, alternative land uses, geotechnical factors, and environmental management.

### *5.4 Surface Water*

Figure 6 illustrates the catchment delineation for the existing pre-development site with an indication of stormwater flow paths. Due to the highly permeable nature of the soils within the subject site and the existing contours which allow surface water to drain freely across the land it is unlikely to encounter any perched water tables within the proposed development area.

The Land Capability and Geotechnical Assessment report prepared by Landform Research in 2005 states that there is no surface drainage on the site with all infiltration moving vertically downwards to the water table. From this analogy it is reasonable to assume that in the predevelopment condition, due to the relatively high permeability of the spoils present throughout the site, stormwater runoff will only occur in major storm events such as the 1 in 100yr ARI event.

Tests measuring the absorptive capacity of the soils in the subdivision of Lot 1 Kailis Drive, Springfield were conducted by Blacktop Materials Engineering in 2007 (the test certificate is included hereto as Appendix A. Whilst the location of these soil tests is approximately 11km south of the subject site, the site soil conditions are similar to that of the subject site, Lot 1 Kailis Drive being situated on the same coastal dune system to the subject site. These test result show that the dunal system soils have absorptive capacities ranging from $1.6 \times 10^{-4}$ m/s (13.82 m/day) in the valley of sand dune foundations to $3.3 \times 10^{-4}$ m/s (28.51 m/day) at the top of the dune formations. It is reasonable to assume the subject site will have soils of similar absorptive capabilities. For the purposes of preparing this report an infiltration rate of $1.8 \times 10^{-4}$ m/s (15.55 m/day) has been adopted for drainage calculations.

### *5.5 Groundwater*

There is one inactive bore within the site previously installed by the Department of Water. The recorded drill depth was 6.10 metres deep making the water table at about 2 metres AHD. There are also existing Department of Water groundwater bores in operation located on the east side of Brand Highway, and these show water levels between 6 to 8 metres deep. Six metres from groundwater level is considered as sufficient separation distance from the existing surface level.

Despite the proximity of the site from the ocean, it is unlikely to encounter shallow groundwater due to the elevation of the site above the ground water table.

The bore water quality on site has been tested and results indicate a groundwater salinity of 2,475mg/L in the north and 1,705mg/L in the south. The water is suitable for stock and hardy plants but is not generally suited for horticultural purposes (Reference: *Land Capability and Geotechnical Assessment – Lots 10, 15, 16 and 17, Francisco Road, Dongara* – Landform Research (June 2005)

### *5.6 Acid Sulphate Soils*

The Shire of Irwin's Draft District Water Management Strategy states that Acid Sulphate soils are wetland soils and unconsolidated settlements that contain iron sulphides which form in protected low energy environments such as barrier estuary's, coastal lakes and costal alluvial valleys. It also states there is a high to moderate risk of acid sulphate soils occurring within 3m of the surface along the Irwin River and its banks. This risk extends to approximately 2.5km inland or the river mouth. Given that;

a) The subject site is approximately 3.6 Km north of the Irwin River.
b) There are no nearby wetlands.
c) And due to the dry sandy nature of the soils located in the subject site.

There is a low to no risk of encountering Acid sulphate soils within 3 m of the surface.

# 6 WATER SUSTAINABILITY INITIATIVES

## *6.1 Water Efficiency Measures*

Water-wise landscaping will be maximised throughout the subject site by way of the utilisation of water sensitive measures that maximise efficiency and reduce wastage, spillage and leakage.

These water sensitive measures are to be applied to irrigation requirements for both public and private spaces, as well as water sustainability initiatives within the development. Particular consideration should be made to imported drinking water, rainwater harvesting, groundwater extraction and waste water recycling opportunities.

Road surface runoff is proposed to be collected by roadside swales, running parallel the road, and redirected into bio-retention swales where it is utilised for watering the vegetation and recharging of the groundwater table.

## *6.2 Water Supply*

Due to high salinity levels, bore water on site is suitable for stock but is not potable.

Potable water for domestic use can therefore be provided by scheme water, roof water collection tanks, desalination and/or bore water combined with a UV steriliser.

Due to the size of the proposed lots and their low density residential nature of the proposal, it is unlikely that any significant stocking on the lots will occur.

In turn, the above mentioned factors place a low level of reliance upon groundwater extraction.

### 6.2.1 Potable Water Reticulation

Based on information provided by the Water Corporation, a 150mm diameter water main is present on Francisco Road with two water services for Lot 10 and Lot 17. Presently, these services have special arrangements in place between the Water Corporation and the landowner because they do not meet the usual standards for a normal water supply service in respect of pressure and flow rate.

Discussions with the Water Corporation (Mark Willson *pers comm 29/8/2014)* reveal that the Water Corporation are prepared to supply reticulated water to the proposed new lots being produced out of subdivision of the subject site on a staged basis (4 stages over 15 years) and provided that network upgrades are in place and the developer funds the local reticulation network extensions. Much of the network upgrade work will be funded by the Water Corporation and, based on present work programming of the Water Corporation, is likely to be completed before each phase of the proposed subdivision is commenced.

### 6.2.2 Potable on site water supply

The use of rainwater storage tanks for potable water supply is encouraged to reduce the demand on the proposed reticulation water supply.

An analysis has been conducted as to whether rainwater collection is a viable method for potable water supply. This analysis is set below.

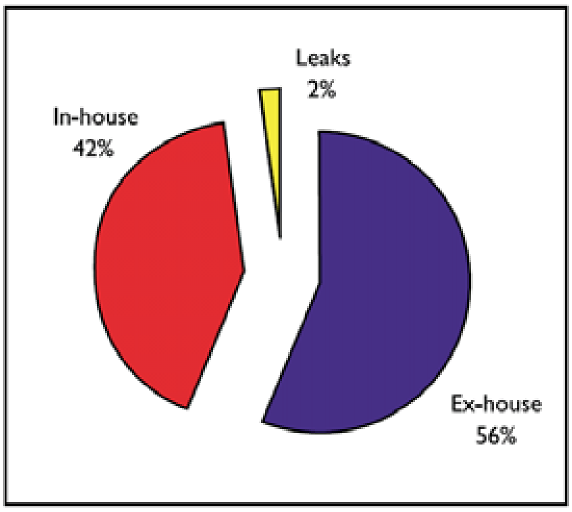
The following data has been relied upon to determine whether the use of on-site potable water supply is feasible:

- A study conducted by the Water Corporation in 2003 which measured the typical domestic water consumption.

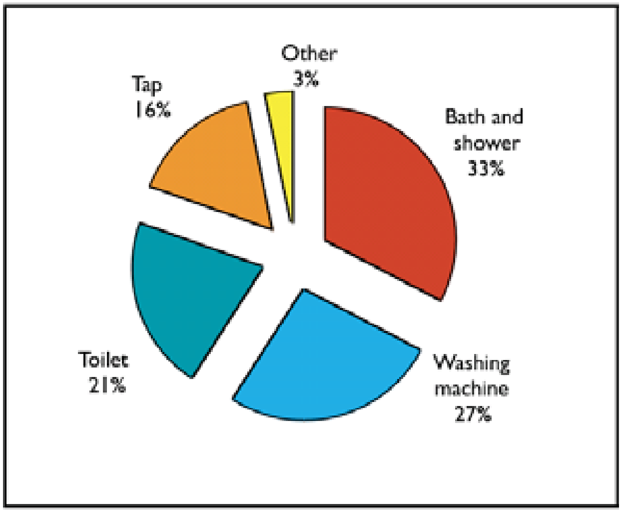
- The historical average monthly rainfall data provided by the Bureau of Meteorology (BOM) for the subject site (this can be seen in Figure A).

- The census data collected by the Australian Bureau of Statistics (ABS) which has determined the average person per dwelling for the Dongara locality.

Set out below as Figure B is an extract of Water Corporation's 2003 Domestic Water Use study which shows the percentage of water used in a typical domestic situation and allocates percentages of water consumed for several facets of domestic water use compared to the total domestic water use.




(a) Single residential




(a) Single residential

**Figure B: The above images show the proportion of total water usage (left) and allocation of in-house use (right). Taken from the 2003 Water Corporations Domestic Water Use Study.**

The study found that on average an average household consumes 1227 litres of water per day. This figure is split into two categories consisting of 523 litres per day for in-house uses and 707 litres per day for ex-house uses. In-house refers to the use of water for human consumption and other potable water uses (some more examples shown above in Figure B). Ex-house refers to the consumption of water mainly for watering of gardens. The study also concluded that on average there were 3.4 people per dwelling in the confined study area. Thus, it can be established that on average a person will consume 155 litres per day for in-house uses and 208 litres per day for ex-house uses, totalling to 363 L/person/day.

In calculating the optimum design capacity of rainwater storage unit required for a typical lot, the ex-house use defined by the pie charts shown above as Figure B above was ignored because the rainwater collected is to be used for in-house applications only. That assumption was made based on the fact that the Water Corporations study was done in Perth and in a sewer area whereas the domestic wastewater from proposed lots will be treated by ATU treatment units and that those units have the capability of providing for garden reticulation. As mentioned above, the average consumption of water for in-house uses per person per day was found to be 155 litres. For the purposes of the analysis set out in this report, a consumption rate of 160L/person/day was adopted, in order to be conservative.

The ABS 2011 Census found that the average number of people per household, in the Dongara region, was 2.5. Therefore, in order to be conservative and account for the possible increase in number of people per household, the average number of people per household was assumed to be 3.

The available areas for collection of roof water were determined by studying the roof areas generated within a local subdivision located on Tyford Road, Dongara which is approximately 2.5 km south of the subject site. From satellite images of the Tyford Road subdivision (which has 2000$m^2$ sized lots) it can be seen that, on average, the dwelling roof catchment area on each lot is about 500$m^2$ and each lot has a shed with a roof catchment area of about 150 $m^2$. It would be reasonable to assume the lots produced from the subdivision of the subject site will produce roof and shed catchment areas of about the same size.

This data (modified by the author to allow for the likely facets of consumption in respect of the particular uses likely to be conducted on the subject site), taken together with the BOM and ABS data was collated into the spreadsheet which is annexed hereto as *Appendix B.* This spreadsheet provides a basic model of the net capacity of stored rainwater based on expected inflow from storm events versus the expected consumption and a graphical model is produced.

From the data obtained from the spreadsheet and graph included hereto as *Appendix B*, it has been determined that a domestic dwelling located on a propose new lot produced by the subdivision of the subject site could entirely depend on rainwater alone for a sufficient potable water supply, but would require the installation of a rainwater tank (or tanks) with a total capacity of 150 kilolitres. This would allow the efficient use of the rainfall within the proposed lot and allow a sufficient buffer in the event of an extended dry period. Further, because it will take some time to fill the tanks from naturally occurring rainfall, it would be necessary that to source at least 80,000 litres of water to partially fill the proposed rainwater tanks to begin with. A starting capacity any less than that amount may result in initial consumption outstripping received rainfall to the point where storage will not properly accumulate.

### 6.3 *Wastewater Management*

The pre development wastewater disposal on the subject site was undertaken by the utilisation of onsite effluent disposal systems. This method of wastewater disposal is not proposed to change.

A Land Capability and Geotechnical Assessment conducted by Landform Research found that the subject site was suitable for onsite effluent disposal for proposed lots down to 2000m$^2$ in area. However smaller lots in the future would need to be connects to reticulated sewer system.

Wastewater is proposed to be treated, using onsite wastewater treatment systems (Alternate Treatment Units), and discharged into the surrounding ground where it will eventually reach the groundwater environment. Although some water will be lost in the wastewater treatment process, due to evapotranspiration, the input of water into each lot being drained from the reticulated water supply into the proposed subdivision should provide a reasonable groundwater balance

# 7 STORMWATER MANAGEMENT STRATEGY

The potential presence of deep sands within the development provides for adequate stormwater drainage disposal and, in addition, the opportunity to apply water sensitive stormwater design principles that encourages stormwater to be contained at source as far as practicable.

Some of the drainage controls preferred by the Department of Water include the use of swales, soakwells and landscaped infiltration basins. An effective drainage strategy can be developed for the site given that the high level of soil permeability do not allow for surface drainage to accumulate on the site, with all infiltration moving vertically downwards to the water table. The existing rural subdivision south of the site utilises swales on the road reserve, and a similar arrangement can be adopted for the development of the site.

Predevelopment flow paths will be determined and compared to the re-direction of flows in the post-development scenario as part of this LWMS.

## *7.1 Pre-Development Surface Drainage*

Almost the whole site is well drained by means of ground infiltration, with no risk of inundation or flooding because of the presence of deep sands overlying Tamala Limestone. Figure 6 illustrates the pre-development catchment delineation for the subject site including direction of the surface runoff flow paths.

Catchment characteristics for each of the four pre-development catchments (A, B, C and D) are analysed, including area, mainstream lengths, slope, ground imperviousness, rainfall data, and ultimately the surface runoff flow rates for each design ARI storm event.

These are generated using hydrological analysis based on methodology provided in “Australian Rainfall and Runoff - A Guide to Flood Estimation” (1987). The Rational Method was used together with the Kinematic Wave Equation for generating times of concentration. This formula incorporates the majority of site specific data and parameters available for hydrological analysis.

Appendix C is a brief write-up explaining the Rational Method used by AR&R (1987) in generating hydrological design data.

Appendix D shows the rainfall IFD data generated for the site using the Bureau of Meteorology website tools. The nearest meteorological location to the subject site was selected by the website tool to be on the edge of the proposed POS area at the south-western corner of the subject site.

Appendix E illustrates the catchment details including the generated equal slope areas and the mainstream profile for each pre-development catchment within the subject site.

Appendix F shows the hydrological and drainage data for all catchments. The following values were used in the generation of peak stormwater flows for the pre-development scenario:

- The Runoff Coefficient selected for Roads (%) = 90%
- The Runoff Coefficient selected for Verges (%) = 20%
- The Runoff Coefficient selected for Lots (%) = 5%

Table 1 below shows the site-specific pre-development catchment analysis including surface runoff flow rates generated for each design ARI storm event.

**TABLE 1:**
**PRE-DEVELOPMENT CATCHMENT DETAILS**

| CATCH. | Area, A ($m^2$) | Mainstream Length, L (km) | Mainstream Equal Area Slope, s (m/km) | Time of concentration $t_c$ (mins) | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1 yrs ARI | 5 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **A** | 317,134 | 0.710 | 17 | 38 | **0.06** | **0.12** | **0.18** | **0.27** |
| **B** | 85,582 | 0.260 | 50 | 12 | **0.04** | **0.07** | **0.10** | **0.15** |
| **C** | 171,838 | 0.550 | 18 | 31 | **0.04** | **0.08** | **0.11** | **0.17** |
| **D** | 50,187 | 0.258 | 54 | 11 | **0.02** | **0.04** | **0.06** | **0.09** |

The pre-development receiving environment for the stormwater runoff can be classified into three as follows:

a) *Groundwater*

The groundwater table receives stormwater directly by way of stormwater infiltrating into the ground from all 4 existing surface catchments within the subject site. In the case of the ODP area, the ground surface slopes and soil types are such that it is unlikely to create run-off of any significance and as such all stormwater received by the soils of the site will result in an evenly distributed collection of that stormwater for groundwater recharge.

b) *Public Open Space - Landscape Buffer Zone*

This buffer zone is 20m wide and exists along the entire stretch of subject site boundary along Brand Highway. It receives pre-development stormwater runoff from Catchments B, C and D.

c) *Public Open Space*

This is considered to be the outflow point on the western edge of the subject site boundary, along the north-south stretch of Francisco Road. It receives pre-development stormwater runoff from Catchment A.

The following table analyses the stormwater runoff for the pre-development receiving environment.

**TABLE 2:**
**PRE-DEVELOPMENT RECEIVING ENVIRONMENT**

| RECEIVING ENVIRONMENT | Pre-Development Contributing Catchment/s | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | |
|---|---|---|---|---|---|
| | | 1 yrs ARI | 5 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **Public Open Space** (western edge of site boundary) | A | 0.06 | 0.12 | 0.18 | 0.27 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.06** | **0.12** | **0.18** | **0.27** |
| **Landscape Buffer Zone** (eastern edge of site boundary) | B | 0.04 | 0.07 | 0.10 | 0.15 |
| | C | 0.04 | 0.08 | 0.11 | 0.17 |
| | D | 0.02 | 0.04 | 0.06 | 0.09 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.10** | **0.19** | **0.27** | **0.41** |

### *7.2 Post-Development Drainage Scenario*

Given the soil conditions on site and the high permeability achieved for all surface runoff, it is inevitable that most of the stormwater received at the surface of the site will infiltrate on site, with the exception of hardstand areas such as roads, footpaths, driveways and paved areas (with an impervious fraction of catchment area, $f$ = 0.8 (80%)) which will be conveyed by roadside swales (A typical cross-section is illustrated in Figure 8) to the proposed discharge points. The roadside swales are proposed to be 500mm deep with 1 in 3 batter slopes. The sizing calculations for the proposed road side swales are attached hereto as *Appendix G*

Within individual lots, it is expected to have all stormwater runoff from the roof areas directed into soakwells which enables the infiltration and seepage of stormwater back into the natural groundwater environment. This direct routing of part of the surface runoff within the individual lots into the groundwater will virtually mirror the ground infiltration rate so that it does not differ from the pre-development scenario.

All other stormwater runoff generated within the subject site (including paddocks located within the individual lot areas) has be designed so that it is redirected, using a roadside swale drainage system located in the road shoulder running parallel to the proposed pavements. Where necessary the stormwater will be piped under intersecting road pavements by way of concrete culverts. The system will discharge by way of bubble up pits (with pervious slab bases to allow stormwater to seep through) that overflow into the bio-infiltration swales located within the 20 m landscape buffer to the east. The post-development stormwater runoff will also discharge into two bio-infiltration swales located along the western boundary of the subject site (refer to Figure 7). The stormwater will then, by process of ground infiltration, ultimately find its way into the natural groundwater environment. This method of stormwater disposal ensures that all post-development stormwater runoff that exceeds the amount of the predevelopment condition is, in any event, disposed of within the subject site and does not run off onto neighbouring land, thus maintaining the predevelopment scenario.

This method of stormwater disposal further encourages infiltration and also redirects any runoff from large stormwater events (more than 5yr ARI storms) to the proposed bio-infiltration swales located on western boundary of the subject site, as well as to the 20m landscape buffer alongside Brand Highway. This is further illustrated in Figure 7.

Table 3 below shows the site-specific pre-development catchment analysis including surface runoff flow rates generated for each design ARI storm event. Also refer to *Appendix F* for the hydrological and drainage data for all catchments.

**TABLE 3:**
**POST-DEVELOPMENT CATCHMENT DETAILS**

| CATCH. | Area, A ($m^2$) | Mainstream Length, L (km) | Mainstream Equal Area Slope, s (m/km) | Time of concentration $t_c$ (mins) | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1 yrs ARI | 5 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| $A_1$ | 331,000 | 0.900 | 29 | 32 | **0.16** | **0.31** | **0.45** | **0.67** |
| $B_1$ | 67,300 | 0.36 | 67 | 11 | **0.03** | **0.05** | **0.08** | **0.12** |
| $C_1$ | 212,500 | 0.830 | 30 | 29 | **0.12** | **0.23** | **0.34** | **0.50** |
| $D_1$ | 43,900 | 0.270 | 37 | 11 | **0.04** | **0.07** | **0.11** | **0.16** |

The post-development receiving environment for the stormwater runoff can also be classified into 4 disposal areas as follows:

a) *Groundwater*

The groundwater will receive stormwater that directly infiltrates into the ground from all the soakwells servicing the proposed new dwellings that will be developed within the individual developed lots within the subject site. Although this cannot be quantitatively assessed through standard hydrological methods until the size of the development in each proposed lot is known, the post development value for ground infiltration would be identical to that of the pre-development scenario for the following reasons:

- The ground composition for the pre-development land and the post-development individual lots is the same, i.e. sandy soil.
- All rainfall and stormwater runoff from the roof areas within the post-development individual lots will be directed into the groundwater via soakwell disposal systems, whereas in the pre-development scenario, the stormwater will directly infiltrate into the ground. Thus, the only difference between the post development and pre development scenario will be that there could be point concentration of stormwater where soakwells are located but this will quickly dissipate into the groundwater table below due to the high permeability of the site. This will not affect groundwater condition as the overall volume of infiltration into the groundwater does not change and, given the depth of soil between the surface and the groundwater, the infiltration in the post development condition will distribute evenly through that separation depth.

b) *Public Open Space - Landscape Buffer Zone*

This buffer zone is 20m wide and exists along the entire stretch of subject site boundary along the Brand Highway frontage. It will receive post-development stormwater runoff from Catchments $B_1$, $C_1$ and $D_1$. It is proposed to have two stormwater discharge points within the Landscape Buffer Zone, one located near the centre of the eastern boundary, to receive stormwater discharge from Catchment $C_1$, and the other at the southeast corner of the subject site, to receive stormwater runoff from catchment $D_1$ (as shown in Figure 7). As Catchment $B_1$ does not generate any more stormwater runoff than the pre-development condition, there is no need to detain the stormwater runoff generated within this post-development catchment area (refer to *Appendix F* for pre and post-development analysis).

A typical cross-section of the proposed stormwater discharge point located within the Landscape Buffer Zone is illustrated in Figure 8.

Design calculations used for the sizing and capacity of these swales are included in *Appendix F.* The design details of these calculations are described below.

c) *Bio-Infiltration Swale*

In the post development scenario the topographical low points for the subject site remain in the same location, thus it is deemed logical to detain the excess stormwater runoff, produced as a result of the proposed development, at these locations. Therefore, it is proposed to detain the stormwater runoff, produced as a result of this development, by means of a bio-infiltration swale located within the locally widened road reserve, the location of which is shown in Figure 7.

The proposed bio-infiltration swale will receive stormwater runoff from Catchment $A_1$, which consists of most of the western part of the subject site. However, when the land to the west of the subject site is developed this catchment will also consist of Catchment $E_1$ as well as the land to the east of the future road alignment (this future catchment area is shown in Figure 7)

A typical layout of the proposed bio-infiltration swale is shown in Figure 9.

Design calculations used for the sizing and capacity of this swale are included in Appendix F. These calculations compare the predevelopment drainage condition with the proposed post development to determine how much stormwater runoff needs to be retained within the subject site so that the post development runoff does not differ to that of the predevelopment condition. This is done by using the IFD data for Bonniefield, provided by the Bureau of Meteorology (included hereto as Appendix D), and establishing the predevelopment and post development rainfall intensity. From this data, it is possible to calculate the stormwater inflow for the pre and post development conditions which enables a determination of the volume of water to be retained.

*d) Temporary Bio-Infiltration Swale*

It is proposed to have a temporary bio-infiltration swale located in an easement within a proposed lot (shown on Figure 7) to capture the stormwater runoff from Catchment $E_1$. Ultimately, as mentioned previously, this area will form part of Catchment $A_1$ when the land to the west of the subject site is developed. However, until this time the stormwater runoff will be detained in the temporary bio-infiltration swale.

The proposed temporary bio-infiltration swale is designed to be 600mm deep and have a total footprint area of approximately 70m$^2$ in area, therefore it will not impact the lot on which it is proposed to be located which has a total area of 8000m$^2$. A typical layout of the proposed temporary bio-infiltration swale is shown on Figure 9.

Design calculations used for the sizing and capacity of this swale are included in *Appendix F.* The details of these calculations are described above.

The following table analyses the stormwater runoff for the pre-development receiving environment.

**TABLE 4:
POST-DEVELOPMENT RECEIVING ENVIRONMENT**

| RECEIVING ENVIRONMENT | Pre-Development Contributing Catchment/s | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | |
|---|---|---|---|---|---|
| | | 1 yrs ARI | 5 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **Bio-Infiltration Swales** (western edge of site boundary) | A | 0.16 | 0.31 | 0.45 | 0.67 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.16** | **0.31** | **0.45** | **0.67** |
| **Landscape Buffer Zone** (eastern edge of site boundary) | B | 0.03 | 0.05 | 0.08 | 0.12 |
| | C | 0.12 | 0.23 | 0.34 | 0.50 |
| | D | 0.04 | 0.07 | 0.11 | 0.16 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.19** | **0.35** | **0.53** | **0.78** |

### *7.3 Water Quantity Management*

From the above analyses of pre-development versus post-development scenarios, a comparison is made between the two for each category of receiving environment, in order to ascertain the stormwater management objective of achieving water quantity management. The following table demonstrates this comparison.

**TABLE 5:
WATER QUANTITY MANAGEMENT AT RECEIVING ENVIRONMENTS**

| RECEIVING ENVIRONMENT | SCENARIOS | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | |
|---|---|---|---|---|---|
| | | 1 yrs ARI | 5 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **Public Open Spaces (Pre) Bio-Infiltration Swales (Post)** (western edge of site boundary) | **Pre-Development** | **0.06** | **0.12** | **0.18** | **0.27** |
| | **Post-Development** | **0.16** | **0.31** | **0.45** | **0.67** |
| **Landscape Buffer Zone** (eastern edge of site boundary) | **Pre-Development** | **0.10** | **0.19** | **0.27** | **0.41** |
| | **Post-Development** | **0.19** | **0.35** | **0.53** | **0.78** |

This comparison clearly shows that as far as the overland stormwater runoff to the POS areas is concerned, the post-development peak flows are to a certain extent maintained, and are relatively comparable to the pre-development condition. The excess stormwater runoff will be detained in bio-infiltration swales located in easements on the western boundary as shown in Figure 7.

As far as the Landscape Buffer Zone is concerned, the relative peak flows are also maintained and relatively comparable to pre-development conditions. The excess stormwater runoff will be detained in bio-infiltration swales located in the POS landscape buffer zone as shown in Figure 7.

Since groundwater comprises a major component of the receiving environment, it can be deduced that the overall receiving environment (including POS areas, Landscape Buffer Zones and Groundwater) would not be affected in terms of stormwater quantity maintenance when comparing the pre-development condition to the post-development scenario.

### *7.4 Water Quality Management & Disposal Strategies*

Given that the general topographical environment, geological formation (i.e. sandy soils) and stormwater re-direction strategies will not be significantly altered between the pre-development conditions to the post-development scenario, it is reasonable to deduce that the surface water and groundwater quality will be maintained.

However, it is preferable to improve the water leaving the development area, especially from those hardstand areas that are created as part of the development, such as internal roads, footpaths, driveways and paved areas so that the water quality does not diminish below the pre-development quality. As illustrated in Figure 7, all the stormwater generated from these areas will initially be redirected to via roadside swales into bio-infiltration swales before eventually being discharged into the receiving environment. The bio-infiltration swales are sized using the calculations attached hereto as *Appendix F*. Each bio-infiltration point will have a vegetated storage footprint area not less than 2% of the total catchment area.

Furthermore, the soakwell disposal systems within the individual lots will provide a means of stormwater detention and filtration before final disposal into the groundwater environment through gradual seepage and infiltration.

In this manner, stormwater management objective of achieving water quality management is achieved by ensuring that runoff contained within the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater Management Manual for Western Australia (2004-07)*.

# 8 MONITORING

## *8.1 Monitoring and Contingencies*

### 8.1.1 Surface Water Monitoring

The existence of surface water in the bio-infiltration swales will be ephemeral, and therefore only opportunistic sampling and testing of surface water from the bio-infiltration swales will be possible. This will be conducted as and when practicable, and the results monitored to ensure continuing quality improvement.

### 8.1.2 Groundwater Quality Monitoring

A monitoring program will be implemented to provide an ongoing assessment of development impacts on groundwater levels and groundwater quality.

Monitoring will be undertaken by the sub-divider annually during each year that the development is being constructed plus an additional period of two years in order to assess the impact of water quality arising from urbanization of the Site.

Groundwater will be extracted from bore locations as used in the original baseline testing, and tested for pollutants.

The monitoring program sets performance criteria against which the results of monitoring can be assessed, and identifies contingency actions to be taken in the event that any of the criteria is breached. If any result reaches the trigger level an additional test will be conducted. If confirmed, appropriate action will be taken in consultation with a suitably qualified environmental consultant.

The proposed monitoring program is shown in Table 6.

**TABLE 6:**
**MONITORING SCHEDULE & REPORTING**

| Monitoring Type | Parameter | Source Location | Method | Frequency & Timeframe |
|---|---|---|---|---|
| Groundwater Level | Water level (m AHD) | Groundwater sampling from monitoring bores | Electrical depth probe or similar | Annually from start of project until 2 years post completion of subdivision |
| Groundwater Quality | pH, EC, TSS, Nitrogen, Phosphorus | | | Annually from start of project until 2 years post completion of subdivision |

An annual report will be submitted by the sub-divider to the Department of Water and Shire of Irwin for the duration of the development-related monitoring program.

Following handover it will be the responsibility of the Shire of Irwin to determine an appropriate monitoring frequency.

### 8.1.3 Bio-infiltration Swale Soil Monitoring

The bio-infiltration swales will be inspected after every significant storm event (or at least annually) by the subdivider for signs of sediment accumulation, weed invasion and poor plant health, and remedial action will be taken to remove sediment and weeds and replace diseased and deceased plants.

Responsibility for the bio-infiltration swale soil monitoring will revert to the Shire of Irwin after a period of 24 months from completion of the relevant stage of the project where the bio-infiltration swale/s have, as part of that stage, been constructed.

# 9 IMPLEMENTATION AND MAINTENANCE

## *9.1 Implementation*

The subdivider shall be responsible for the implementation of an Urban Water Management Plan (once subdivision of the land is approved), implementation of the monitoring program and maintenance in accordance with Table 7 below.

## *9.2 Ongoing Maintenance*

It is proposed that the Shire of Irwin will assume responsibility for the ongoing operation and maintenance of the proposed drainage system following a period of 24 months from the completion of the site works, with the subdivider being responsible for maintaining the system during the 24 month prior period.

The maintenance regime will include erosion control, sediment removal, weed control, plant inspection and plant replacement in the bio-infiltration swale.

## *9.3 Maintenance Schedule*

Table 7 below provides a maintenance schedule for the infrastructure proposed to be installed as part of the subdivision.

**TABLE 7:**
**MAINTENANCE SCHEDULE - DRAINAGE**

| Maintenance Requirement | Specific Requirement | Responsibility |
|---|---|---|
| Pits and gullies | Inspect after significant storm events or quarterly as a minimum to ensure correct functioning. | Subdivider up until final inspection of roadworks, then Shire of Irwin |
| Street sweeping | Remove silt from road surface at completion of the roads constructed in the subdivision | As per pits and gullies |
| Monitoring plants | Inspect monthly, remove invading exotic plants and weeds, and re-plant as required. | Subdivider for a period of 24 months, then Shire of Irwin |
| Bio-infiltration swale | Inspect monthly and remove excess sediment and litter as required to maintain function | Subdivider for a period of 24 months, then Shire of Irwin |

# 10 SUMMARY

Previous studies indicate the extensive sandy nature of the soils, which promotes ground infiltration of stormwater runoff into the groundwater table. Soakwells located within the individual lots of the proposed subdivision will further ensure that the stormwater runoff from rooftops will be redirected into the groundwater receiving environment.

The topography of the subject site will result in similar catchment delineations as between the pre-development and post-development scenarios. The comparisons of peak design stormwater flow rates show a similarity between the pre-development and post-development conditions.

To ensure that there is sufficient area for nutrient management and stormwater runoff disposal for the proposed development; two disposal points have been created on the western edge of Lot 10, one being located in a very small easement within a Lot and the other within a widened section of the existing Francisco Road road reserve. These two disposal points will service the western half of the proposed development. This will be achieve through the construction of a roadside swale drainage system (with piped culverts where the drains need to pass under road/footpath pavements) where the stormwater runoff is directed into the proposed bio-infiltration swales and which will ultimately discharge into the groundwater environment by process of infiltration.

Similarly, the eastern half of the proposed development will have its post-development surface runoff directed to the 20m landscape buffer area between the proposed development and Brand Highway. Stormwater runoff disposal management will also be achieved within this landscape buffer zone by first directing the runoff through a roadside swale drainage system (again with piped culverts where the drains need to pass under road/footpath pavements) connected to bubble-up pits, then discharging into bio-retention swales within the buffer zone.

An ongoing monitoring and maintenance schedule coupled with the proposed development infrastructure will aid in providing an ongoing assessment of development impacts on groundwater levels and groundwater quality.

## 11 CONCLUSION

The proposed development of Lots 4, 5 and 10 Francisco Road, Bonniefield is sustainable from a water management perspective. Given the existing ground and environmental conditions of the subject site, a total water cycle management is achievable by integrating the various components of the stormwater drainage system directing runoff into the receiving public open space environment in a controlled and sustainable way.

This is achieved by using a stormwater management system which will maintain water quantity and quality matching that of the pre-development condition in accordance with the principles and objectives outlined in this Local Water Management Strategy.

Signed by:

Christopher Elms *(BSc. Civil Eng. (Hons))*
Design Manager

Date: 3 September 2014

Signed by:

Ian McKellar
Project Manager

Date: 3 September 2014

# 12 REFERENCES


1. Australian Bureau of Statistics (2014). *2011 Census QuickStats: Dongara.* http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/SSC50222?opendocument&navpos=220

2. Bureau of Meteorology (2013). *Climate Statistics for Australian Locations: Geraldton Airport Comparison.* http://www.bom.gov.au/jsp/ncc/cdio/cvg/av

3. Department of Water (2004-2007). *Stormwater Management Manual for Western Australia*. Perth.

4. Department of Water (2004a). *Perth Groundwater Atlas. Second Edition*. Perth.

5. Department of Water (2004-7). *Decision Process for Stormwater Management in WA*.

6. Chappell, Lambert Everett (October 2010). *Shire of Irwin Local Planning Scheme No. 5, Amendment No. 10 – Scheme Amendment Report.*

7. GHD (2012). *Dongara Draft District Structure Plan: District Water Management Strategy. Shire of Irwin*. http://www.irwin.wa.gov.au/Planning.aspx

8. Landform Research (June 2005). *Land Capability and Geotechnical Assessment – Lots 10, 15, 16 and 17, Francisco Road, Dongara.*

9. WAPC (October 2008). *Better Urban Water Management*.

10. WAPC (June 2013). *Approved Local Planning Scheme Amendment, Shire of Irwin, Local Planning Scheme No. 5 – Amendment No. 15 (TPS/1014).*

11. Water Corporation (2003). *Domestic Water Use Study*. Perth, WA. Water Corporation.

12. Water Corporation (2014). *Average Persons Water Use*. https://www.watercorporation.com.au/home/faqs/saving-water/how-many-litres-of-water-does-the-average-perth-household-use

13. AECOM (June 2012). *Francisco Road Proposed Rezoning – Desktop Preliminary Engineering Services Review; Revision 3.*

14. York Gum Services (October 2013). *Bushfire Management Plan: Francisco Road, Dongara.*

15. Department of Water (December 2008). *Interim: Developing a local water management strategy.*

16. Pilgrim, DH, (ed)., *Australian Rainfall and Runoff - A Guide to Flood Estimation,* Institution of Engineers, Australia, Barton, ACT, 1987.

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## 14 APPENDICES:


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| **APPENDIX G:** | Open Channel Flow Calculation Sheet. |

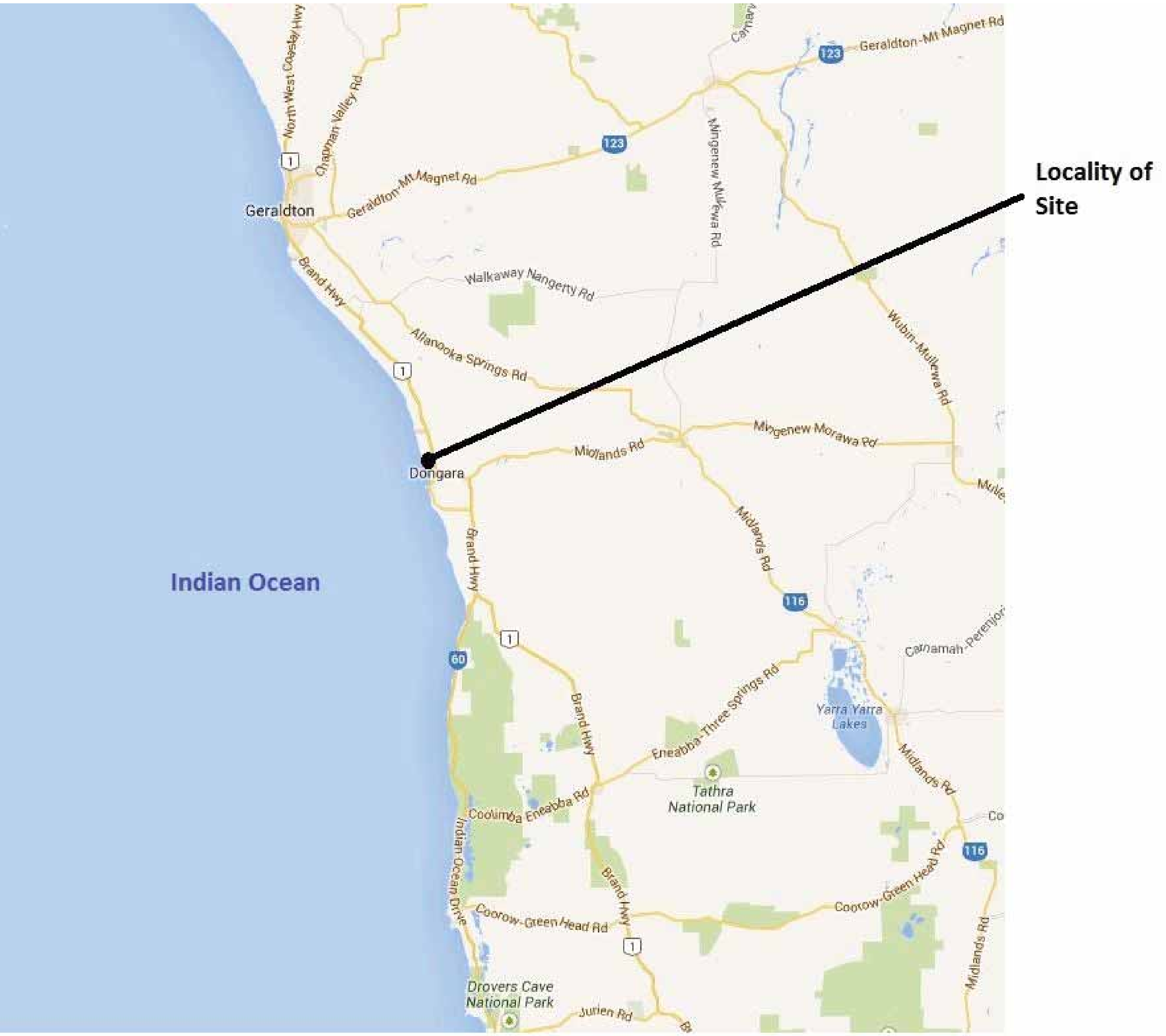



Figure 1: Locality of Subject Site

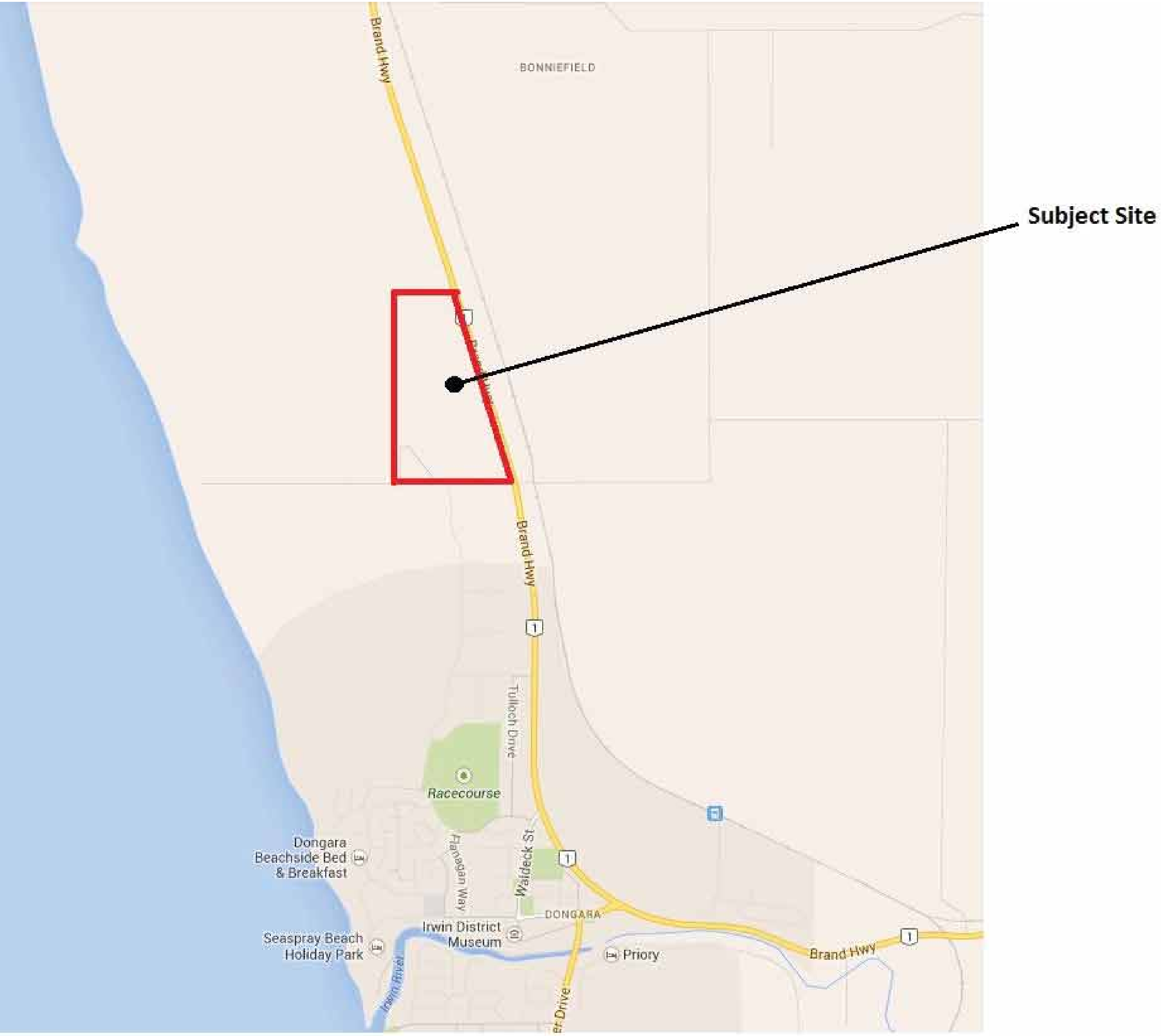



**Figure 2: Subject Site Boundary**


**Figure 3: Development Concept Plan** *(courtesy CLE - 2014)*

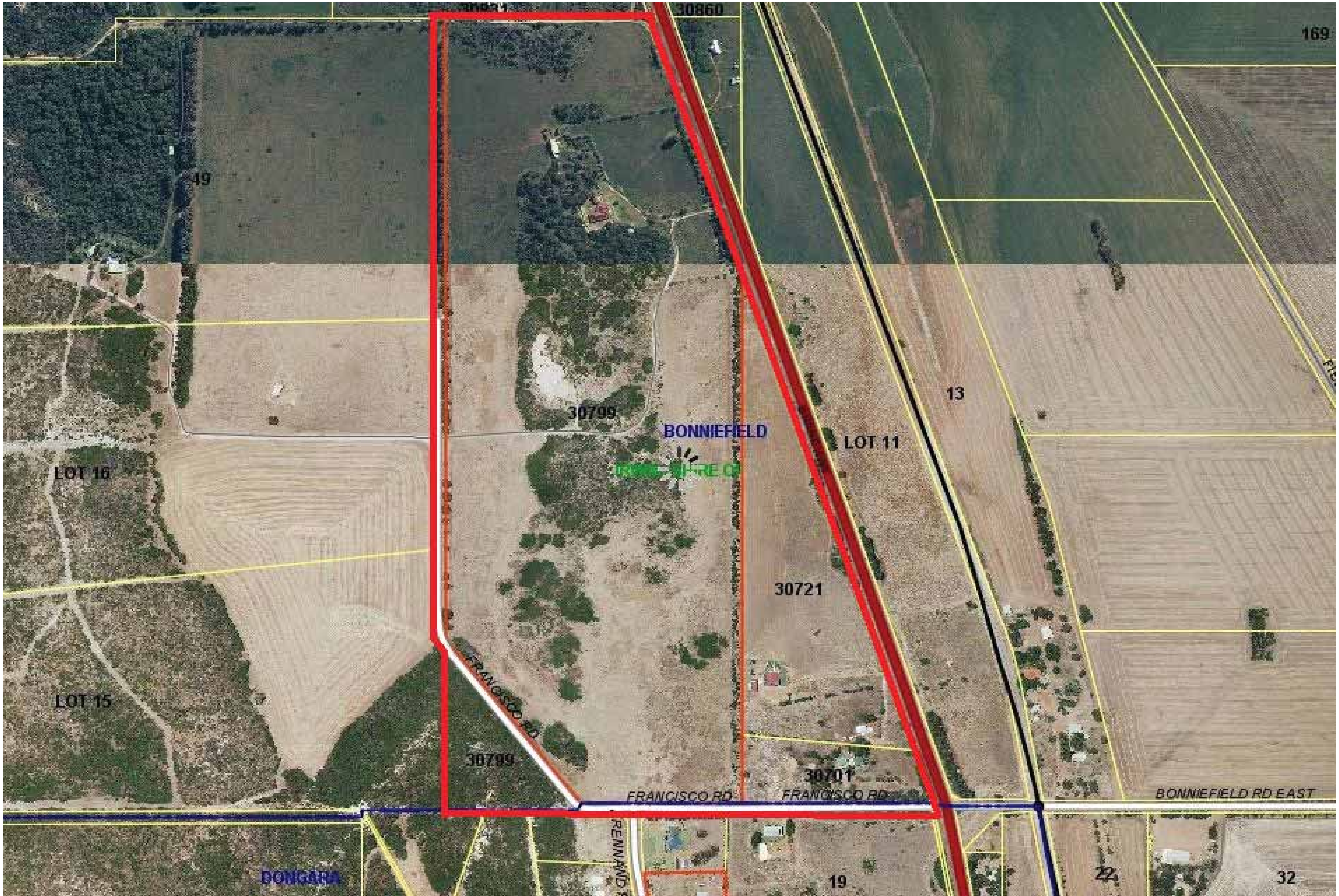
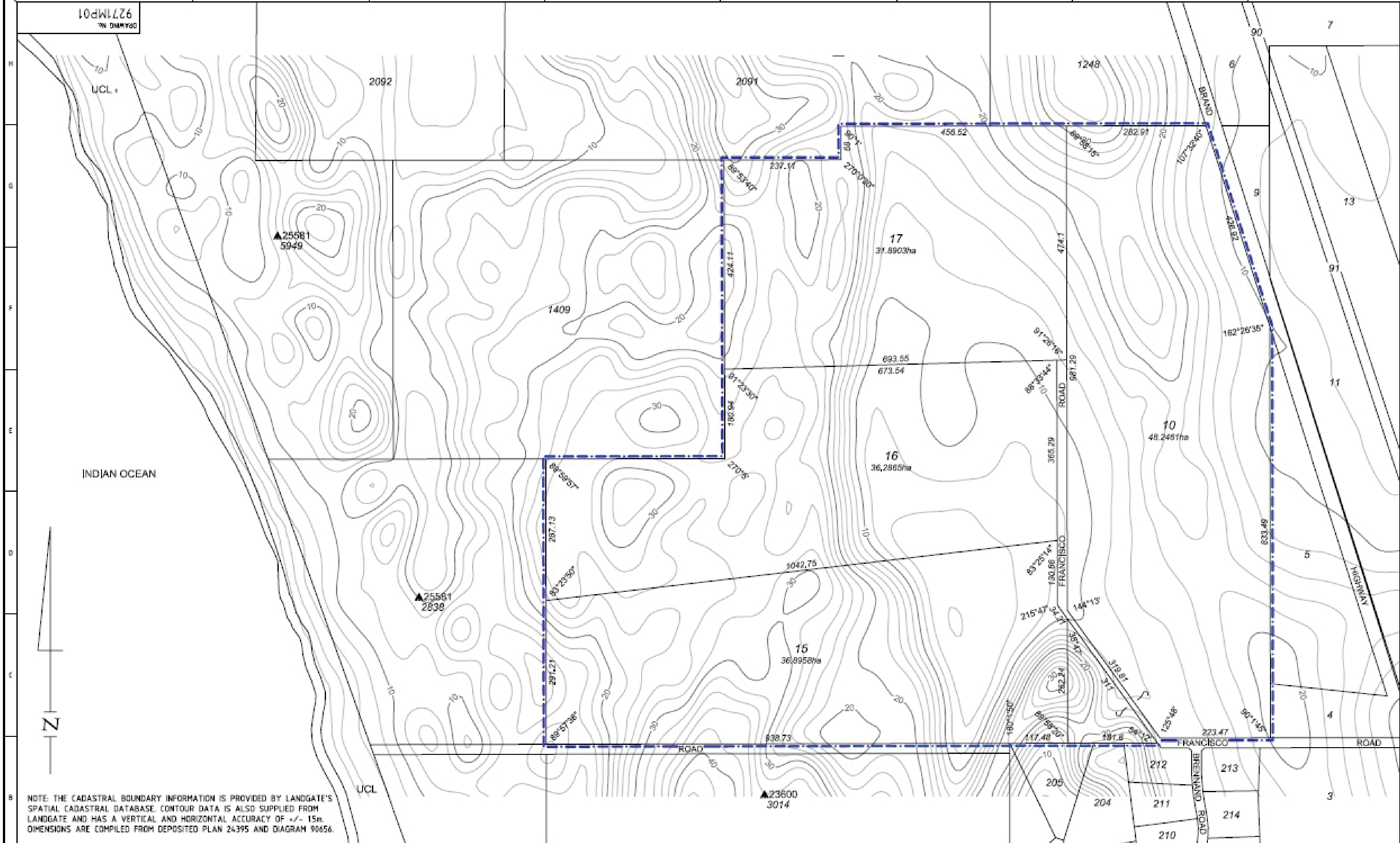



Figure 4: Aerial Photo of Subject Site *(courtesy Landgate WA)*




| CLIENT | | SURVEYED | DATE | PROJECT | DRAWING No. 9271MP01 |
|---|---|---|---|---|---|
| CLARKE & Co REAL ESTATE | Quantum SURVEYS PTY LTD<br>GERALDTON CENTRAL, Suite 2<br>65 Chapman Road, GERALDTON WA 6530<br>PO Box 695, GERALDTON WA 6531<br>Email: info@quantumsurveys.com.au<br>PHONE: (08) 9965 0077<br>FAX: (08) 9965 0088<br>LAND • ENGINEERING • MINING | COMPUTED R. HUNT | 21/07/2009 | TITLE<br>CONTOUR PLAN<br>LOTS 10, 15, 16 & 17<br>FRANCISCO ROAD,<br>BONNIEFIELD | JOB No. 9271 / SCALE 1:5000 @ A2 / REV. |
| | | DRAWN S. D'MELLO | 21/07/2009 | | HORIZONTAL DATUM MGA ZONE 50 / VERTICAL DATUM A.H.D |
| | | CHECKED R. HUNT | 21/07/2009 | | FIELD BOOK / LEVEL BOOK |
| | | APPROVED R. HUNT | 21/07/2009 | | ADDITIONAL INFORMATION |

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**Figure 5: Site Contour Plan**
*(courtesy Quantum Surveys - 2009)*

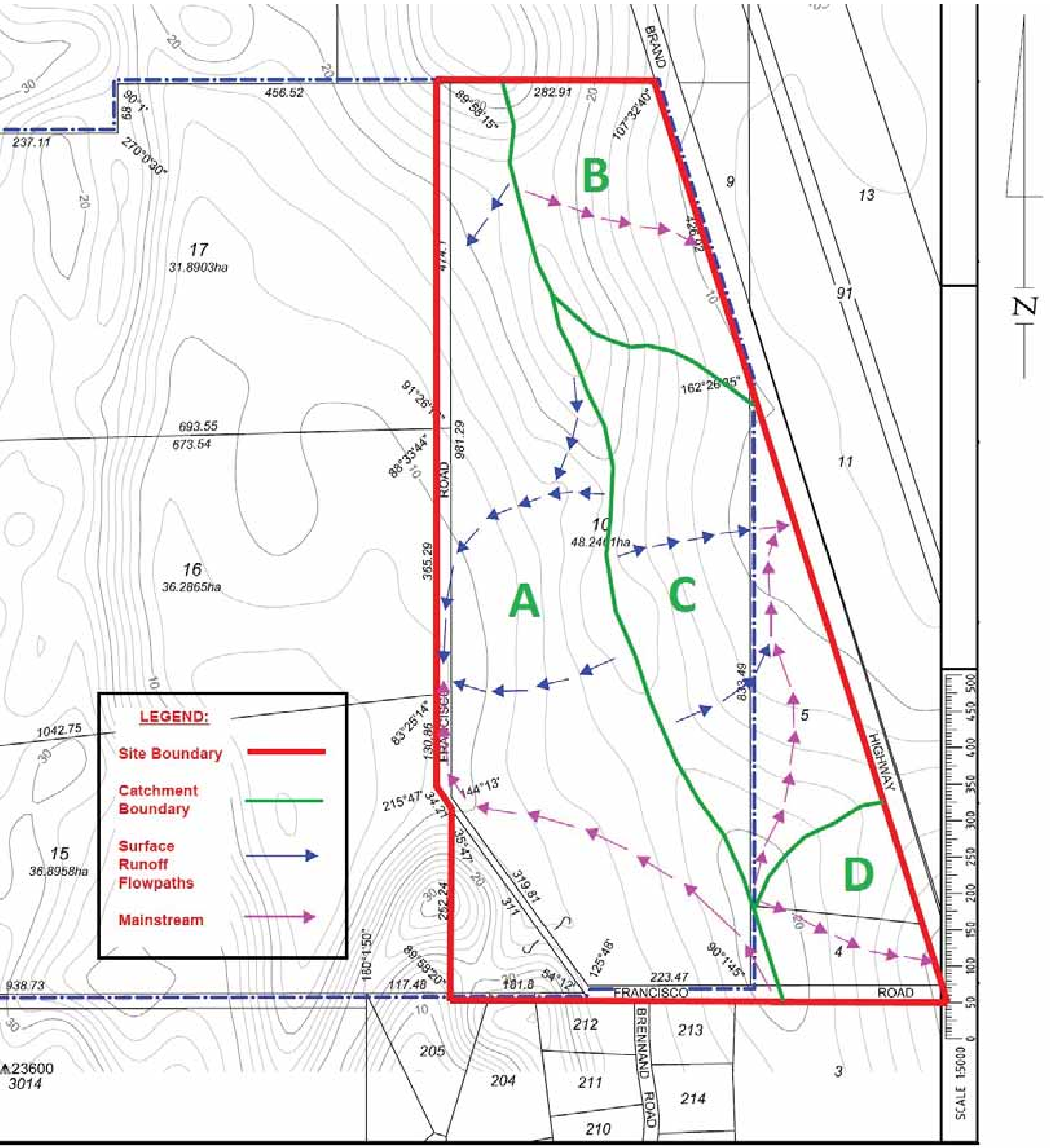
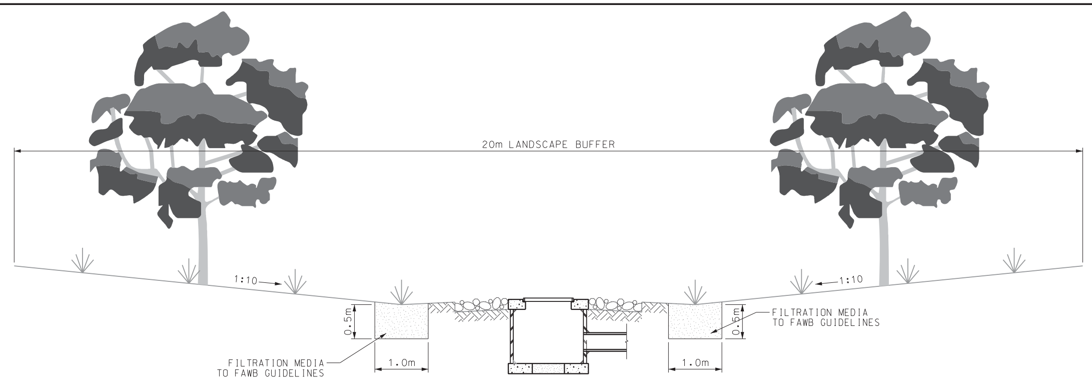



Figure 6: Pre-development Catchment Delineation and Surface Runoff


**Figure 7: Post-development Surface Runoff and Disposal**




TYPICAL CROSS-SECTION OF A
BIO-RETENTION BASIN IN THE
VEGETATION BUFFER

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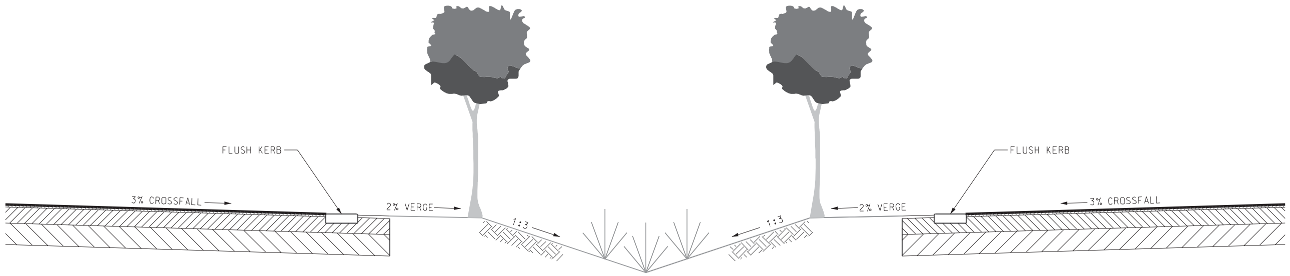


TYPICAL CROSS-SECTION OF A
CENTRALLY LOCATED DRAINAGE SWALE

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TYPICAL CROSS-SECTION OF A
ROADSIDE SWALE

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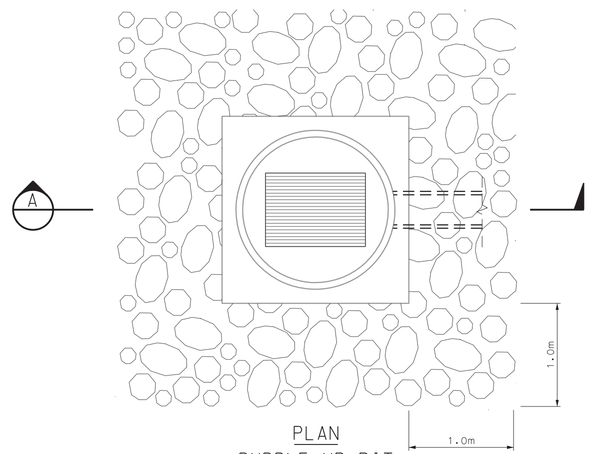


PLAN
BUBBLE UP PIT

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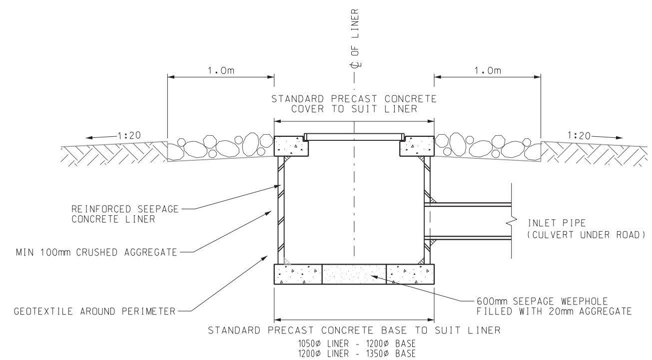


SECTION A

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W.A.P.C. No.:

**BEN CLARKE**

PROPOSED SUBDIVISION OF
LOTS 4, 5 AND 10
FRANCISCO ROAD, BONNIEFIELD
TYPICAL DRAINAGE DETAILS

FILE NAME: 796-01-FIGURE 8.dgn

DATE: 10.04.14

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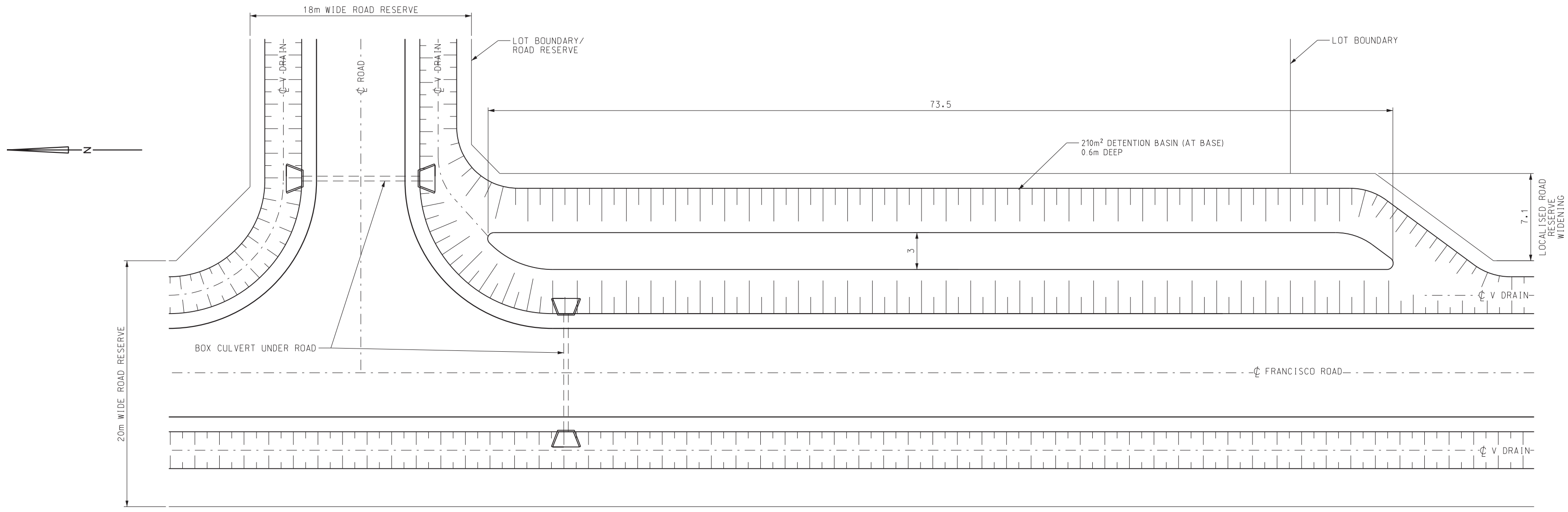
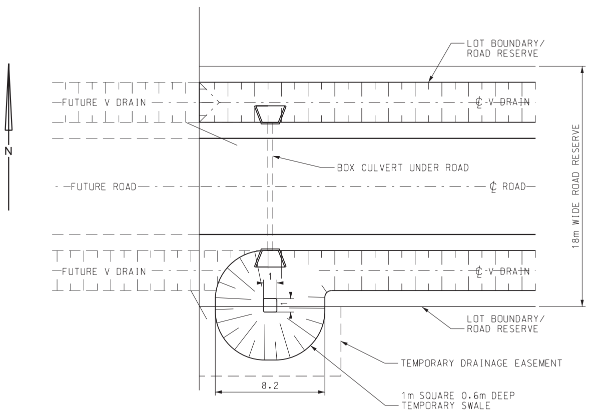



BIO-INFILTRATION SWALE
WESTERN EDGE OF SUBJECT SITE




TEMPORARY BIO-INFILTRATION SWALE
WESTERN EDGE OF SUBJECT SITE

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PROPOSED SUBDIVISION OF
LOTS 4, 5 AND 10
FRANCISCO ROAD, BONNIEFIELD
DETENTION BASIN - GENERAL ARRANGEMENT

FILE NAME: 796-01-FIGURE 9.DGN
DATE: 02.09.14
DRAWING No.: FIGURE 9
AMDT No.: A

# APPENDIX A: Lot 1 Kailis Drive Permeability Certificate

BCE

# BLACKTOP CONSULTING ENGINEERS


ACN: 098 257 071 ABN: 52 098 257 071
PO Box 1018 Geraldton WA 6531
PHONE : (08) 9921 1878
FAX: (08) 9965 5730


# FACSIMILE MESSAGE

| | | | |
|---|---|---|---|
| To: | Civil Technology | | |
| Att: | Mr Ian McKellar | Fax: | 9367 8046 |
| Date: | 8/08/07 | No. of pages: | 3 |
| Job No. | | Your ref: | |

Dear Ian

**Project: Lot 1 Kailis Drive**
**Permeability**

Please find attached permeability test certificate and site plan as requested.

Any queries please do not hesitate to contact me on 99 211 878.

Yours faithfully

**Lester Smith**
Engineering Manager
Attach Report

BME

BLACKTOP MATERIALS ENGINEERING
ACN: 098 257 071 ABN: 52 098 257 071
PO Box 1018 GERALDTON WA 6531
PHONE: (08) 9921 1878
FAX: (08) 99655730

# TEST CERTIFICATE



| | | | |
|---|---|---|---|
| **CLIENT:** | Civil Technology<br>17 Lyall Street South Perth WA 6151 | **JOB NO.:** | BCE263 |
| | | **CLIENT ORDER NO.:** | - |
| **PROJECT:** | Proposed subdivision of Lot 1 Kailis Drive Port Denison | **DATE FIELD TESTED** | 31/07/07 |
| **LOCATION:** | Refer to attached test pit locality plan | **DATE LAB RECIEVED** | N/A |
| **DESCRIPTION:** | Brown silty sand, similar in appearance to wattle sand (dune sand with degraded organic material from Acacia species) | **DATE LAB TESTED** | N/A |
| **SAMPLE NO:** | 07BME2118 | **CERTIFICATE No.** | 07BME2118 |

**Method for determining the absorptive capacity of a soil in accordance with Schedule 8 – Health Regulations 1974**

| Test Site Location (Refer to site plan) | Soil Description | Moisture condition of soil | Time taken for water level to fall 25mm | Calculated infiltration rate (m/s) |
|---|---|---|---|---|
| Test Location 1 (Test depth 300mm below ground surface) | Wattle sand | Moist from recent rainfall | 2 minutes & 16 seconds | $1.8 \times 10^{-4}$ m/s |
| Test Location 2 (Test depth 300mm below ground surface) | Wattle sand | Moist from recent rainfall | 2 minutes & 37 seconds | $1.6 \times 10^{-4}$ m/s |
| Test Location 3 (Test depth 300mm below ground surface) | Wattle sand | Moist from recent rainfall | 1 minute & 22 seconds | $3.0 \times 10^{-4}$ m/s |
| Test Location 4 (Test depth 300mm below ground surface) | Wattle sand | Moist from recent rainfall | 1 minute & 16 seconds | $3.3 \times 10^{-4}$ m/s |

**Notes:**
Site is heavily vegetated and site access was difficult beyond established tracks. Tests were spread as far apart as was possible to achieve with existing site access tracks.
Test sites 1 & 2 were situated in the valley of sand dune formations.
Test sites 3 & 4 were situated on top of sand dune formations.

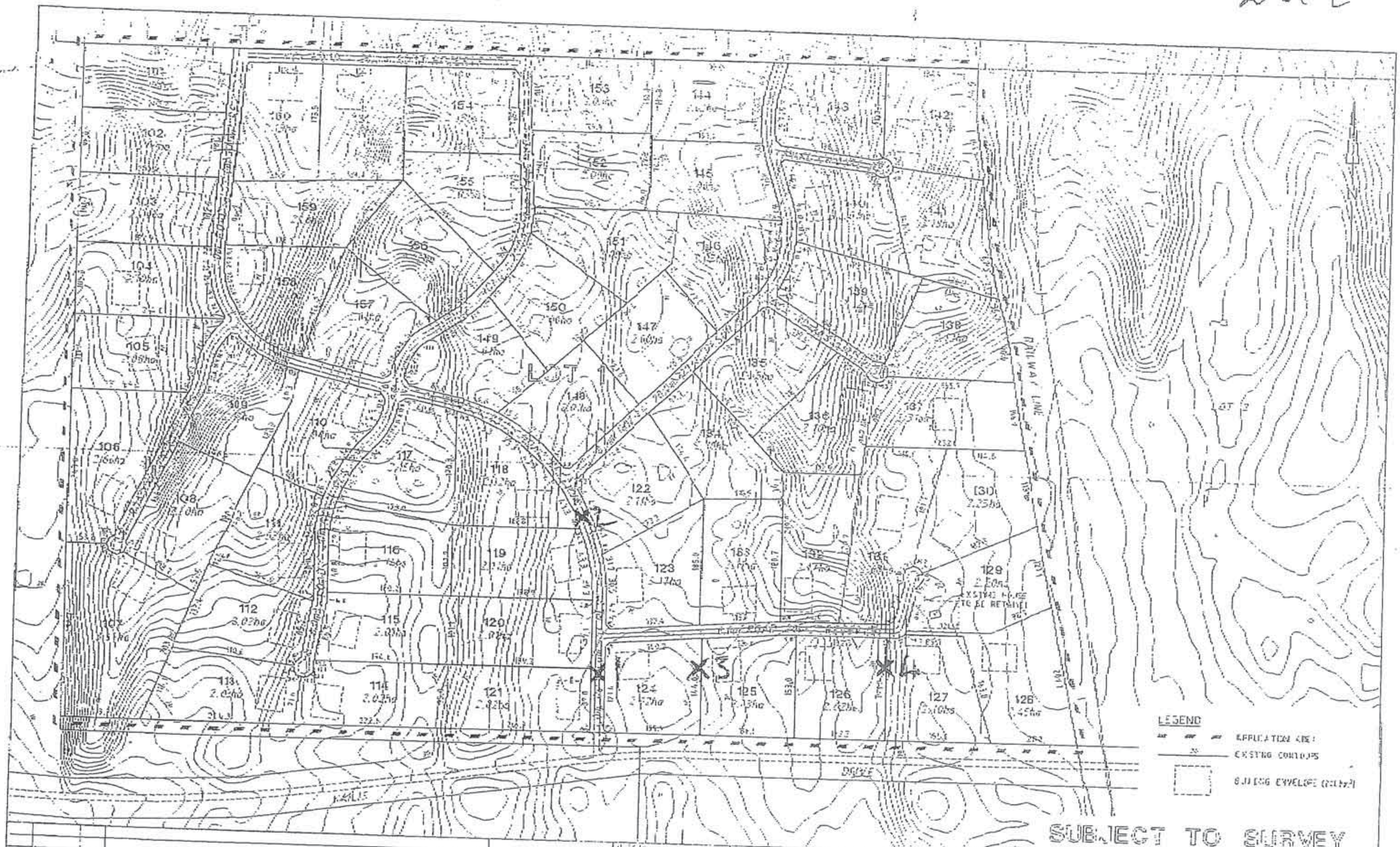
Notes: This information does not conform to any Australian Standard test method and is not NATA endorsed.

Authorised Signatory : (L. Smith)

Date : 2/8/07

Form No.: R-AS-14-00

2 of 2




DONGARA HOLDINGS PTY. LTD.

PROPOSED SUBDIVISION OF
LOT 1 KAILIS DRIVE, PORT DENISON
APPLICATION PLAN
SHIRE OF IRWIN

582-00-000

TO BE ISSUED

CIVIL TECHNOLOGY
CONSULTING CIVIL AND STRUCTURAL ENGINEERS

AMENDMENTS

TEST LOCALITY PLAN

# APPENDIX B: On-site Potable Water Supply Study

**PROJECT: SUBDIVISION OF LOTS 4, 5 AND 10 FRANCISCO ROAD, BONNIEFIELD**

# APPENDIX B

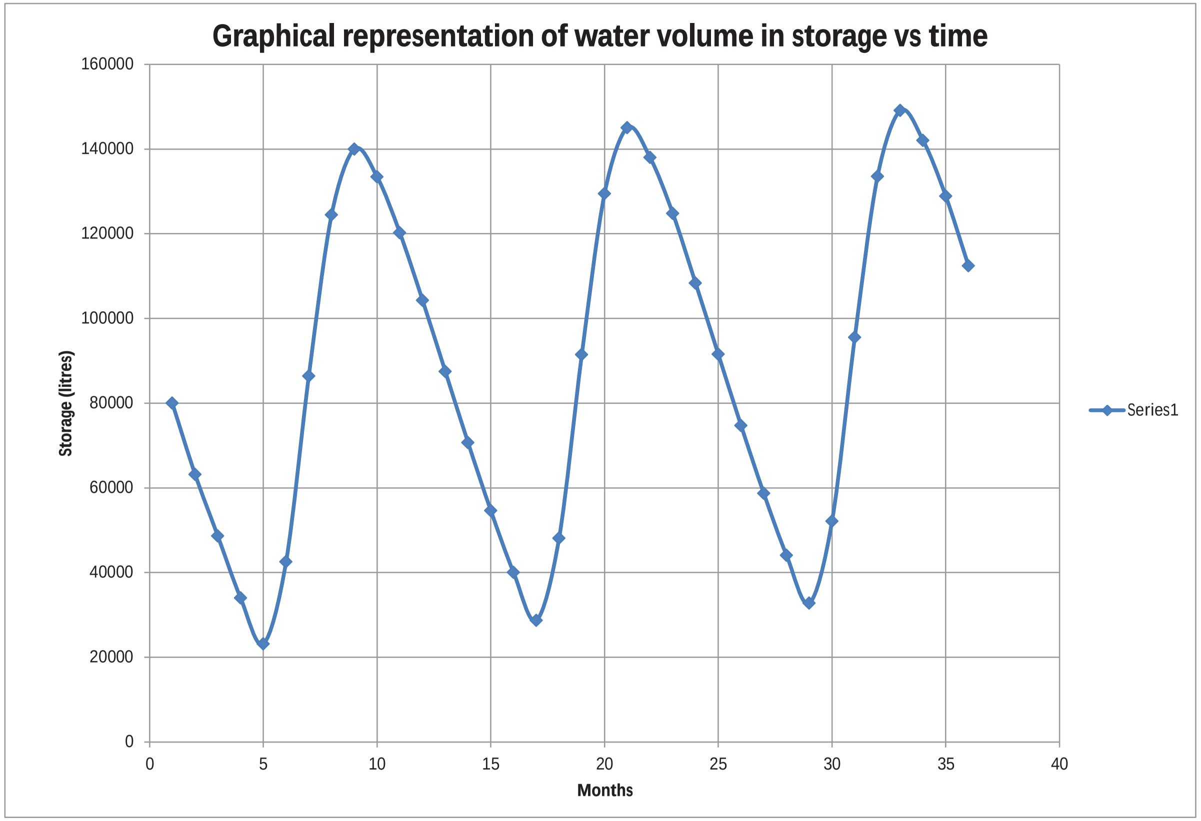
**ROOF RAINWATER CAPTURE AND DOMESTIC USE ANALYSIS** — **SHEET ONE OF TWO**

**Average number of persons per household:** 3 persons
**Insitu water tank storage volume:** 150 kilolitres
**Assumed built form dwelling roof sub-catchment area:** 500 m2
**Assumed built form shed roof sub-catchment area:** 150 m2
**Storage tank roof sub-catchment area (2.5m depth tank):** 60 m2
**Total catchment area:** 710 m2
**System losses (House consumption per person per day)** -160 litres

Other notes: 1 Rainfall Data extracted from Australian Bureau of Meteorology site number 008051 recorded since 1941 reduced by 6.8% to account for possible rainfall average decrease by 2030.*
2 Runoff co-oefficient logarithmic based on minimum 20% at lowest rainfall and maximum 90% at highest rainfall
3 System loss based on a flat total household usuage of 160 litres per person per day at 3 persons per household, grey water re-used for garden reticulation
4 System Loss is based on the Water Corporations Domestic Water Use Study and the number of people per household is based on the 2011 Census provided by the Australian Bureau of Statistics

| | Month | Starting storage at beginning of month (litres) | Added volume from other source | Average Rainfall in month (mm)[1] | Estimated runoff collection efficiency %[2] | Gross volume delivered to storage tank per month (litres) | System losses House consumption per person per day (litres)[3] | Number of persons per house | System losses Total consumption per house per day (litres) | System losses Total household consumption per month (litres) | Leakage per month (at 2% of consumption) (litres)[5] | Losses from tank overflow (litres) | Net volume added to storage for the month (litres) | Net volume in storage (litres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 1 | January | **80000** | | 5.3 | -43 | -1630 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16808 | 63192 |
| | February | 63192 | | 10.3 | -12 | -858 | -160.0 | 3.0 | -480 | -13440 | -269 | 0 | -14566 | 48626 |
| | March | 48626 | | 14.8 | 5 | 561 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -14616 | 34009 |
| | April | 34009 | | 22.2 | 24 | 3847 | -160.0 | 3.0 | -480 | -14400 | -288 | 0 | -10841 | 23169 |
| | May | 23169 | | 64.8 | 75 | 34565 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 19388 | 42557 |
| | June | 42557 | | 90.6 | 91 | 58555 | -160.0 | 3.0 | -480 | -14400 | -288 | 0 | 43867 | 86424 |
| | July | 86424 | | 85.1 | 88 | 53210 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 38033 | 124456 |
| | August | 124456 | | 60.3 | 72 | 30728 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 15550 | 140007 |
| | September | 140007 | | 29.8 | 38 | 8141 | -160.0 | 3.0 | -480 | -14400 | -288 | 0 | -6547 | 133459 |
| | October | 133459 | | 18.3 | 15 | 1976 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -13201 | 120258 |
| | November | 120258 | | 8.5 | -21 | -1269 | -160.0 | 3.0 | -480 | -14400 | -288 | 0 | -15957 | 104301 |
| | December | 104301 | | 4.9 | -47 | -1637 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16814 | 87486 |
| Year 2 | January | 87486 | | 5.3 | -43 | -1630 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16808 | 70678 |
| | February | 70678 | | 10.3 | -12 | -858 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16035 | 54643 |
| | March | 54643 | | 14.8 | 5 | 561 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -14616 | 40027 |
| | April | 40027 | | 22.2 | 24 | 3847 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -11330 | 28697 |
| | May | 28697 | | 64.8 | 75 | 34565 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 19388 | 48084 |
| | June | 48084 | | 90.6 | 91 | 58555 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 43378 | 91462 |
| | July | 91462 | | 85.1 | 88 | 53210 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 38033 | 129495 |
| | August | 129495 | | 60.3 | 72 | 30728 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 15550 | 145045 |
| | September | 145045 | | 29.8 | 38 | 8141 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -7037 | 138008 |
| | October | 138008 | | 18.3 | 15 | 1976 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -13201 | 124807 |
| | November | 124807 | | 8.5 | -21 | -1269 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16447 | 108360 |
| | December | 108360 | | 4.9 | -47 | -1637 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16814 | 91545 |
| Year 3 | January | 91545 | | 5.3 | -43 | -1630 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16808 | 74737 |
| | February | 74737 | | 10.3 | -12 | -858 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16035 | 58702 |
| | March | 58702 | | 14.8 | 5 | 561 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -14616 | 44086 |
| | April | 44086 | | 22.2 | 24 | 3847 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -11330 | 32756 |
| | May | 32756 | | 64.8 | 75 | 34565 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 19388 | 52143 |
| | June | 52143 | | 90.6 | 91 | 58555 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 43378 | 95521 |
| | July | 95521 | | 85.1 | 88 | 53210 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 38033 | 133554 |
| | August | 133554 | | 60.3 | 72 | 30728 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | 15550 | 149104 |
| | September | 149104 | | 29.8 | 38 | 8141 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -7037 | 142067 |
| | October | 142067 | | 18.3 | 15 | 1976 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -13201 | 128866 |
| | November | 128866 | | 8.5 | -21 | -1269 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16447 | 112419 |
| | December | 112419 | | 4.9 | -47 | -1637 | -160.0 | 3.0 | -480 | -14880 | -298 | 0 | -16814 | 95604 |

## GRAPH OF APPENDIX B



# APPENDIX C: Brief Write-up on Rational Method Used as per AR&R 1987.

# Brief write-up on the Rational Method used as per AR&R 1987

*by John Rostom (2013)*

The Rational Method is a relatively conservative method for analysing stormwater surface runoff flows for various storm events. It is also the most commonly used approach. It is a probabilistic or statistical method for estimating design floods and peak flows of selected Average Recurrence Intervals (ARI) from an average rainfall intensity.

The peak flow rate ($m^3/s$) of average recurrence interval (ARI) of $Y$ years, $Q_y$, is derived using the following equation:

$$Q_y = C_y \cdot I_{tc\,,\,y} \cdot A$$

where $C_y$ = runoff coefficient (dimensionless) for ARI of Y years;
$I_{tc\,,\,y}$ = average rainfall intensity ($mm/h$) for design duration of $t_c$ hours and ARI of $Y$ years;
$A$ = area of catchment ($km^2$).

***Selection of $C_y$:***

Runoff coefficient $C$ for urban stormwater drainage can be interpreted in different ways. Fig. 14.13 of AR&R (1987) illustrates the preferred runoff coefficient relationship based on experience of drainage authorities and evidenced gauging from urban catchments. It relates the coefficient for a 10 year ARI, $C_{10}$, to the pervious and impervious fractions of the catchment, and to its rainfall climate, expressed through the 10 year ARI, 1 hour duration rainfall intensity, ${}^{10}I_1$.

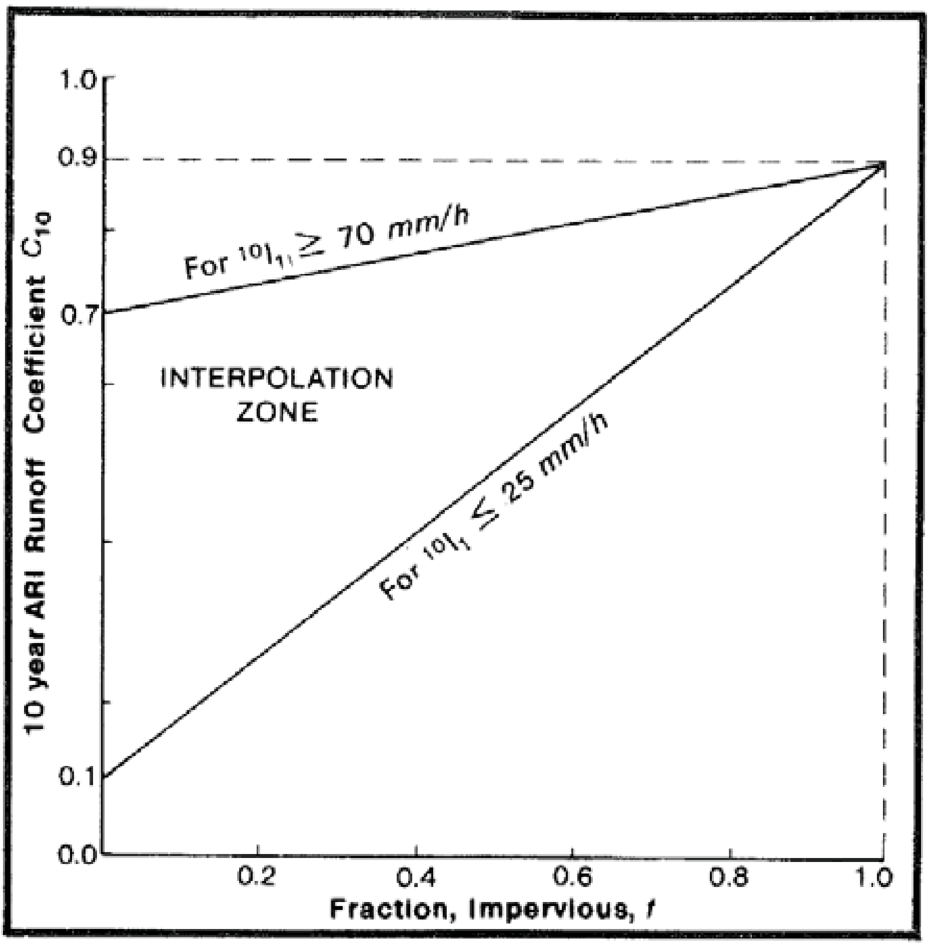



**Figure 14.13 – Runoff Coefficients**

The Runoff coefficient $C$ is calculated as follows:

$$C_y = F_y \cdot C_{10}$$

where $F_y$ = Frequency Factor for Rational Method Runoff Coefficients;
$C_{10}$ = Runoff Coefficient for a 10 year ARI.

$F_y$ is selected from the following table:

| ARI (*years*) | Frequency Factor, $F_y$ |
|---|---|
| 1 | 0.8 |
| 2 | 0.85 |
| 5 | 0.95 |
| 10 | 1.0 |
| 20 | 1.05 |
| 50 | 1.15 |
| 100 | 1.2 |

$C_{10}$ is calculated as follows:

$$C_{10} = 0.9 \text{ x } f + C^1_{10} \text{ x } (1 - f)$$

and

$$C^1_{10} = 0.1 + 0.0133 \text{ x } ({}^{10}I_1 - 25)$$

where $C^1_{10}$ = Pervious Area Runoff Coefficients;
${}^{10}I_1$ = Fraction Impervious (0.0 to 1.0).

***Selection of $I_{tc,y}$:***

Over the years, various procedures have been used to estimate the value of $t_c$, which is considered to be the travel time from the most remote point on the catchment to the outlet, or the time taken from the start of rainfall until all of the catchment is simultaneously contributing flow to the outlet. The procedure considered for the Rational Method analysis is the Bransby Williams procedure.

The following formula is used for deriving $t_c$:

$$t_c = \frac{58L}{A^{0.1}S_e^{0.2}}$$

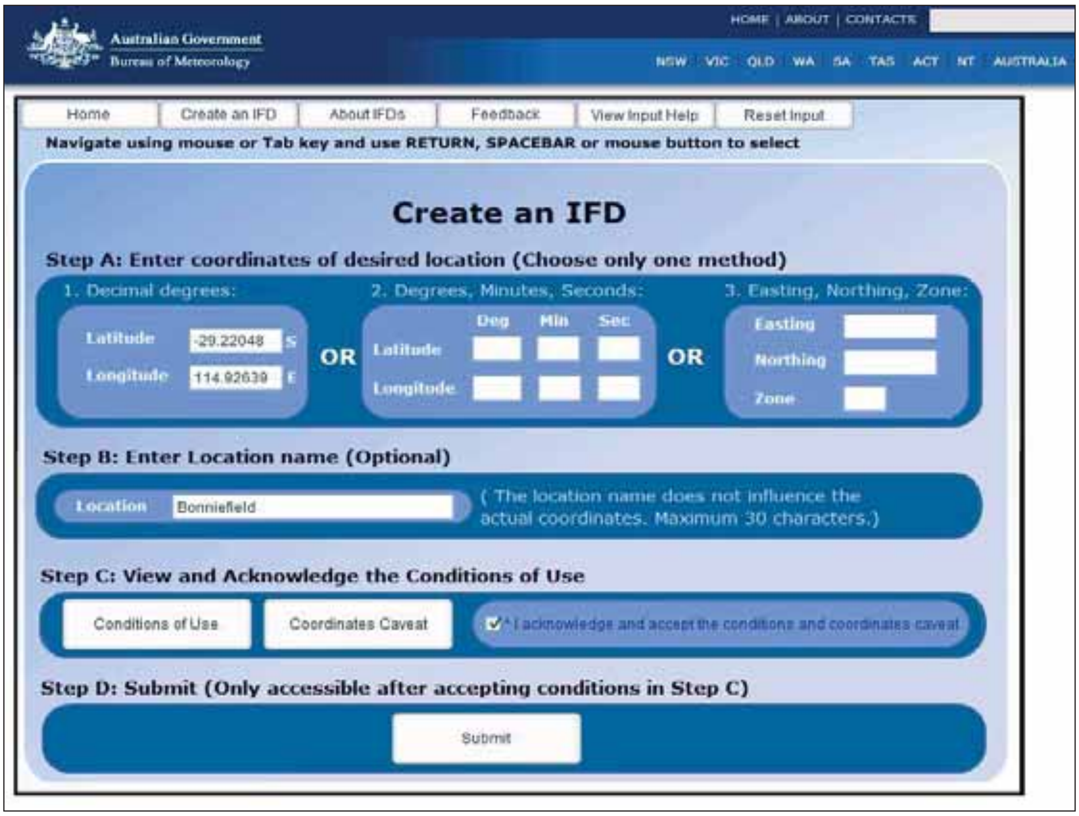
where $t_c$ = time of concentration (*min.*)
$L$ = mainstream length measured to the catchment divide (*km*)
$A$ = catchment area ($km^2$)
$S_e$ = equal area slope of the mainstream projected to the catchment divide (*m/km*)

For the procedure above, a unique $I_{tc,y}$ value is selected depending on the estimated $t_c$ and $C_y$ values.

# APPENDIX D: Design IFD Rainfall Data – Bureau of Meteorology

## Design Intensity-Frequency-Duration (IFD) Rainfall Data

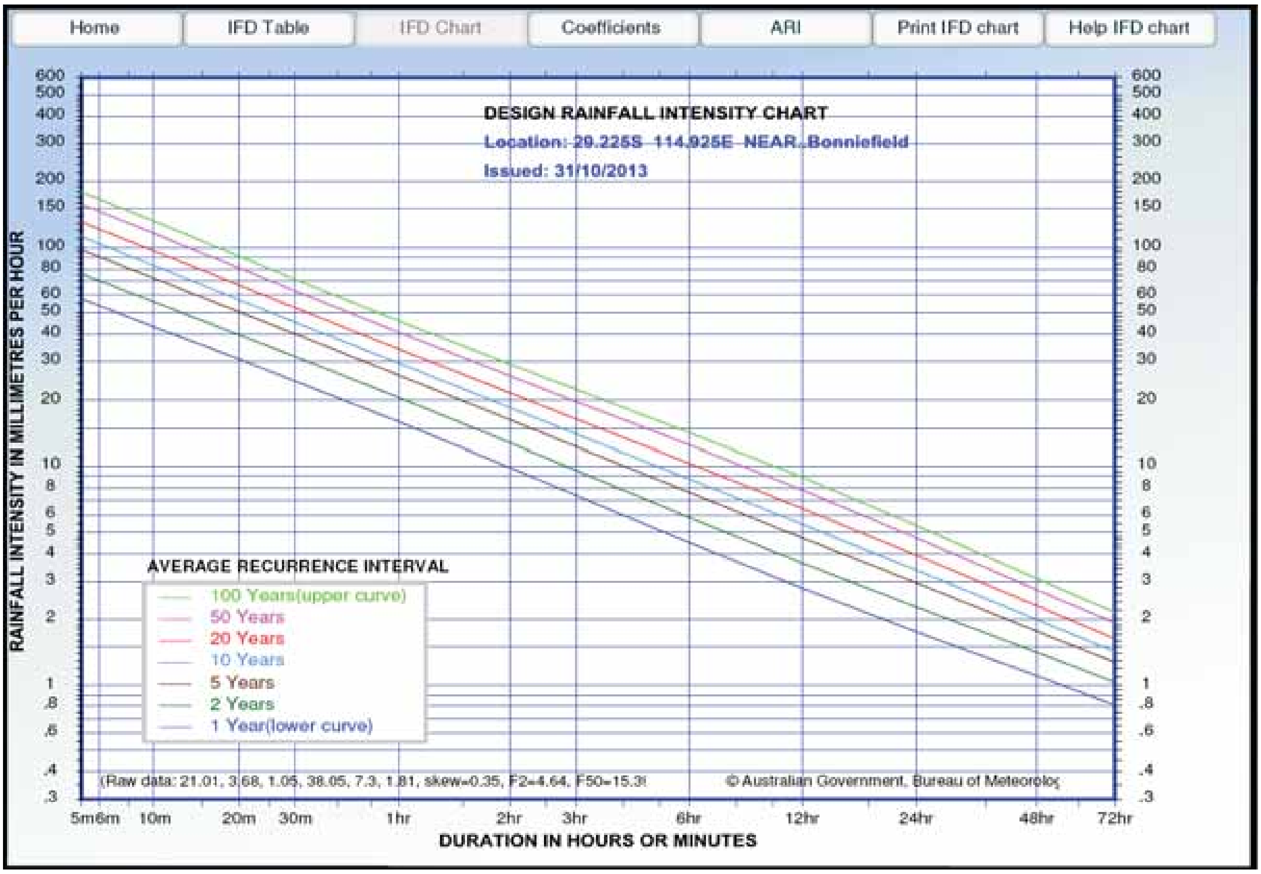
| | | | | |
|---|---|---|---|---|
| **By:** | John Rostom | | | |
| **Date:** | 31st October 2013 | | | |
| | | | | |
| **Source:** | Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System | | | |
| **Location:** | Bonniefield | | | |
| | | | *Latitude* | *Longitude* |
| **Inputs:** | **Geographic Coordinates:** | Decimal Degrees: | -29.22048° S | 114.92639° E |
| **IFD Tool Selection:** | **Geographic Coordinates:** | Decimal Degrees: | -29.225° S | 114.925° E |



## Design Intensity-Frequency-Duration (IFD) Rainfall Data

**By:** John Rostom
**Date:** 31st October 2013

**Source:** Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System
**Location:** Bonniefield



## Design Intensity-Frequency-Duration (IFD) Rainfall Data

**By:** John Rostom
**Date:** 31st October 2013

**Source:** Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System
**Location:** Bonniefield

### Polynomial Coefficients Table

Location: 29.225S 114.925E NEAR., Bonniefield Issued: 31/10/2013

List of coefficients to equations of the form

$$\log_e(I) = A + B \times (\log_e(T)) + C \times (\log_e(T))^2 + D \times (\log_e(T))^3 + E \times (\log_e(T))^4 + F \times (\log_e(T))^5 + G \times (\log_e(T))^6$$

T = Time in hours and I = Intensity in millimetres per hour

| YEARS | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | 2.7653331757 | -6.5761656E-1 | -4.6487994E-2 | 8.4572183E-3 | 2.0212787E-3 | -1.9751323E-4 | -6.0452916E-5 |
| 2 | 3.02054739 | -6.5514797E-1 | -4.2871047E-2 | 7.3963557E-3 | 1.7703272E-3 | -6.6952320E-5 | -7.8525030E-5 |
| 5 | 3.255695343 | -6.5385479E-1 | -3.2302871E-2 | 8.9688348E-3 | 2.8445110E-4 | -2.7972783E-4 | -4.1769400E-6 |
| 10 | 3.3803436756 | -6.5240002E-1 | -2.6748074E-2 | 9.2602381E-3 | -4.0829750E-4 | -3.2711477E-4 | 2.1444281E-5 |
| 20 | 3.5300955772 | -6.5121728E-1 | -2.1613294E-2 | 9.6158953E-3 | -1.0782350E-3 | -3.7923179E-4 | 4.7622714E-5 |
| 50 | 3.7057449818 | -6.4978689E-1 | -1.5788674E-2 | 9.9562742E-3 | -1.8504282E-3 | -4.3431760E-4 | 7.8021709E-5 |
| 100 | 3.8266773224 | -6.4937431E-1 | -1.1371864E-2 | 1.0492197E-2 | -2.4563114E-3 | -5.0131162E-4 | 1.0521018E-4 |

(Raw data: 21.01, 3.68, 1.05, 38.05, 7.3, 1.81, skew=0.35, F2=4.64, F50=15.39)



| ARI in years | coefficient A | coefficient B | coefficient C | coefficient D | coefficient E | coefficient F | coefficient G |
|---|---|---|---|---|---|---|---|
| 1 | 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |
| 2 | 3.0205473900E+00 | -6.5514797000E-01 | -4.2871047000E-02 | 7.3963557000E-03 | 1.7703272000E-03 | -6.6952320000E-05 | -7.8525030000E-05 |
| 5 | 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |
| 10 | 3.3803436756E+00 | -6.5240002000E-01 | -2.6748074000E-02 | 9.2602381000E-03 | -4.0829750000E-04 | -3.2711477000E-04 | 2.1444281000E-05 |
| 20 | 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |
| 50 | 3.7057449818E+00 | -6.4978689000E-01 | -1.5788674000E-02 | 9.9562742000E-03 | -1.8504282000E-03 | -4.3431760000E-04 | 7.8021709000E-05 |
| 100 | 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

## Design Intensity-Frequency-Duration (IFD) Rainfall Data

**By:** John Rostom
**Date:** 31st October 2013

**Source:** Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System
**Location:** Bonniefield

### Intensity-Frequency-Duration Table

Location: 29.225S 114.925E NEAR.. Bonniefield Issued: 31/10/2013

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

| | Average Recurrence Interval | | | | | | |
|---|---|---|---|---|---|---|---|
| Duration | 1 YEAR | 2 YEARS | 5 YEARS | 10 YEARS | 20 YEARS | 50 YEARS | 100 YEARS |
| 5Mins | 58.2 | 75.6 | 97.5 | 112 | 131 | 157 | 179 |
| 6Mins | 54.1 | 70.4 | 90.6 | 104 | 121 | 146 | 166 |
| 10Mins | 43.3 | 56.3 | 72.2 | 82.5 | 96.5 | 116 | 132 |
| 20Mins | 30.7 | 39.7 | 50.6 | 57.5 | 67.1 | 80.3 | 90.9 |
| 30Mins | 24.4 | 31.6 | 40.1 | 45.4 | 52.9 | 63.1 | 71.3 |
| 1Hr | 15.9 | 20.5 | 25.9 | 29.4 | 34.1 | 40.7 | 45.9 |
| 2Hrs | 9.88 | 12.8 | 16.3 | 18.5 | 21.6 | 25.8 | 29.2 |
| 3Hrs | 7.39 | 9.59 | 12.3 | 14.0 | 16.4 | 19.7 | 22.4 |
| 6Hrs | 4.49 | 5.85 | 7.61 | 8.75 | 10.3 | 12.5 | 14.2 |
| 12Hrs | 2.77 | 3.61 | 4.72 | 5.44 | 6.42 | 7.79 | 8.91 |
| 24Hrs | 1.75 | 2.27 | 2.93 | 3.35 | 3.92 | 4.72 | 5.37 |
| 48Hrs | 1.10 | 1.41 | 1.76 | 1.99 | 2.30 | 2.72 | 3.06 |
| 72Hrs | .809 | 1.03 | 1.27 | 1.42 | 1.63 | 1.92 | 2.15 |

(Raw data: 21.01, 3.68, 1.05, 38.05, 7.3, 1.81, skew=0.35, F2=4.64, F50=15.39)

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 1 | 0.02 | -4.094 | 100.3 | 107.9 | 173.8 | 206.5 | 252.6 | 319.1 | 386.4 |
| 2 | 0.03 | -3.401 | 81.3 | 100.3 | 135.9 | 156.5 | 184.7 | 224.1 | 258.1 |
| 3 | 0.05 | -2.996 | 70.6 | 90.2 | 118.0 | 135.3 | 158.8 | 191.5 | 218.6 |
| 4 | 0.07 | -2.708 | 63.5 | 82.1 | 106.2 | 121.7 | 142.6 | 171.8 | 195.6 |
| **5** | **0.08** | **-2.485** | **58.2** | **75.6** | **97.5** | **111.6** | **130.8** | **157.5** | **179.1** |
| **6** | **0.10** | **-2.303** | **54.1** | **70.4** | **90.6** | **103.6** | **121.4** | **146.1** | **166.1** |
| 7 | 0.12 | -2.148 | 50.7 | 66.0 | 84.8 | 97.0 | 113.7 | 136.8 | 155.4 |
| 8 | 0.13 | -2.015 | 47.9 | 62.3 | 80.0 | 91.5 | 107.1 | 128.8 | 146.4 |
| 9 | 0.15 | -1.897 | 45.4 | 59.1 | 75.9 | 86.7 | 101.5 | 122.0 | 138.6 |
| **10** | **0.17** | **-1.792** | **43.3** | **56.3** | **72.2** | **82.5** | **96.5** | **116.0** | **131.7** |
| 11 | 0.18 | -1.696 | 41.4 | 53.9 | 69.0 | 78.8 | 92.1 | 110.7 | 125.7 |
| 12 | 0.20 | -1.609 | 39.8 | 51.6 | 66.1 | 75.5 | 88.2 | 105.9 | 120.2 |
| 13 | 0.22 | -1.529 | 38.2 | 49.7 | 63.6 | 72.5 | 84.7 | 101.6 | 115.3 |
| 14 | 0.23 | -1.455 | 36.9 | 47.8 | 61.2 | 69.8 | 81.5 | 97.8 | 110.9 |
| 15 | 0.25 | -1.386 | 35.6 | 46.2 | 59.1 | 67.3 | 78.6 | 94.2 | 106.8 |
| 16 | 0.27 | -1.322 | 34.5 | 44.7 | 57.1 | 65.0 | 75.9 | 91.0 | 103.1 |
| 17 | 0.28 | -1.261 | 33.4 | 43.3 | 55.3 | 62.9 | 73.4 | 88.0 | 99.7 |
| 18 | 0.30 | -1.204 | 32.4 | 42.0 | 53.6 | 61.0 | 71.2 | 85.2 | 96.6 |
| 19 | 0.32 | -1.150 | 31.5 | 40.8 | 52.1 | 59.2 | 69.0 | 82.7 | 93.6 |
| **20** | **0.33** | **-1.099** | **30.7** | **39.7** | **50.6** | **57.5** | **67.1** | **80.3** | **90.9** |
| 21 | 0.35 | -1.050 | 29.9 | 38.7 | 49.2 | 56.0 | 65.2 | 78.1 | 88.4 |
| 22 | 0.37 | -1.003 | 29.1 | 37.7 | 48.0 | 54.5 | 63.5 | 76.0 | 86.0 |
| 23 | 0.38 | -0.959 | 28.4 | 36.8 | 46.8 | 53.1 | 61.9 | 74.0 | 83.8 |
| 24 | 0.40 | -0.916 | 27.8 | 35.9 | 45.7 | 51.9 | 60.4 | 72.2 | 81.7 |
| 25 | 0.42 | -0.875 | 27.1 | 35.1 | 44.6 | 50.6 | 59.0 | 70.5 | 79.7 |
| 26 | 0.43 | -0.836 | 26.5 | 34.3 | 43.6 | 49.5 | 57.6 | 68.8 | 77.8 |
| 27 | 0.45 | -0.799 | 26.0 | 33.6 | 42.6 | 48.4 | 56.3 | 67.3 | 76.1 |
| 28 | 0.47 | -0.762 | 25.4 | 32.9 | 41.7 | 47.4 | 55.1 | 65.8 | 74.4 |
| 29 | 0.48 | -0.727 | 24.9 | 32.2 | 40.9 | 46.4 | 54.0 | 64.4 | 72.8 |
| **30** | **0.50** | **-0.693** | **24.4** | **31.6** | **40.1** | **45.4** | **52.9** | **63.1** | **71.3** |
| 31 | 0.52 | -0.660 | 24.0 | 31.0 | 39.3 | 44.6 | 51.8 | 61.9 | 69.9 |
| 32 | 0.53 | -0.629 | 23.5 | 30.4 | 38.5 | 43.7 | 50.8 | 60.7 | 68.5 |
| 33 | 0.55 | -0.598 | 23.1 | 29.8 | 37.8 | 42.9 | 49.9 | 59.5 | 67.2 |
| 34 | 0.57 | -0.568 | 22.7 | 29.3 | 37.2 | 42.1 | 49.0 | 58.4 | 66.0 |
| 35 | 0.58 | -0.539 | 22.3 | 28.8 | 36.5 | 41.4 | 48.1 | 57.4 | 64.8 |
| 36 | 0.60 | -0.511 | 21.9 | 28.3 | 35.9 | 40.7 | 47.3 | 56.4 | 63.7 |
| 37 | 0.62 | -0.483 | 21.6 | 27.8 | 35.3 | 40.0 | 46.5 | 55.4 | 62.6 |
| 38 | 0.63 | -0.457 | 21.2 | 27.4 | 34.7 | 39.3 | 45.7 | 54.5 | 61.5 |
| 39 | 0.65 | -0.431 | 20.9 | 27.0 | 34.1 | 38.7 | 45.0 | 53.6 | 60.5 |
| 40 | 0.67 | -0.405 | 20.6 | 26.5 | 33.6 | 38.1 | 44.3 | 52.8 | 59.6 |
| 41 | 0.68 | -0.381 | 20.3 | 26.1 | 33.1 | 37.5 | 43.6 | 52.0 | 58.7 |
| 42 | 0.70 | -0.357 | 20.0 | 25.8 | 32.6 | 36.9 | 42.9 | 51.2 | 57.8 |
| 43 | 0.72 | -0.333 | 19.7 | 25.4 | 32.1 | 36.4 | 42.3 | 50.4 | 56.9 |
| 44 | 0.73 | -0.310 | 19.4 | 25.0 | 31.7 | 35.9 | 41.7 | 49.7 | 56.1 |
| 45 | 0.75 | -0.288 | 19.1 | 24.7 | 31.2 | 35.4 | 41.1 | 49.0 | 55.3 |
| 46 | 0.77 | -0.266 | 18.9 | 24.3 | 30.8 | 34.9 | 40.5 | 48.3 | 54.5 |
| 47 | 0.78 | -0.244 | 18.6 | 24.0 | 30.4 | 34.4 | 40.0 | 47.6 | 53.8 |
| 48 | 0.80 | -0.223 | 18.4 | 23.7 | 30.0 | 33.9 | 39.4 | 47.0 | 53.0 |
| 49 | 0.82 | -0.203 | 18.1 | 23.4 | 29.6 | 33.5 | 38.9 | 46.4 | 52.3 |
| 50 | 0.83 | -0.182 | 17.9 | 23.1 | 29.2 | 33.1 | 38.4 | 45.8 | 51.7 |
| 51 | 0.85 | -0.163 | 17.7 | 22.8 | 28.8 | 32.6 | 37.9 | 45.2 | 51.0 |
| 52 | 0.87 | -0.143 | 17.4 | 22.5 | 28.5 | 32.2 | 37.4 | 44.6 | 50.4 |
| 53 | 0.88 | -0.124 | 17.2 | 22.2 | 28.1 | 31.8 | 37.0 | 44.1 | 49.8 |
| 54 | 0.90 | -0.105 | 17.0 | 22.0 | 27.8 | 31.5 | 36.5 | 43.6 | 49.2 |
| 55 | 0.92 | -0.087 | 16.8 | 21.7 | 27.4 | 31.1 | 36.1 | 43.0 | 48.6 |
| 56 | 0.93 | -0.069 | 16.6 | 21.4 | 27.1 | 30.7 | 35.7 | 42.5 | 48.0 |
| 57 | 0.95 | -0.051 | 16.4 | 21.2 | 26.8 | 30.4 | 35.3 | 42.1 | 47.5 |
| 58 | 0.97 | -0.034 | 16.2 | 21.0 | 26.5 | 30.0 | 34.9 | 41.6 | 46.9 |
| 59 | 0.98 | -0.017 | 16.1 | 20.7 | 26.2 | 29.7 | 34.5 | 41.1 | 46.4 |
| **60** | **1.00** | **0.000** | **15.9** | **20.5** | **25.9** | **29.4** | **34.1** | **40.7** | **45.9** |
| 61 | 1.02 | 0.017 | 15.7 | 20.3 | 25.7 | 29.1 | 33.8 | 40.2 | 45.4 |
| 62 | 1.03 | 0.033 | 15.5 | 20.1 | 25.4 | 28.8 | 33.4 | 39.8 | 44.9 |
| 63 | 1.05 | 0.049 | 15.4 | 19.9 | 25.1 | 28.5 | 33.1 | 39.4 | 44.5 |
| 64 | 1.07 | 0.065 | 15.2 | 19.7 | 24.9 | 28.2 | 32.7 | 39.0 | 44.0 |
| 65 | 1.08 | 0.080 | 15.1 | 19.4 | 24.6 | 27.9 | 32.4 | 38.6 | 43.6 |
| 66 | 1.10 | 0.095 | 14.9 | 19.3 | 24.4 | 27.6 | 32.1 | 38.2 | 43.2 |
| 67 | 1.12 | 0.110 | 14.8 | 19.1 | 24.1 | 27.3 | 31.8 | 37.9 | 42.7 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 68 | 1.13 | 0.125 | 14.6 | 18.9 | 23.9 | 27.1 | 31.4 | 37.5 | 42.3 |
| 69 | 1.15 | 0.140 | 14.5 | 18.7 | 23.7 | 26.8 | 31.1 | 37.1 | 41.9 |
| 70 | 1.17 | 0.154 | 14.3 | 18.5 | 23.4 | 26.6 | 30.9 | 36.8 | 41.5 |
| 71 | 1.18 | 0.168 | 14.2 | 18.3 | 23.2 | 26.3 | 30.6 | 36.5 | 41.1 |
| 72 | 1.20 | 0.182 | 14.1 | 18.2 | 23.0 | 26.1 | 30.3 | 36.1 | 40.8 |
| 73 | 1.22 | 0.196 | 13.9 | 18.0 | 22.8 | 25.8 | 30.0 | 35.8 | 40.4 |
| 74 | 1.23 | 0.210 | 13.8 | 17.8 | 22.6 | 25.6 | 29.7 | 35.5 | 40.0 |
| 75 | 1.25 | 0.223 | 13.7 | 17.7 | 22.4 | 25.4 | 29.5 | 35.2 | 39.7 |
| 76 | 1.27 | 0.236 | 13.6 | 17.5 | 22.2 | 25.1 | 29.2 | 34.9 | 39.4 |
| 77 | 1.28 | 0.249 | 13.4 | 17.4 | 22.0 | 24.9 | 29.0 | 34.6 | 39.0 |
| 78 | 1.30 | 0.262 | 13.3 | 17.2 | 21.8 | 24.7 | 28.7 | 34.3 | 38.7 |
| 79 | 1.32 | 0.275 | 13.2 | 17.1 | 21.6 | 24.5 | 28.5 | 34.0 | 38.4 |
| 80 | 1.33 | 0.288 | 13.1 | 16.9 | 21.4 | 24.3 | 28.3 | 33.7 | 38.1 |
| 81 | 1.35 | 0.300 | 13.0 | 16.8 | 21.3 | 24.1 | 28.0 | 33.4 | 37.8 |
| 82 | 1.37 | 0.312 | 12.9 | 16.6 | 21.1 | 23.9 | 27.8 | 33.2 | 37.5 |
| 83 | 1.38 | 0.324 | 12.8 | 16.5 | 20.9 | 23.7 | 27.6 | 32.9 | 37.2 |
| 84 | 1.40 | 0.336 | 12.7 | 16.4 | 20.7 | 23.5 | 27.4 | 32.6 | 36.9 |
| 85 | 1.42 | 0.348 | 12.6 | 16.2 | 20.6 | 23.3 | 27.1 | 32.4 | 36.6 |
| 86 | 1.43 | 0.360 | 12.5 | 16.1 | 20.4 | 23.2 | 26.9 | 32.1 | 36.3 |
| 87 | 1.45 | 0.372 | 12.4 | 16.0 | 20.3 | 23.0 | 26.7 | 31.9 | 36.0 |
| 88 | 1.47 | 0.383 | 12.3 | 15.9 | 20.1 | 22.8 | 26.5 | 31.7 | 35.8 |
| 89 | 1.48 | 0.394 | 12.2 | 15.7 | 20.0 | 22.6 | 26.3 | 31.4 | 35.5 |
| 90 | 1.50 | 0.405 | 12.1 | 15.6 | 19.8 | 22.5 | 26.1 | 31.2 | 35.2 |
| 91 | 1.52 | 0.417 | 12.0 | 15.5 | 19.7 | 22.3 | 25.9 | 31.0 | 35.0 |
| 92 | 1.53 | 0.427 | 11.9 | 15.4 | 19.5 | 22.1 | 25.8 | 30.7 | 34.7 |
| 93 | 1.55 | 0.438 | 11.8 | 15.3 | 19.4 | 22.0 | 25.6 | 30.5 | 34.5 |
| 94 | 1.57 | 0.449 | 11.7 | 15.2 | 19.2 | 21.8 | 25.4 | 30.3 | 34.3 |
| 95 | 1.58 | 0.460 | 11.6 | 15.0 | 19.1 | 21.7 | 25.2 | 30.1 | 34.0 |
| 96 | 1.60 | 0.470 | 11.6 | 14.9 | 19.0 | 21.5 | 25.0 | 29.9 | 33.8 |
| 97 | 1.62 | 0.480 | 11.5 | 14.8 | 18.8 | 21.4 | 24.9 | 29.7 | 33.6 |
| 98 | 1.63 | 0.491 | 11.4 | 14.7 | 18.7 | 21.2 | 24.7 | 29.5 | 33.3 |
| 99 | 1.65 | 0.501 | 11.3 | 14.6 | 18.6 | 21.1 | 24.5 | 29.3 | 33.1 |
| 100 | 1.67 | 0.511 | 11.2 | 14.5 | 18.4 | 20.9 | 24.4 | 29.1 | 32.9 |
| 101 | 1.68 | 0.521 | 11.2 | 14.4 | 18.3 | 20.8 | 24.2 | 28.9 | 32.7 |
| 102 | 1.70 | 0.531 | 11.1 | 14.3 | 18.2 | 20.7 | 24.0 | 28.7 | 32.5 |
| 103 | 1.72 | 0.540 | 11.0 | 14.2 | 18.1 | 20.5 | 23.9 | 28.5 | 32.3 |
| 104 | 1.73 | 0.550 | 10.9 | 14.1 | 18.0 | 20.4 | 23.7 | 28.4 | 32.1 |
| 105 | 1.75 | 0.560 | 10.9 | 14.0 | 17.8 | 20.3 | 23.6 | 28.2 | 31.9 |
| 106 | 1.77 | 0.569 | 10.8 | 13.9 | 17.7 | 20.1 | 23.4 | 28.0 | 31.7 |
| 107 | 1.78 | 0.578 | 10.7 | 13.9 | 17.6 | 20.0 | 23.3 | 27.8 | 31.5 |
| 108 | 1.80 | 0.588 | 10.6 | 13.8 | 17.5 | 19.9 | 23.1 | 27.7 | 31.3 |
| 109 | 1.82 | 0.597 | 10.6 | 13.7 | 17.4 | 19.8 | 23.0 | 27.5 | 31.1 |
| 110 | 1.83 | 0.606 | 10.5 | 13.6 | 17.3 | 19.6 | 22.9 | 27.3 | 30.9 |
| 111 | 1.85 | 0.615 | 10.4 | 13.5 | 17.2 | 19.5 | 22.7 | 27.2 | 30.7 |
| 112 | 1.87 | 0.624 | 10.4 | 13.4 | 17.1 | 19.4 | 22.6 | 27.0 | 30.5 |
| 113 | 1.88 | 0.633 | 10.3 | 13.3 | 17.0 | 19.3 | 22.5 | 26.8 | 30.4 |
| 114 | 1.90 | 0.642 | 10.2 | 13.3 | 16.9 | 19.2 | 22.3 | 26.7 | 30.2 |
| 115 | 1.92 | 0.651 | 10.2 | 13.2 | 16.8 | 19.0 | 22.2 | 26.5 | 30.0 |
| 116 | 1.93 | 0.659 | 10.1 | 13.1 | 16.7 | 18.9 | 22.1 | 26.4 | 29.8 |
| 117 | 1.95 | 0.668 | 10.1 | 13.0 | 16.6 | 18.8 | 21.9 | 26.2 | 29.7 |
| 118 | 1.97 | 0.676 | 10.0 | 12.9 | 16.5 | 18.7 | 21.8 | 26.1 | 29.5 |
| 119 | 1.98 | 0.685 | 9.9 | 12.9 | 16.4 | 18.6 | 21.7 | 25.9 | 29.4 |
| 120 | 2.00 | 0.693 | 9.9 | 12.8 | 16.3 | 18.5 | 21.6 | 25.8 | 29.2 |
| 121 | 2.02 | 0.701 | 9.8 | 12.7 | 16.2 | 18.4 | 21.4 | 25.7 | 29.0 |
| 122 | 2.03 | 0.710 | 9.8 | 12.6 | 16.1 | 18.3 | 21.3 | 25.5 | 28.9 |
| 123 | 2.05 | 0.718 | 9.7 | 12.6 | 16.0 | 18.2 | 21.2 | 25.4 | 28.7 |
| 124 | 2.07 | 0.726 | 9.7 | 12.5 | 15.9 | 18.1 | 21.1 | 25.3 | 28.6 |
| 125 | 2.08 | 0.734 | 9.6 | 12.4 | 15.8 | 18.0 | 21.0 | 25.1 | 28.4 |
| 126 | 2.10 | 0.742 | 9.5 | 12.4 | 15.7 | 17.9 | 20.9 | 25.0 | 28.3 |
| 127 | 2.12 | 0.750 | 9.5 | 12.3 | 15.7 | 17.8 | 20.8 | 24.9 | 28.1 |
| 128 | 2.13 | 0.758 | 9.4 | 12.2 | 15.6 | 17.7 | 20.7 | 24.7 | 28.0 |
| 129 | 2.15 | 0.765 | 9.4 | 12.2 | 15.5 | 17.6 | 20.5 | 24.6 | 27.8 |
| 130 | 2.17 | 0.773 | 9.3 | 12.1 | 15.4 | 17.5 | 20.4 | 24.5 | 27.7 |
| 131 | 2.18 | 0.781 | 9.3 | 12.0 | 15.3 | 17.4 | 20.3 | 24.4 | 27.6 |
| 132 | 2.20 | 0.788 | 9.2 | 12.0 | 15.2 | 17.4 | 20.2 | 24.2 | 27.4 |
| 133 | 2.22 | 0.796 | 9.2 | 11.9 | 15.2 | 17.3 | 20.1 | 24.1 | 27.3 |
| 134 | 2.23 | 0.803 | 9.1 | 11.8 | 15.1 | 17.2 | 20.0 | 24.0 | 27.2 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 135 | 2.25 | 0.811 | 9.1 | 11.8 | 15.0 | 17.1 | 19.9 | 23.9 | 27.0 |
| 136 | 2.27 | 0.818 | 9.0 | 11.7 | 14.9 | 17.0 | 19.8 | 23.8 | 26.9 |
| 137 | 2.28 | 0.826 | 9.0 | 11.7 | 14.9 | 16.9 | 19.7 | 23.6 | 26.8 |
| 138 | 2.30 | 0.833 | 8.9 | 11.6 | 14.8 | 16.8 | 19.6 | 23.5 | 26.6 |
| 139 | 2.32 | 0.840 | 8.9 | 11.5 | 14.7 | 16.8 | 19.5 | 23.4 | 26.5 |
| 140 | 2.33 | 0.847 | 8.9 | 11.5 | 14.6 | 16.7 | 19.5 | 23.3 | 26.4 |
| 141 | 2.35 | 0.854 | 8.8 | 11.4 | 14.6 | 16.6 | 19.4 | 23.2 | 26.3 |
| 142 | 2.37 | 0.861 | 8.8 | 11.4 | 14.5 | 16.5 | 19.3 | 23.1 | 26.2 |
| 143 | 2.38 | 0.869 | 8.7 | 11.3 | 14.4 | 16.4 | 19.2 | 23.0 | 26.0 |
| 144 | 2.40 | 0.875 | 8.7 | 11.2 | 14.4 | 16.4 | 19.1 | 22.9 | 25.9 |
| 145 | 2.42 | 0.882 | 8.6 | 11.2 | 14.3 | 16.3 | 19.0 | 22.8 | 25.8 |
| 146 | 2.43 | 0.889 | 8.6 | 11.1 | 14.2 | 16.2 | 18.9 | 22.7 | 25.7 |
| 147 | 2.45 | 0.896 | 8.6 | 11.1 | 14.2 | 16.1 | 18.8 | 22.6 | 25.6 |
| 148 | 2.47 | 0.903 | 8.5 | 11.0 | 14.1 | 16.1 | 18.7 | 22.5 | 25.5 |
| 149 | 2.48 | 0.910 | 8.5 | 11.0 | 14.0 | 16.0 | 18.7 | 22.4 | 25.3 |
| 150 | 2.50 | 0.916 | 8.4 | 10.9 | 14.0 | 15.9 | 18.6 | 22.3 | 25.2 |
| 151 | 2.52 | 0.923 | 8.4 | 10.9 | 13.9 | 15.8 | 18.5 | 22.2 | 25.1 |
| 152 | 2.53 | 0.930 | 8.3 | 10.8 | 13.8 | 15.8 | 18.4 | 22.1 | 25.0 |
| 153 | 2.55 | 0.936 | 8.3 | 10.8 | 13.8 | 15.7 | 18.3 | 22.0 | 24.9 |
| 154 | 2.57 | 0.943 | 8.3 | 10.7 | 13.7 | 15.6 | 18.2 | 21.9 | 24.8 |
| 155 | 2.58 | 0.949 | 8.2 | 10.7 | 13.6 | 15.6 | 18.2 | 21.8 | 24.7 |
| 156 | 2.60 | 0.956 | 8.2 | 10.6 | 13.6 | 15.5 | 18.1 | 21.7 | 24.6 |
| 157 | 2.62 | 0.962 | 8.2 | 10.6 | 13.5 | 15.4 | 18.0 | 21.6 | 24.5 |
| 158 | 2.63 | 0.968 | 8.1 | 10.5 | 13.5 | 15.4 | 17.9 | 21.5 | 24.4 |
| 159 | 2.65 | 0.975 | 8.1 | 10.5 | 13.4 | 15.3 | 17.9 | 21.4 | 24.3 |
| 160 | 2.67 | 0.981 | 8.0 | 10.4 | 13.4 | 15.2 | 17.8 | 21.3 | 24.2 |
| 161 | 2.68 | 0.987 | 8.0 | 10.4 | 13.3 | 15.2 | 17.7 | 21.3 | 24.1 |
| 162 | 2.70 | 0.993 | 8.0 | 10.3 | 13.2 | 15.1 | 17.6 | 21.2 | 24.0 |
| 163 | 2.72 | 0.999 | 7.9 | 10.3 | 13.2 | 15.0 | 17.6 | 21.1 | 23.9 |
| 164 | 2.73 | 1.006 | 7.9 | 10.3 | 13.1 | 15.0 | 17.5 | 21.0 | 23.8 |
| 165 | 2.75 | 1.012 | 7.9 | 10.2 | 13.1 | 14.9 | 17.4 | 20.9 | 23.7 |
| 166 | 2.77 | 1.018 | 7.8 | 10.2 | 13.0 | 14.8 | 17.4 | 20.8 | 23.6 |
| 167 | 2.78 | 1.024 | 7.8 | 10.1 | 13.0 | 14.8 | 17.3 | 20.7 | 23.5 |
| 168 | 2.80 | 1.030 | 7.8 | 10.1 | 12.9 | 14.7 | 17.2 | 20.7 | 23.4 |
| 169 | 2.82 | 1.036 | 7.7 | 10.0 | 12.9 | 14.7 | 17.1 | 20.6 | 23.3 |
| 170 | 2.83 | 1.041 | 7.7 | 10.0 | 12.8 | 14.6 | 17.1 | 20.5 | 23.3 |
| 171 | 2.85 | 1.047 | 7.7 | 10.0 | 12.8 | 14.5 | 17.0 | 20.4 | 23.2 |
| 172 | 2.87 | 1.053 | 7.6 | 9.9 | 12.7 | 14.5 | 16.9 | 20.3 | 23.1 |
| 173 | 2.88 | 1.059 | 7.6 | 9.9 | 12.7 | 14.4 | 16.9 | 20.3 | 23.0 |
| 174 | 2.90 | 1.065 | 7.6 | 9.8 | 12.6 | 14.4 | 16.8 | 20.2 | 22.9 |
| 175 | 2.92 | 1.070 | 7.5 | 9.8 | 12.6 | 14.3 | 16.7 | 20.1 | 22.8 |
| 176 | 2.93 | 1.076 | 7.5 | 9.7 | 12.5 | 14.3 | 16.7 | 20.0 | 22.7 |
| 177 | 2.95 | 1.082 | 7.5 | 9.7 | 12.5 | 14.2 | 16.6 | 20.0 | 22.7 |
| 178 | 2.97 | 1.087 | 7.5 | 9.7 | 12.4 | 14.2 | 16.6 | 19.9 | 22.6 |
| 179 | 2.98 | 1.093 | 7.4 | 9.6 | 12.4 | 14.1 | 16.5 | 19.8 | 22.5 |
| **180** | **3.00** | **1.099** | **7.4** | **9.6** | **12.3** | **14.0** | **16.4** | **19.7** | **22.4** |
| 181 | 3.02 | 1.104 | 7.4 | 9.6 | 12.3 | 14.0 | 16.4 | 19.7 | 22.3 |
| 182 | 3.03 | 1.110 | 7.3 | 9.5 | 12.2 | 13.9 | 16.3 | 19.6 | 22.2 |
| 183 | 3.05 | 1.115 | 7.3 | 9.5 | 12.2 | 13.9 | 16.3 | 19.5 | 22.2 |
| 184 | 3.07 | 1.121 | 7.3 | 9.4 | 12.1 | 13.8 | 16.2 | 19.5 | 22.1 |
| 185 | 3.08 | 1.126 | 7.2 | 9.4 | 12.1 | 13.8 | 16.1 | 19.4 | 22.0 |
| 186 | 3.10 | 1.131 | 7.2 | 9.4 | 12.0 | 13.7 | 16.1 | 19.3 | 21.9 |
| 187 | 3.12 | 1.137 | 7.2 | 9.3 | 12.0 | 13.7 | 16.0 | 19.3 | 21.9 |
| 188 | 3.13 | 1.142 | 7.2 | 9.3 | 11.9 | 13.6 | 16.0 | 19.2 | 21.8 |
| 189 | 3.15 | 1.147 | 7.1 | 9.3 | 11.9 | 13.6 | 15.9 | 19.1 | 21.7 |
| 190 | 3.17 | 1.153 | 7.1 | 9.2 | 11.9 | 13.5 | 15.8 | 19.0 | 21.6 |
| 191 | 3.18 | 1.158 | 7.1 | 9.2 | 11.8 | 13.5 | 15.8 | 19.0 | 21.6 |
| 192 | 3.20 | 1.163 | 7.1 | 9.2 | 11.8 | 13.4 | 15.7 | 18.9 | 21.5 |
| 193 | 3.22 | 1.168 | 7.0 | 9.1 | 11.7 | 13.4 | 15.7 | 18.9 | 21.4 |
| 194 | 3.23 | 1.174 | 7.0 | 9.1 | 11.7 | 13.3 | 15.6 | 18.8 | 21.3 |
| 195 | 3.25 | 1.179 | 7.0 | 9.1 | 11.6 | 13.3 | 15.6 | 18.7 | 21.3 |
| 196 | 3.27 | 1.184 | 7.0 | 9.0 | 11.6 | 13.3 | 15.5 | 18.7 | 21.2 |
| 197 | 3.28 | 1.189 | 6.9 | 9.0 | 11.6 | 13.2 | 15.5 | 18.6 | 21.1 |
| 198 | 3.30 | 1.194 | 6.9 | 9.0 | 11.5 | 13.2 | 15.4 | 18.5 | 21.1 |
| 199 | 3.32 | 1.199 | 6.9 | 8.9 | 11.5 | 13.1 | 15.4 | 18.5 | 21.0 |
| 200 | 3.33 | 1.204 | 6.9 | 8.9 | 11.4 | 13.1 | 15.3 | 18.4 | 20.9 |
| 201 | 3.35 | 1.209 | 6.8 | 8.9 | 11.4 | 13.0 | 15.3 | 18.4 | 20.8 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 202 | 3.37 | 1.214 | 6.8 | 8.8 | 11.4 | 13.0 | 15.2 | 18.3 | 20.8 |
| 203 | 3.38 | 1.219 | 6.8 | 8.8 | 11.3 | 12.9 | 15.2 | 18.2 | 20.7 |
| 204 | 3.40 | 1.224 | 6.8 | 8.8 | 11.3 | 12.9 | 15.1 | 18.2 | 20.6 |
| 205 | 3.42 | 1.229 | 6.7 | 8.7 | 11.2 | 12.9 | 15.1 | 18.1 | 20.6 |
| 206 | 3.43 | 1.234 | 6.7 | 8.7 | 11.2 | 12.8 | 15.0 | 18.1 | 20.5 |
| 207 | 3.45 | 1.238 | 6.7 | 8.7 | 11.2 | 12.8 | 15.0 | 18.0 | 20.5 |
| 208 | 3.47 | 1.243 | 6.7 | 8.7 | 11.1 | 12.7 | 14.9 | 17.9 | 20.4 |
| 209 | 3.48 | 1.248 | 6.6 | 8.6 | 11.1 | 12.7 | 14.9 | 17.9 | 20.3 |
| 210 | 3.50 | 1.253 | 6.6 | 8.6 | 11.1 | 12.6 | 14.8 | 17.8 | 20.3 |
| 211 | 3.52 | 1.258 | 6.6 | 8.6 | 11.0 | 12.6 | 14.8 | 17.8 | 20.2 |
| 212 | 3.53 | 1.262 | 6.6 | 8.5 | 11.0 | 12.6 | 14.7 | 17.7 | 20.1 |
| 213 | 3.55 | 1.267 | 6.5 | 8.5 | 11.0 | 12.5 | 14.7 | 17.7 | 20.1 |
| 214 | 3.57 | 1.272 | 6.5 | 8.5 | 10.9 | 12.5 | 14.6 | 17.6 | 20.0 |
| 215 | 3.58 | 1.276 | 6.5 | 8.4 | 10.9 | 12.4 | 14.6 | 17.6 | 20.0 |
| 216 | 3.60 | 1.281 | 6.5 | 8.4 | 10.8 | 12.4 | 14.5 | 17.5 | 19.9 |
| 217 | 3.62 | 1.286 | 6.5 | 8.4 | 10.8 | 12.4 | 14.5 | 17.4 | 19.8 |
| 218 | 3.63 | 1.290 | 6.4 | 8.4 | 10.8 | 12.3 | 14.4 | 17.4 | 19.8 |
| 219 | 3.65 | 1.295 | 6.4 | 8.3 | 10.7 | 12.3 | 14.4 | 17.3 | 19.7 |
| 220 | 3.67 | 1.299 | 6.4 | 8.3 | 10.7 | 12.3 | 14.4 | 17.3 | 19.7 |
| 221 | 3.68 | 1.304 | 6.4 | 8.3 | 10.7 | 12.2 | 14.3 | 17.2 | 19.6 |
| 222 | 3.70 | 1.308 | 6.4 | 8.3 | 10.6 | 12.2 | 14.3 | 17.2 | 19.5 |
| 223 | 3.72 | 1.313 | 6.3 | 8.2 | 10.6 | 12.1 | 14.2 | 17.1 | 19.5 |
| 224 | 3.73 | 1.317 | 6.3 | 8.2 | 10.6 | 12.1 | 14.2 | 17.1 | 19.4 |
| 225 | 3.75 | 1.322 | 6.3 | 8.2 | 10.5 | 12.1 | 14.1 | 17.0 | 19.4 |
| 226 | 3.77 | 1.326 | 6.3 | 8.2 | 10.5 | 12.0 | 14.1 | 17.0 | 19.3 |
| 227 | 3.78 | 1.331 | 6.3 | 8.1 | 10.5 | 12.0 | 14.1 | 16.9 | 19.3 |
| 228 | 3.80 | 1.335 | 6.2 | 8.1 | 10.4 | 12.0 | 14.0 | 16.9 | 19.2 |
| 229 | 3.82 | 1.339 | 6.2 | 8.1 | 10.4 | 11.9 | 14.0 | 16.8 | 19.1 |
| 230 | 3.83 | 1.344 | 6.2 | 8.1 | 10.4 | 11.9 | 13.9 | 16.8 | 19.1 |
| 231 | 3.85 | 1.348 | 6.2 | 8.0 | 10.4 | 11.8 | 13.9 | 16.7 | 19.0 |
| 232 | 3.87 | 1.352 | 6.2 | 8.0 | 10.3 | 11.8 | 13.9 | 16.7 | 19.0 |
| 233 | 3.88 | 1.357 | 6.1 | 8.0 | 10.3 | 11.8 | 13.8 | 16.6 | 18.9 |
| 234 | 3.90 | 1.361 | 6.1 | 8.0 | 10.3 | 11.7 | 13.8 | 16.6 | 18.9 |
| 235 | 3.92 | 1.365 | 6.1 | 7.9 | 10.2 | 11.7 | 13.7 | 16.6 | 18.8 |
| 236 | 3.93 | 1.369 | 6.1 | 7.9 | 10.2 | 11.7 | 13.7 | 16.5 | 18.8 |
| 237 | 3.95 | 1.374 | 6.1 | 7.9 | 10.2 | 11.6 | 13.7 | 16.5 | 18.7 |
| 238 | 3.97 | 1.378 | 6.0 | 7.9 | 10.1 | 11.6 | 13.6 | 16.4 | 18.7 |
| 239 | 3.98 | 1.382 | 6.0 | 7.8 | 10.1 | 11.6 | 13.6 | 16.4 | 18.6 |
| 240 | 4.00 | 1.386 | 6.0 | 7.8 | 10.1 | 11.5 | 13.5 | 16.3 | 18.6 |
| 241 | 4.02 | 1.390 | 6.0 | 7.8 | 10.1 | 11.5 | 13.5 | 16.3 | 18.5 |
| 242 | 4.03 | 1.395 | 6.0 | 7.8 | 10.0 | 11.5 | 13.5 | 16.2 | 18.5 |
| 243 | 4.05 | 1.399 | 6.0 | 7.7 | 10.0 | 11.4 | 13.4 | 16.2 | 18.4 |
| 244 | 4.07 | 1.403 | 5.9 | 7.7 | 10.0 | 11.4 | 13.4 | 16.1 | 18.4 |
| 245 | 4.08 | 1.407 | 5.9 | 7.7 | 9.9 | 11.4 | 13.4 | 16.1 | 18.3 |
| 246 | 4.10 | 1.411 | 5.9 | 7.7 | 9.9 | 11.4 | 13.3 | 16.1 | 18.3 |
| 247 | 4.12 | 1.415 | 5.9 | 7.6 | 9.9 | 11.3 | 13.3 | 16.0 | 18.2 |
| 248 | 4.13 | 1.419 | 5.9 | 7.6 | 9.9 | 11.3 | 13.2 | 16.0 | 18.2 |
| 249 | 4.15 | 1.423 | 5.8 | 7.6 | 9.8 | 11.3 | 13.2 | 15.9 | 18.1 |
| 250 | 4.17 | 1.427 | 5.8 | 7.6 | 9.8 | 11.2 | 13.2 | 15.9 | 18.1 |
| 251 | 4.18 | 1.431 | 5.8 | 7.6 | 9.8 | 11.2 | 13.1 | 15.8 | 18.0 |
| 252 | 4.20 | 1.435 | 5.8 | 7.5 | 9.7 | 11.2 | 13.1 | 15.8 | 18.0 |
| 253 | 4.22 | 1.439 | 5.8 | 7.5 | 9.7 | 11.1 | 13.1 | 15.8 | 17.9 |
| 254 | 4.23 | 1.443 | 5.8 | 7.5 | 9.7 | 11.1 | 13.0 | 15.7 | 17.9 |
| 255 | 4.25 | 1.447 | 5.7 | 7.5 | 9.7 | 11.1 | 13.0 | 15.7 | 17.9 |
| 256 | 4.27 | 1.451 | 5.7 | 7.5 | 9.6 | 11.0 | 13.0 | 15.6 | 17.8 |
| 257 | 4.28 | 1.455 | 5.7 | 7.4 | 9.6 | 11.0 | 12.9 | 15.6 | 17.8 |
| 258 | 4.30 | 1.459 | 5.7 | 7.4 | 9.6 | 11.0 | 12.9 | 15.6 | 17.7 |
| 259 | 4.32 | 1.462 | 5.7 | 7.4 | 9.6 | 11.0 | 12.9 | 15.5 | 17.7 |
| 260 | 4.33 | 1.466 | 5.7 | 7.4 | 9.5 | 10.9 | 12.8 | 15.5 | 17.6 |
| 261 | 4.35 | 1.470 | 5.7 | 7.4 | 9.5 | 10.9 | 12.8 | 15.4 | 17.6 |
| 262 | 4.37 | 1.474 | 5.6 | 7.3 | 9.5 | 10.9 | 12.8 | 15.4 | 17.5 |
| 263 | 4.38 | 1.478 | 5.6 | 7.3 | 9.5 | 10.8 | 12.7 | 15.4 | 17.5 |
| 264 | 4.40 | 1.482 | 5.6 | 7.3 | 9.4 | 10.8 | 12.7 | 15.3 | 17.5 |
| 265 | 4.42 | 1.485 | 5.6 | 7.3 | 9.4 | 10.8 | 12.7 | 15.3 | 17.4 |
| 266 | 4.43 | 1.489 | 5.6 | 7.3 | 9.4 | 10.8 | 12.6 | 15.2 | 17.4 |
| 267 | 4.45 | 1.493 | 5.6 | 7.2 | 9.4 | 10.7 | 12.6 | 15.2 | 17.3 |
| 268 | 4.47 | 1.497 | 5.5 | 7.2 | 9.3 | 10.7 | 12.6 | 15.2 | 17.3 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 269 | 4.48 | 1.500 | 5.5 | 7.2 | 9.3 | 10.7 | 12.5 | 15.1 | 17.2 |
| 270 | 4.50 | 1.504 | 5.5 | 7.2 | 9.3 | 10.7 | 12.5 | 15.1 | 17.2 |
| 271 | 4.52 | 1.508 | 5.5 | 7.2 | 9.3 | 10.6 | 12.5 | 15.1 | 17.2 |
| 272 | 4.53 | 1.511 | 5.5 | 7.1 | 9.2 | 10.6 | 12.4 | 15.0 | 17.1 |
| 273 | 4.55 | 1.515 | 5.5 | 7.1 | 9.2 | 10.6 | 12.4 | 15.0 | 17.1 |
| 274 | 4.57 | 1.519 | 5.5 | 7.1 | 9.2 | 10.5 | 12.4 | 15.0 | 17.0 |
| 275 | 4.58 | 1.522 | 5.4 | 7.1 | 9.2 | 10.5 | 12.4 | 14.9 | 17.0 |
| 276 | 4.60 | 1.526 | 5.4 | 7.1 | 9.1 | 10.5 | 12.3 | 14.9 | 17.0 |
| 277 | 4.62 | 1.530 | 5.4 | 7.0 | 9.1 | 10.5 | 12.3 | 14.8 | 16.9 |
| 278 | 4.63 | 1.533 | 5.4 | 7.0 | 9.1 | 10.4 | 12.3 | 14.8 | 16.9 |
| 279 | 4.65 | 1.537 | 5.4 | 7.0 | 9.1 | 10.4 | 12.2 | 14.8 | 16.8 |
| 280 | 4.67 | 1.540 | 5.4 | 7.0 | 9.1 | 10.4 | 12.2 | 14.7 | 16.8 |
| 281 | 4.68 | 1.544 | 5.4 | 7.0 | 9.0 | 10.4 | 12.2 | 14.7 | 16.8 |
| 282 | 4.70 | 1.548 | 5.3 | 7.0 | 9.0 | 10.3 | 12.1 | 14.7 | 16.7 |
| 283 | 4.72 | 1.551 | 5.3 | 6.9 | 9.0 | 10.3 | 12.1 | 14.6 | 16.7 |
| 284 | 4.73 | 1.555 | 5.3 | 6.9 | 9.0 | 10.3 | 12.1 | 14.6 | 16.6 |
| 285 | 4.75 | 1.558 | 5.3 | 6.9 | 8.9 | 10.3 | 12.1 | 14.6 | 16.6 |
| 286 | 4.77 | 1.562 | 5.3 | 6.9 | 8.9 | 10.2 | 12.0 | 14.5 | 16.6 |
| 287 | 4.78 | 1.565 | 5.3 | 6.9 | 8.9 | 10.2 | 12.0 | 14.5 | 16.5 |
| 288 | 4.80 | 1.569 | 5.3 | 6.9 | 8.9 | 10.2 | 12.0 | 14.5 | 16.5 |
| 289 | 4.82 | 1.572 | 5.3 | 6.8 | 8.9 | 10.2 | 12.0 | 14.4 | 16.4 |
| 290 | 4.83 | 1.576 | 5.2 | 6.8 | 8.8 | 10.1 | 11.9 | 14.4 | 16.4 |
| 291 | 4.85 | 1.579 | 5.2 | 6.8 | 8.8 | 10.1 | 11.9 | 14.4 | 16.4 |
| 292 | 4.87 | 1.582 | 5.2 | 6.8 | 8.8 | 10.1 | 11.9 | 14.3 | 16.3 |
| 293 | 4.88 | 1.586 | 5.2 | 6.8 | 8.8 | 10.1 | 11.8 | 14.3 | 16.3 |
| 294 | 4.90 | 1.589 | 5.2 | 6.8 | 8.8 | 10.0 | 11.8 | 14.3 | 16.3 |
| 295 | 4.92 | 1.593 | 5.2 | 6.7 | 8.7 | 10.0 | 11.8 | 14.2 | 16.2 |
| 296 | 4.93 | 1.596 | 5.2 | 6.7 | 8.7 | 10.0 | 11.8 | 14.2 | 16.2 |
| 297 | 4.95 | 1.599 | 5.2 | 6.7 | 8.7 | 10.0 | 11.7 | 14.2 | 16.2 |
| 298 | 4.97 | 1.603 | 5.1 | 6.7 | 8.7 | 10.0 | 11.7 | 14.1 | 16.1 |
| 299 | 4.98 | 1.606 | 5.1 | 6.7 | 8.7 | 9.9 | 11.7 | 14.1 | 16.1 |
| 300 | 5.00 | 1.609 | 5.1 | 6.7 | 8.6 | 9.9 | 11.7 | 14.1 | 16.1 |
| 301 | 5.02 | 1.613 | 5.1 | 6.6 | 8.6 | 9.9 | 11.6 | 14.0 | 16.0 |
| 302 | 5.03 | 1.616 | 5.1 | 6.6 | 8.6 | 9.9 | 11.6 | 14.0 | 16.0 |
| 303 | 5.05 | 1.619 | 5.1 | 6.6 | 8.6 | 9.8 | 11.6 | 14.0 | 15.9 |
| 304 | 5.07 | 1.623 | 5.1 | 6.6 | 8.6 | 9.8 | 11.5 | 14.0 | 15.9 |
| 305 | 5.08 | 1.626 | 5.1 | 6.6 | 8.5 | 9.8 | 11.5 | 13.9 | 15.9 |
| 306 | 5.10 | 1.629 | 5.0 | 6.6 | 8.5 | 9.8 | 11.5 | 13.9 | 15.8 |
| 307 | 5.12 | 1.633 | 5.0 | 6.5 | 8.5 | 9.8 | 11.5 | 13.9 | 15.8 |
| 308 | 5.13 | 1.636 | 5.0 | 6.5 | 8.5 | 9.7 | 11.4 | 13.8 | 15.8 |
| 309 | 5.15 | 1.639 | 5.0 | 6.5 | 8.5 | 9.7 | 11.4 | 13.8 | 15.7 |
| 310 | 5.17 | 1.642 | 5.0 | 6.5 | 8.4 | 9.7 | 11.4 | 13.8 | 15.7 |
| 311 | 5.18 | 1.645 | 5.0 | 6.5 | 8.4 | 9.7 | 11.4 | 13.7 | 15.7 |
| 312 | 5.20 | 1.649 | 5.0 | 6.5 | 8.4 | 9.7 | 11.3 | 13.7 | 15.6 |
| 313 | 5.22 | 1.652 | 5.0 | 6.5 | 8.4 | 9.6 | 11.3 | 13.7 | 15.6 |
| 314 | 5.23 | 1.655 | 5.0 | 6.4 | 8.4 | 9.6 | 11.3 | 13.7 | 15.6 |
| 315 | 5.25 | 1.658 | 4.9 | 6.4 | 8.3 | 9.6 | 11.3 | 13.6 | 15.5 |
| 316 | 5.27 | 1.661 | 4.9 | 6.4 | 8.3 | 9.6 | 11.3 | 13.6 | 15.5 |
| 317 | 5.28 | 1.665 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.6 | 15.5 |
| 318 | 5.30 | 1.668 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.5 | 15.4 |
| 319 | 5.32 | 1.671 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.5 | 15.4 |
| 320 | 5.33 | 1.674 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.5 | 15.4 |
| 321 | 5.35 | 1.677 | 4.9 | 6.3 | 8.2 | 9.5 | 11.1 | 13.5 | 15.4 |
| 322 | 5.37 | 1.680 | 4.9 | 6.3 | 8.2 | 9.4 | 11.1 | 13.4 | 15.3 |
| 323 | 5.38 | 1.683 | 4.9 | 6.3 | 8.2 | 9.4 | 11.1 | 13.4 | 15.3 |
| 324 | 5.40 | 1.686 | 4.8 | 6.3 | 8.2 | 9.4 | 11.1 | 13.4 | 15.3 |
| 325 | 5.42 | 1.689 | 4.8 | 6.3 | 8.2 | 9.4 | 11.0 | 13.4 | 15.2 |
| 326 | 5.43 | 1.693 | 4.8 | 6.3 | 8.2 | 9.4 | 11.0 | 13.3 | 15.2 |
| 327 | 5.45 | 1.696 | 4.8 | 6.3 | 8.1 | 9.3 | 11.0 | 13.3 | 15.2 |
| 328 | 5.47 | 1.699 | 4.8 | 6.2 | 8.1 | 9.3 | 11.0 | 13.3 | 15.1 |
| 329 | 5.48 | 1.702 | 4.8 | 6.2 | 8.1 | 9.3 | 11.0 | 13.2 | 15.1 |
| 330 | 5.50 | 1.705 | 4.8 | 6.2 | 8.1 | 9.3 | 10.9 | 13.2 | 15.1 |
| 331 | 5.52 | 1.708 | 4.8 | 6.2 | 8.1 | 9.3 | 10.9 | 13.2 | 15.0 |
| 332 | 5.53 | 1.711 | 4.8 | 6.2 | 8.1 | 9.2 | 10.9 | 13.2 | 15.0 |
| 333 | 5.55 | 1.714 | 4.7 | 6.2 | 8.0 | 9.2 | 10.9 | 13.1 | 15.0 |
| 334 | 5.57 | 1.717 | 4.7 | 6.2 | 8.0 | 9.2 | 10.8 | 13.1 | 15.0 |
| 335 | 5.58 | 1.720 | 4.7 | 6.2 | 8.0 | 9.2 | 10.8 | 13.1 | 14.9 |

| Duration, T (minutes) | Duration, T (hours) | *ln* T | Design Average Rainfall Intensities (mm/hr) ARI (yrs): 1 | 2 | 5 | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| 336 | 5.60 | 1.723 | 4.7 | 6.1 | 8.0 | 9.2 | 10.8 | 13.1 | 14.9 |
| 337 | 5.62 | 1.726 | 4.7 | 6.1 | 8.0 | 9.2 | 10.8 | 13.0 | 14.9 |
| 338 | 5.63 | 1.729 | 4.7 | 6.1 | 8.0 | 9.1 | 10.8 | 13.0 | 14.8 |
| 339 | 5.65 | 1.732 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 13.0 | 14.8 |
| 340 | 5.67 | 1.735 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 13.0 | 14.8 |
| 341 | 5.68 | 1.738 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 12.9 | 14.8 |
| 342 | 5.70 | 1.740 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 12.9 | 14.7 |
| 343 | 5.72 | 1.743 | 4.6 | 6.1 | 7.9 | 9.0 | 10.6 | 12.9 | 14.7 |
| 344 | 5.73 | 1.746 | 4.6 | 6.0 | 7.9 | 9.0 | 10.6 | 12.9 | 14.7 |
| 345 | 5.75 | 1.749 | 4.6 | 6.0 | 7.8 | 9.0 | 10.6 | 12.8 | 14.6 |
| 346 | 5.77 | 1.752 | 4.6 | 6.0 | 7.8 | 9.0 | 10.6 | 12.8 | 14.6 |
| 347 | 5.78 | 1.755 | 4.6 | 6.0 | 7.8 | 9.0 | 10.6 | 12.8 | 14.6 |
| 348 | 5.80 | 1.758 | 4.6 | 6.0 | 7.8 | 9.0 | 10.5 | 12.8 | 14.6 |
| 349 | 5.82 | 1.761 | 4.6 | 6.0 | 7.8 | 8.9 | 10.5 | 12.7 | 14.5 |
| 350 | 5.83 | 1.764 | 4.6 | 6.0 | 7.8 | 8.9 | 10.5 | 12.7 | 14.5 |
| 351 | 5.85 | 1.766 | 4.6 | 6.0 | 7.7 | 8.9 | 10.5 | 12.7 | 14.5 |
| 352 | 5.87 | 1.769 | 4.6 | 5.9 | 7.7 | 8.9 | 10.5 | 12.7 | 14.5 |
| 353 | 5.88 | 1.772 | 4.6 | 5.9 | 7.7 | 8.9 | 10.4 | 12.6 | 14.4 |
| 354 | 5.90 | 1.775 | 4.5 | 5.9 | 7.7 | 8.9 | 10.4 | 12.6 | 14.4 |
| 355 | 5.92 | 1.778 | 4.5 | 5.9 | 7.7 | 8.8 | 10.4 | 12.6 | 14.4 |
| 356 | 5.93 | 1.781 | 4.5 | 5.9 | 7.7 | 8.8 | 10.4 | 12.6 | 14.3 |
| 357 | 5.95 | 1.783 | 4.5 | 5.9 | 7.7 | 8.8 | 10.4 | 12.5 | 14.3 |
| 358 | 5.97 | 1.786 | 4.5 | 5.9 | 7.6 | 8.8 | 10.3 | 12.5 | 14.3 |
| 359 | 5.98 | 1.789 | 4.5 | 5.9 | 7.6 | 8.8 | 10.3 | 12.5 | 14.3 |
| **360** | **6.00** | **1.792** | **4.5** | **5.8** | **7.6** | **8.8** | **10.3** | **12.5** | **14.2** |
| 361 | 6.02 | 1.795 | 4.5 | 5.8 | 7.6 | 8.7 | 10.3 | 12.4 | 14.2 |
| 362 | 6.03 | 1.797 | 4.5 | 5.8 | 7.6 | 8.7 | 10.3 | 12.4 | 14.2 |
| 363 | 6.05 | 1.800 | 4.5 | 5.8 | 7.6 | 8.7 | 10.2 | 12.4 | 14.2 |
| 364 | 6.07 | 1.803 | 4.5 | 5.8 | 7.6 | 8.7 | 10.2 | 12.4 | 14.1 |
| 365 | 6.08 | 1.806 | 4.4 | 5.8 | 7.5 | 8.7 | 10.2 | 12.4 | 14.1 |
| 366 | 6.10 | 1.808 | 4.4 | 5.8 | 7.5 | 8.7 | 10.2 | 12.3 | 14.1 |
| 367 | 6.12 | 1.811 | 4.4 | 5.8 | 7.5 | 8.6 | 10.2 | 12.3 | 14.1 |
| 368 | 6.13 | 1.814 | 4.4 | 5.8 | 7.5 | 8.6 | 10.2 | 12.3 | 14.0 |
| 369 | 6.15 | 1.816 | 4.4 | 5.7 | 7.5 | 8.6 | 10.1 | 12.3 | 14.0 |
| 370 | 6.17 | 1.819 | 4.4 | 5.7 | 7.5 | 8.6 | 10.1 | 12.2 | 14.0 |
| 371 | 6.18 | 1.822 | 4.4 | 5.7 | 7.5 | 8.6 | 10.1 | 12.2 | 14.0 |
| 372 | 6.20 | 1.825 | 4.4 | 5.7 | 7.4 | 8.6 | 10.1 | 12.2 | 13.9 |
| 373 | 6.22 | 1.827 | 4.4 | 5.7 | 7.4 | 8.5 | 10.1 | 12.2 | 13.9 |
| 374 | 6.23 | 1.830 | 4.4 | 5.7 | 7.4 | 8.5 | 10.0 | 12.2 | 13.9 |
| 375 | 6.25 | 1.833 | 4.4 | 5.7 | 7.4 | 8.5 | 10.0 | 12.1 | 13.9 |
| 376 | 6.27 | 1.835 | 4.4 | 5.7 | 7.4 | 8.5 | 10.0 | 12.1 | 13.8 |
| 377 | 6.28 | 1.838 | 4.3 | 5.7 | 7.4 | 8.5 | 10.0 | 12.1 | 13.8 |
| 378 | 6.30 | 1.841 | 4.3 | 5.6 | 7.4 | 8.5 | 10.0 | 12.1 | 13.8 |
| 379 | 6.32 | 1.843 | 4.3 | 5.6 | 7.3 | 8.4 | 10.0 | 12.1 | 13.8 |
| 380 | 6.33 | 1.846 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 381 | 6.35 | 1.848 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 382 | 6.37 | 1.851 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 383 | 6.38 | 1.854 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 384 | 6.40 | 1.856 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 11.9 | 13.6 |
| 385 | 6.42 | 1.859 | 4.3 | 5.6 | 7.3 | 8.4 | 9.8 | 11.9 | 13.6 |
| 386 | 6.43 | 1.861 | 4.3 | 5.6 | 7.3 | 8.3 | 9.8 | 11.9 | 13.6 |
| 387 | 6.45 | 1.864 | 4.3 | 5.6 | 7.2 | 8.3 | 9.8 | 11.9 | 13.6 |
| 388 | 6.47 | 1.867 | 4.3 | 5.5 | 7.2 | 8.3 | 9.8 | 11.9 | 13.6 |
| 389 | 6.48 | 1.869 | 4.2 | 5.5 | 7.2 | 8.3 | 9.8 | 11.8 | 13.5 |
| 390 | 6.50 | 1.872 | 4.2 | 5.5 | 7.2 | 8.3 | 9.8 | 11.8 | 13.5 |
| 391 | 6.52 | 1.874 | 4.2 | 5.5 | 7.2 | 8.3 | 9.7 | 11.8 | 13.5 |
| 392 | 6.53 | 1.877 | 4.2 | 5.5 | 7.2 | 8.3 | 9.7 | 11.8 | 13.5 |
| 393 | 6.55 | 1.879 | 4.2 | 5.5 | 7.2 | 8.2 | 9.7 | 11.8 | 13.4 |
| 394 | 6.57 | 1.882 | 4.2 | 5.5 | 7.2 | 8.2 | 9.7 | 11.7 | 13.4 |
| 395 | 6.58 | 1.885 | 4.2 | 5.5 | 7.1 | 8.2 | 9.7 | 11.7 | 13.4 |
| 396 | 6.60 | 1.887 | 4.2 | 5.5 | 7.1 | 8.2 | 9.7 | 11.7 | 13.4 |
| 397 | 6.62 | 1.890 | 4.2 | 5.5 | 7.1 | 8.2 | 9.6 | 11.7 | 13.3 |
| 398 | 6.63 | 1.892 | 4.2 | 5.4 | 7.1 | 8.2 | 9.6 | 11.7 | 13.3 |
| 399 | 6.65 | 1.895 | 4.2 | 5.4 | 7.1 | 8.2 | 9.6 | 11.6 | 13.3 |
| 400 | 6.67 | 1.897 | 4.2 | 5.4 | 7.1 | 8.1 | 9.6 | 11.6 | 13.3 |
| 401 | 6.68 | 1.900 | 4.2 | 5.4 | 7.1 | 8.1 | 9.6 | 11.6 | 13.3 |
| 402 | 6.70 | 1.902 | 4.2 | 5.4 | 7.1 | 8.1 | 9.6 | 11.6 | 13.2 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 403 | 6.72 | 1.905 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.6 | 13.2 |
| 404 | 6.73 | 1.907 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.5 | 13.2 |
| 405 | 6.75 | 1.910 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.5 | 13.2 |
| 406 | 6.77 | 1.912 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.5 | 13.1 |
| 407 | 6.78 | 1.914 | 4.1 | 5.4 | 7.0 | 8.0 | 9.5 | 11.5 | 13.1 |
| 408 | 6.80 | 1.917 | 4.1 | 5.4 | 7.0 | 8.0 | 9.5 | 11.5 | 13.1 |
| 409 | 6.82 | 1.919 | 4.1 | 5.3 | 7.0 | 8.0 | 9.5 | 11.5 | 13.1 |
| 410 | 6.83 | 1.922 | 4.1 | 5.3 | 7.0 | 8.0 | 9.4 | 11.4 | 13.1 |
| 411 | 6.85 | 1.924 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 412 | 6.87 | 1.927 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 413 | 6.88 | 1.929 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 414 | 6.90 | 1.932 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 415 | 6.92 | 1.934 | 4.1 | 5.3 | 6.9 | 7.9 | 9.4 | 11.3 | 13.0 |
| 416 | 6.93 | 1.936 | 4.1 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 417 | 6.95 | 1.939 | 4.0 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 418 | 6.97 | 1.941 | 4.0 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 419 | 6.98 | 1.944 | 4.0 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 420 | 7.00 | 1.946 | 4.0 | 5.2 | 6.8 | 7.9 | 9.3 | 11.3 | 12.9 |
| 421 | 7.02 | 1.948 | 4.0 | 5.2 | 6.8 | 7.9 | 9.3 | 11.2 | 12.8 |
| 422 | 7.03 | 1.951 | 4.0 | 5.2 | 6.8 | 7.9 | 9.3 | 11.2 | 12.8 |
| 423 | 7.05 | 1.953 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.2 | 12.8 |
| 424 | 7.07 | 1.955 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.2 | 12.8 |
| 425 | 7.08 | 1.958 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.2 | 12.8 |
| 426 | 7.10 | 1.960 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.1 | 12.7 |
| 427 | 7.12 | 1.962 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.1 | 12.7 |
| 428 | 7.13 | 1.965 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.1 | 12.7 |
| 429 | 7.15 | 1.967 | 4.0 | 5.2 | 6.7 | 7.8 | 9.2 | 11.1 | 12.7 |
| 430 | 7.17 | 1.969 | 4.0 | 5.2 | 6.7 | 7.8 | 9.1 | 11.1 | 12.7 |
| 431 | 7.18 | 1.972 | 4.0 | 5.1 | 6.7 | 7.7 | 9.1 | 11.1 | 12.6 |
| 432 | 7.20 | 1.974 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 433 | 7.22 | 1.976 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 434 | 7.23 | 1.979 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 435 | 7.25 | 1.981 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 436 | 7.27 | 1.983 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.5 |
| 437 | 7.28 | 1.986 | 3.9 | 5.1 | 6.7 | 7.7 | 9.0 | 11.0 | 12.5 |
| 438 | 7.30 | 1.988 | 3.9 | 5.1 | 6.6 | 7.7 | 9.0 | 10.9 | 12.5 |
| 439 | 7.32 | 1.990 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.5 |
| 440 | 7.33 | 1.992 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.5 |
| 441 | 7.35 | 1.995 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.4 |
| 442 | 7.37 | 1.997 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.4 |
| 443 | 7.38 | 1.999 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.4 |
| 444 | 7.40 | 2.001 | 3.9 | 5.0 | 6.6 | 7.6 | 8.9 | 10.8 | 12.4 |
| 445 | 7.42 | 2.004 | 3.9 | 5.0 | 6.6 | 7.6 | 8.9 | 10.8 | 12.4 |
| 446 | 7.43 | 2.006 | 3.9 | 5.0 | 6.6 | 7.6 | 8.9 | 10.8 | 12.4 |
| 447 | 7.45 | 2.008 | 3.9 | 5.0 | 6.6 | 7.5 | 8.9 | 10.8 | 12.3 |
| 448 | 7.47 | 2.010 | 3.8 | 5.0 | 6.5 | 7.5 | 8.9 | 10.8 | 12.3 |
| 449 | 7.48 | 2.013 | 3.8 | 5.0 | 6.5 | 7.5 | 8.9 | 10.8 | 12.3 |
| 450 | 7.50 | 2.015 | 3.8 | 5.0 | 6.5 | 7.5 | 8.9 | 10.7 | 12.3 |
| 451 | 7.52 | 2.017 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.3 |
| 452 | 7.53 | 2.019 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 453 | 7.55 | 2.022 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 454 | 7.57 | 2.024 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 455 | 7.58 | 2.026 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 456 | 7.60 | 2.028 | 3.8 | 4.9 | 6.5 | 7.4 | 8.8 | 10.6 | 12.2 |
| 457 | 7.62 | 2.030 | 3.8 | 4.9 | 6.5 | 7.4 | 8.8 | 10.6 | 12.2 |
| 458 | 7.63 | 2.033 | 3.8 | 4.9 | 6.4 | 7.4 | 8.8 | 10.6 | 12.1 |
| 459 | 7.65 | 2.035 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 460 | 7.67 | 2.037 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 461 | 7.68 | 2.039 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 462 | 7.70 | 2.041 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 463 | 7.72 | 2.043 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.5 | 12.0 |
| 464 | 7.73 | 2.046 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.5 | 12.0 |
| 465 | 7.75 | 2.048 | 3.7 | 4.9 | 6.4 | 7.3 | 8.7 | 10.5 | 12.0 |
| 466 | 7.77 | 2.050 | 3.7 | 4.9 | 6.4 | 7.3 | 8.7 | 10.5 | 12.0 |
| 467 | 7.78 | 2.052 | 3.7 | 4.9 | 6.4 | 7.3 | 8.6 | 10.5 | 12.0 |
| 468 | 7.80 | 2.054 | 3.7 | 4.9 | 6.4 | 7.3 | 8.6 | 10.5 | 12.0 |
| 469 | 7.82 | 2.056 | 3.7 | 4.9 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 470 | 7.83 | 2.058 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 471 | 7.85 | 2.061 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 472 | 7.87 | 2.063 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 473 | 7.88 | 2.065 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 474 | 7.90 | 2.067 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 475 | 7.92 | 2.069 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.4 | 11.8 |
| 476 | 7.93 | 2.071 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.3 | 11.8 |
| 477 | 7.95 | 2.073 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.3 | 11.8 |
| 478 | 7.97 | 2.075 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.3 | 11.8 |
| 479 | 7.98 | 2.077 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.8 |
| 480 | 8.00 | 2.079 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.8 |
| 481 | 8.02 | 2.082 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.7 |
| 482 | 8.03 | 2.084 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.7 |
| 483 | 8.05 | 2.086 | 3.6 | 4.8 | 6.2 | 7.2 | 8.4 | 10.2 | 11.7 |
| 484 | 8.07 | 2.088 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.7 |
| 485 | 8.08 | 2.090 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.7 |
| 486 | 8.10 | 2.092 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.7 |
| 487 | 8.12 | 2.094 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.6 |
| 488 | 8.13 | 2.096 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.6 |
| 489 | 8.15 | 2.098 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.6 |
| 490 | 8.17 | 2.100 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.1 | 11.6 |
| 491 | 8.18 | 2.102 | 3.6 | 4.7 | 6.1 | 7.1 | 8.4 | 10.1 | 11.6 |
| 492 | 8.20 | 2.104 | 3.6 | 4.7 | 6.1 | 7.1 | 8.3 | 10.1 | 11.6 |
| 493 | 8.22 | 2.106 | 3.6 | 4.7 | 6.1 | 7.1 | 8.3 | 10.1 | 11.5 |
| 494 | 8.23 | 2.108 | 3.6 | 4.7 | 6.1 | 7.1 | 8.3 | 10.1 | 11.5 |
| 495 | 8.25 | 2.110 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.1 | 11.5 |
| 496 | 8.27 | 2.112 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.1 | 11.5 |
| 497 | 8.28 | 2.114 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.0 | 11.5 |
| 498 | 8.30 | 2.116 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.0 | 11.5 |
| 499 | 8.32 | 2.118 | 3.6 | 4.6 | 6.1 | 7.0 | 8.3 | 10.0 | 11.5 |
| 500 | 8.33 | 2.120 | 3.6 | 4.6 | 6.1 | 7.0 | 8.2 | 10.0 | 11.4 |
| 501 | 8.35 | 2.122 | 3.6 | 4.6 | 6.1 | 7.0 | 8.2 | 10.0 | 11.4 |
| 502 | 8.37 | 2.124 | 3.5 | 4.6 | 6.1 | 7.0 | 8.2 | 10.0 | 11.4 |
| 503 | 8.38 | 2.126 | 3.5 | 4.6 | 6.0 | 7.0 | 8.2 | 10.0 | 11.4 |
| 504 | 8.40 | 2.128 | 3.5 | 4.6 | 6.0 | 7.0 | 8.2 | 10.0 | 11.4 |
| 505 | 8.42 | 2.130 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.4 |
| 506 | 8.43 | 2.132 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.3 |
| 507 | 8.45 | 2.134 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.3 |
| 508 | 8.47 | 2.136 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.3 |
| 509 | 8.48 | 2.138 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.9 | 11.3 |
| 510 | 8.50 | 2.140 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.9 | 11.3 |
| 511 | 8.52 | 2.142 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.9 | 11.3 |
| 512 | 8.53 | 2.144 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.8 | 11.3 |
| 513 | 8.55 | 2.146 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.8 | 11.2 |
| 514 | 8.57 | 2.148 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.8 | 11.2 |
| 515 | 8.58 | 2.150 | 3.5 | 4.5 | 5.9 | 6.9 | 8.1 | 9.8 | 11.2 |
| 516 | 8.60 | 2.152 | 3.5 | 4.5 | 5.9 | 6.8 | 8.1 | 9.8 | 11.2 |
| 517 | 8.62 | 2.154 | 3.5 | 4.5 | 5.9 | 6.8 | 8.1 | 9.8 | 11.2 |
| 518 | 8.63 | 2.156 | 3.5 | 4.5 | 5.9 | 6.8 | 8.1 | 9.8 | 11.2 |
| 519 | 8.65 | 2.158 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.8 | 11.2 |
| 520 | 8.67 | 2.159 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 521 | 8.68 | 2.161 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 522 | 8.70 | 2.163 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 523 | 8.72 | 2.165 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 524 | 8.73 | 2.167 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 525 | 8.75 | 2.169 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 526 | 8.77 | 2.171 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 527 | 8.78 | 2.173 | 3.4 | 4.5 | 5.9 | 6.7 | 8.0 | 9.7 | 11.0 |
| 528 | 8.80 | 2.175 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 529 | 8.82 | 2.177 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 530 | 8.83 | 2.179 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 531 | 8.85 | 2.180 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 532 | 8.87 | 2.182 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 533 | 8.88 | 2.184 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 534 | 8.90 | 2.186 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 10.9 |
| 535 | 8.92 | 2.188 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 10.9 |
| 536 | 8.93 | 2.190 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.5 | 10.9 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 537 | 8.95 | 2.192 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.5 | 10.9 |
| 538 | 8.97 | 2.194 | 3.4 | 4.4 | 5.8 | 6.7 | 7.8 | 9.5 | 10.9 |
| 539 | 8.98 | 2.195 | 3.4 | 4.4 | 5.8 | 6.6 | 7.8 | 9.5 | 10.9 |
| 540 | 9.00 | 2.197 | 3.4 | 4.4 | 5.8 | 6.6 | 7.8 | 9.5 | 10.9 |
| 541 | 9.02 | 2.199 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.5 | 10.8 |
| 542 | 9.03 | 2.201 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.5 | 10.8 |
| 543 | 9.05 | 2.203 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.5 | 10.8 |
| 544 | 9.07 | 2.205 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 545 | 9.08 | 2.206 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 546 | 9.10 | 2.208 | 3.3 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 547 | 9.12 | 2.210 | 3.3 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 548 | 9.13 | 2.212 | 3.3 | 4.4 | 5.7 | 6.6 | 7.7 | 9.4 | 10.8 |
| 549 | 9.15 | 2.214 | 3.3 | 4.3 | 5.7 | 6.6 | 7.7 | 9.4 | 10.7 |
| 550 | 9.17 | 2.216 | 3.3 | 4.3 | 5.7 | 6.6 | 7.7 | 9.4 | 10.7 |
| 551 | 9.18 | 2.217 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.4 | 10.7 |
| 552 | 9.20 | 2.219 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.4 | 10.7 |
| 553 | 9.22 | 2.221 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.3 | 10.7 |
| 554 | 9.23 | 2.223 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.3 | 10.7 |
| 555 | 9.25 | 2.225 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.7 |
| 556 | 9.27 | 2.226 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.6 |
| 557 | 9.28 | 2.228 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.6 |
| 558 | 9.30 | 2.230 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.6 |
| 559 | 9.32 | 2.232 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.3 | 10.6 |
| 560 | 9.33 | 2.234 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.3 | 10.6 |
| 561 | 9.35 | 2.235 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.3 | 10.6 |
| 562 | 9.37 | 2.237 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.2 | 10.6 |
| 563 | 9.38 | 2.239 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.6 |
| 564 | 9.40 | 2.241 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 565 | 9.42 | 2.242 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 566 | 9.43 | 2.244 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 567 | 9.45 | 2.246 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 568 | 9.47 | 2.248 | 3.3 | 4.2 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 569 | 9.48 | 2.250 | 3.3 | 4.2 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 570 | 9.50 | 2.251 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.2 | 10.5 |
| 571 | 9.52 | 2.253 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.5 |
| 572 | 9.53 | 2.255 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 573 | 9.55 | 2.257 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 574 | 9.57 | 2.258 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 575 | 9.58 | 2.260 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 576 | 9.60 | 2.262 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 577 | 9.62 | 2.263 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 578 | 9.63 | 2.265 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 579 | 9.65 | 2.267 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 580 | 9.67 | 2.269 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.0 | 10.3 |
| 581 | 9.68 | 2.270 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 582 | 9.70 | 2.272 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 583 | 9.72 | 2.274 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 584 | 9.73 | 2.276 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 585 | 9.75 | 2.277 | 3.2 | 4.2 | 5.4 | 6.3 | 7.4 | 9.0 | 10.3 |
| 586 | 9.77 | 2.279 | 3.2 | 4.2 | 5.4 | 6.3 | 7.4 | 9.0 | 10.3 |
| 587 | 9.78 | 2.281 | 3.2 | 4.2 | 5.4 | 6.3 | 7.4 | 9.0 | 10.3 |
| 588 | 9.80 | 2.282 | 3.2 | 4.1 | 5.4 | 6.3 | 7.4 | 9.0 | 10.2 |
| 589 | 9.82 | 2.284 | 3.2 | 4.1 | 5.4 | 6.3 | 7.4 | 8.9 | 10.2 |
| 590 | 9.83 | 2.286 | 3.2 | 4.1 | 5.4 | 6.2 | 7.4 | 8.9 | 10.2 |
| 591 | 9.85 | 2.287 | 3.2 | 4.1 | 5.4 | 6.2 | 7.4 | 8.9 | 10.2 |
| 592 | 9.87 | 2.289 | 3.2 | 4.1 | 5.4 | 6.2 | 7.4 | 8.9 | 10.2 |
| 593 | 9.88 | 2.291 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 594 | 9.90 | 2.293 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 595 | 9.92 | 2.294 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 596 | 9.93 | 2.296 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 597 | 9.95 | 2.298 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.1 |
| 598 | 9.97 | 2.299 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.1 |
| 599 | 9.98 | 2.301 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.8 | 10.1 |
| 600 | 10.00 | 2.303 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.8 | 10.1 |
| 601 | 10.02 | 2.304 | 3.1 | 4.1 | 5.3 | 6.2 | 7.3 | 8.8 | 10.1 |
| 602 | 10.03 | 2.306 | 3.1 | 4.1 | 5.3 | 6.2 | 7.3 | 8.8 | 10.1 |
| 603 | 10.05 | 2.308 | 3.1 | 4.1 | 5.3 | 6.2 | 7.3 | 8.8 | 10.1 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 604 | 10.07 | 2.309 | 3.1 | 4.1 | 5.3 | 6.1 | 7.3 | 8.8 | 10.1 |
| 605 | 10.08 | 2.311 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.1 |
| 606 | 10.10 | 2.313 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.0 |
| 607 | 10.12 | 2.314 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.0 |
| 608 | 10.13 | 2.316 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.0 |
| 609 | 10.15 | 2.317 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 610 | 10.17 | 2.319 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 611 | 10.18 | 2.321 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 612 | 10.20 | 2.322 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 613 | 10.22 | 2.324 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 614 | 10.23 | 2.326 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 615 | 10.25 | 2.327 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 9.9 |
| 616 | 10.27 | 2.329 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 9.9 |
| 617 | 10.28 | 2.331 | 3.1 | 4.0 | 5.3 | 6.1 | 7.1 | 8.7 | 9.9 |
| 618 | 10.30 | 2.332 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.7 | 9.9 |
| 619 | 10.32 | 2.334 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 620 | 10.33 | 2.335 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 621 | 10.35 | 2.337 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 622 | 10.37 | 2.339 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 623 | 10.38 | 2.340 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 624 | 10.40 | 2.342 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 625 | 10.42 | 2.343 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 626 | 10.43 | 2.345 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 627 | 10.45 | 2.347 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 628 | 10.47 | 2.348 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 629 | 10.48 | 2.350 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 630 | 10.50 | 2.351 | 3.0 | 4.0 | 5.2 | 6.0 | 7.0 | 8.5 | 9.8 |
| 631 | 10.52 | 2.353 | 3.0 | 4.0 | 5.2 | 6.0 | 7.0 | 8.5 | 9.8 |
| 632 | 10.53 | 2.355 | 3.0 | 3.9 | 5.2 | 6.0 | 7.0 | 8.5 | 9.8 |
| 633 | 10.55 | 2.356 | 3.0 | 3.9 | 5.2 | 5.9 | 7.0 | 8.5 | 9.7 |
| 634 | 10.57 | 2.358 | 3.0 | 3.9 | 5.2 | 5.9 | 7.0 | 8.5 | 9.7 |
| 635 | 10.58 | 2.359 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 636 | 10.60 | 2.361 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 637 | 10.62 | 2.362 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 638 | 10.63 | 2.364 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 639 | 10.65 | 2.366 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 640 | 10.67 | 2.367 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 641 | 10.68 | 2.369 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.4 | 9.7 |
| 642 | 10.70 | 2.370 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.4 | 9.6 |
| 643 | 10.72 | 2.372 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 644 | 10.73 | 2.373 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 645 | 10.75 | 2.375 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 646 | 10.77 | 2.376 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 647 | 10.78 | 2.378 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 648 | 10.80 | 2.380 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 649 | 10.82 | 2.381 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.4 | 9.6 |
| 650 | 10.83 | 2.383 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.4 | 9.6 |
| 651 | 10.85 | 2.384 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.4 | 9.6 |
| 652 | 10.87 | 2.386 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.3 | 9.5 |
| 653 | 10.88 | 2.387 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.3 | 9.5 |
| 654 | 10.90 | 2.389 | 3.0 | 3.9 | 5.0 | 5.8 | 6.9 | 8.3 | 9.5 |
| 655 | 10.92 | 2.390 | 3.0 | 3.9 | 5.0 | 5.8 | 6.9 | 8.3 | 9.5 |
| 656 | 10.93 | 2.392 | 2.9 | 3.8 | 5.0 | 5.8 | 6.9 | 8.3 | 9.5 |
| 657 | 10.95 | 2.393 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 658 | 10.97 | 2.395 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 659 | 10.98 | 2.396 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 660 | 11.00 | 2.398 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 661 | 11.02 | 2.399 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 662 | 11.03 | 2.401 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.4 |
| 663 | 11.05 | 2.402 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.2 | 9.4 |
| 664 | 11.07 | 2.404 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.2 | 9.4 |
| 665 | 11.08 | 2.405 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.2 | 9.4 |
| 666 | 11.10 | 2.407 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 667 | 11.12 | 2.408 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 668 | 11.13 | 2.410 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 669 | 11.15 | 2.411 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 670 | 11.17 | 2.413 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 671 | 11.18 | 2.414 | 2.9 | 3.8 | 5.0 | 5.7 | 6.7 | 8.2 | 9.4 |
| 672 | 11.20 | 2.416 | 2.9 | 3.8 | 5.0 | 5.7 | 6.7 | 8.2 | 9.4 |
| 673 | 11.22 | 2.417 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.2 | 9.3 |
| 674 | 11.23 | 2.419 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.2 | 9.3 |
| 675 | 11.25 | 2.420 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 676 | 11.27 | 2.422 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 677 | 11.28 | 2.423 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 678 | 11.30 | 2.425 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 679 | 11.32 | 2.426 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 680 | 11.33 | 2.428 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 681 | 11.35 | 2.429 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 682 | 11.37 | 2.431 | 2.9 | 3.7 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 683 | 11.38 | 2.432 | 2.9 | 3.7 | 4.9 | 5.6 | 6.7 | 8.1 | 9.2 |
| 684 | 11.40 | 2.434 | 2.9 | 3.7 | 4.9 | 5.6 | 6.7 | 8.1 | 9.2 |
| 685 | 11.42 | 2.435 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.1 | 9.2 |
| 686 | 11.43 | 2.437 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.1 | 9.2 |
| 687 | 11.45 | 2.438 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 688 | 11.47 | 2.439 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 689 | 11.48 | 2.441 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 690 | 11.50 | 2.442 | 2.8 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 691 | 11.52 | 2.444 | 2.8 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 692 | 11.53 | 2.445 | 2.8 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 693 | 11.55 | 2.447 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.2 |
| 694 | 11.57 | 2.448 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 695 | 11.58 | 2.450 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 696 | 11.60 | 2.451 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 697 | 11.62 | 2.452 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 698 | 11.63 | 2.454 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 699 | 11.65 | 2.455 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 700 | 11.67 | 2.457 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 7.9 | 9.1 |
| 701 | 11.68 | 2.458 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 702 | 11.70 | 2.460 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 703 | 11.72 | 2.461 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 704 | 11.73 | 2.462 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 705 | 11.75 | 2.464 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 706 | 11.77 | 2.465 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 707 | 11.78 | 2.467 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 708 | 11.80 | 2.468 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 709 | 11.82 | 2.470 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 710 | 11.83 | 2.471 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 711 | 11.85 | 2.472 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 712 | 11.87 | 2.474 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 713 | 11.88 | 2.475 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.8 | 9.0 |
| 714 | 11.90 | 2.477 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.8 | 9.0 |
| 715 | 11.92 | 2.478 | 2.8 | 3.6 | 4.7 | 5.5 | 6.5 | 7.8 | 9.0 |
| 716 | 11.93 | 2.479 | 2.8 | 3.6 | 4.7 | 5.5 | 6.4 | 7.8 | 8.9 |
| 717 | 11.95 | 2.481 | 2.8 | 3.6 | 4.7 | 5.5 | 6.4 | 7.8 | 8.9 |
| 718 | 11.97 | 2.482 | 2.8 | 3.6 | 4.7 | 5.5 | 6.4 | 7.8 | 8.9 |
| 719 | 11.98 | 2.484 | 2.8 | 3.6 | 4.7 | 5.4 | 6.4 | 7.8 | 8.9 |
| **720** | **12.00** | **2.485** | **2.8** | **3.6** | **4.7** | **5.4** | **6.4** | **7.8** | **8.9** |
| 730 | 12.17 | 2.499 | 2.7 | 3.6 | 4.7 | 5.4 | 6.4 | 7.7 | 8.8 |
| 740 | 12.33 | 2.512 | 2.7 | 3.5 | 4.6 | 5.3 | 6.3 | 7.6 | 8.7 |
| 750 | 12.50 | 2.526 | 2.7 | 3.5 | 4.6 | 5.3 | 6.2 | 7.6 | 8.7 |
| 760 | 12.67 | 2.539 | 2.7 | 3.5 | 4.6 | 5.2 | 6.2 | 7.5 | 8.6 |
| 770 | 12.83 | 2.552 | 2.6 | 3.5 | 4.5 | 5.2 | 6.1 | 7.4 | 8.5 |
| 780 | 13.00 | 2.565 | 2.6 | 3.4 | 4.5 | 5.2 | 6.1 | 7.4 | 8.4 |
| 790 | 13.17 | 2.578 | 2.6 | 3.4 | 4.4 | 5.1 | 6.0 | 7.3 | 8.4 |
| 800 | 13.33 | 2.590 | 2.6 | 3.4 | 4.4 | 5.1 | 6.0 | 7.2 | 8.3 |
| 810 | 13.50 | 2.603 | 2.6 | 3.3 | 4.4 | 5.0 | 5.9 | 7.2 | 8.2 |
| 820 | 13.67 | 2.615 | 2.5 | 3.3 | 4.3 | 5.0 | 5.9 | 7.1 | 8.1 |
| 830 | 13.83 | 2.627 | 2.5 | 3.3 | 4.3 | 4.9 | 5.8 | 7.1 | 8.1 |
| 840 | 14.00 | 2.639 | 2.5 | 3.3 | 4.2 | 4.9 | 5.8 | 7.0 | 8.0 |
| 850 | 14.17 | 2.651 | 2.5 | 3.2 | 4.2 | 4.9 | 5.7 | 6.9 | 7.9 |
| 860 | 14.33 | 2.663 | 2.5 | 3.2 | 4.2 | 4.8 | 5.7 | 6.9 | 7.9 |
| 870 | 14.50 | 2.674 | 2.4 | 3.2 | 4.1 | 4.8 | 5.6 | 6.8 | 7.8 |
| 880 | 14.67 | 2.686 | 2.4 | 3.2 | 4.1 | 4.7 | 5.6 | 6.8 | 7.7 |
| 890 | 14.83 | 2.697 | 2.4 | 3.1 | 4.1 | 4.7 | 5.5 | 6.7 | 7.7 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 900 | 15.00 | 2.708 | 2.4 | 3.1 | 4.1 | 4.7 | 5.5 | 6.7 | 7.6 |
| 910 | 15.17 | 2.719 | 2.4 | 3.1 | 4.0 | 4.6 | 5.5 | 6.6 | 7.6 |
| 920 | 15.33 | 2.730 | 2.3 | 3.1 | 4.0 | 4.6 | 5.4 | 6.6 | 7.5 |
| 930 | 15.50 | 2.741 | 2.3 | 3.0 | 4.0 | 4.6 | 5.4 | 6.5 | 7.4 |
| 940 | 15.67 | 2.752 | 2.3 | 3.0 | 3.9 | 4.5 | 5.3 | 6.5 | 7.4 |
| 950 | 15.83 | 2.762 | 2.3 | 3.0 | 3.9 | 4.5 | 5.3 | 6.4 | 7.3 |
| 960 | 16.00 | 2.773 | 2.3 | 3.0 | 3.9 | 4.5 | 5.3 | 6.4 | 7.3 |
| 970 | 16.17 | 2.783 | 2.3 | 3.0 | 3.8 | 4.4 | 5.2 | 6.3 | 7.2 |
| 980 | 16.33 | 2.793 | 2.2 | 2.9 | 3.8 | 4.4 | 5.2 | 6.3 | 7.2 |
| 990 | 16.50 | 2.803 | 2.2 | 2.9 | 3.8 | 4.4 | 5.1 | 6.2 | 7.1 |
| 1000 | 16.67 | 2.813 | 2.2 | 2.9 | 3.8 | 4.3 | 5.1 | 6.2 | 7.1 |
| 1010 | 16.83 | 2.823 | 2.2 | 2.9 | 3.7 | 4.3 | 5.1 | 6.1 | 7.0 |
| 1020 | 17.00 | 2.833 | 2.2 | 2.9 | 3.7 | 4.3 | 5.0 | 6.1 | 7.0 |
| 1030 | 17.17 | 2.843 | 2.2 | 2.8 | 3.7 | 4.2 | 5.0 | 6.0 | 6.9 |
| 1040 | 17.33 | 2.853 | 2.2 | 2.8 | 3.7 | 4.2 | 5.0 | 6.0 | 6.9 |
| 1050 | 17.50 | 2.862 | 2.1 | 2.8 | 3.6 | 4.2 | 4.9 | 6.0 | 6.8 |
| 1060 | 17.67 | 2.872 | 2.1 | 2.8 | 3.6 | 4.2 | 4.9 | 5.9 | 6.8 |
| 1070 | 17.83 | 2.881 | 2.1 | 2.8 | 3.6 | 4.1 | 4.9 | 5.9 | 6.7 |
| 1080 | 18.00 | 2.890 | 2.1 | 2.8 | 3.6 | 4.1 | 4.8 | 5.8 | 6.7 |
| 1090 | 18.17 | 2.900 | 2.1 | 2.7 | 3.6 | 4.1 | 4.8 | 5.8 | 6.6 |
| 1100 | 18.33 | 2.909 | 2.1 | 2.7 | 3.5 | 4.1 | 4.8 | 5.8 | 6.6 |
| 1110 | 18.50 | 2.918 | 2.1 | 2.7 | 3.5 | 4.0 | 4.7 | 5.7 | 6.5 |
| 1120 | 18.67 | 2.927 | 2.1 | 2.7 | 3.5 | 4.0 | 4.7 | 5.7 | 6.5 |
| 1130 | 18.83 | 2.936 | 2.0 | 2.7 | 3.5 | 4.0 | 4.7 | 5.7 | 6.4 |
| 1140 | 19.00 | 2.944 | 2.0 | 2.7 | 3.4 | 4.0 | 4.6 | 5.6 | 6.4 |
| 1150 | 19.17 | 2.953 | 2.0 | 2.6 | 3.4 | 3.9 | 4.6 | 5.6 | 6.4 |
| 1160 | 19.33 | 2.962 | 2.0 | 2.6 | 3.4 | 3.9 | 4.6 | 5.5 | 6.3 |
| 1170 | 19.50 | 2.970 | 2.0 | 2.6 | 3.4 | 3.9 | 4.6 | 5.5 | 6.3 |
| 1180 | 19.67 | 2.979 | 2.0 | 2.6 | 3.4 | 3.9 | 4.5 | 5.5 | 6.2 |
| 1190 | 19.83 | 2.987 | 2.0 | 2.6 | 3.3 | 3.8 | 4.5 | 5.4 | 6.2 |
| 1200 | 20.00 | 2.996 | 2.0 | 2.6 | 3.3 | 3.8 | 4.5 | 5.4 | 6.2 |
| 1210 | 20.17 | 3.004 | 2.0 | 2.6 | 3.3 | 3.8 | 4.5 | 5.4 | 6.1 |
| 1220 | 20.33 | 3.012 | 1.9 | 2.5 | 3.3 | 3.8 | 4.4 | 5.3 | 6.1 |
| 1230 | 20.50 | 3.020 | 1.9 | 2.5 | 3.3 | 3.7 | 4.4 | 5.3 | 6.1 |
| 1240 | 20.67 | 3.029 | 1.9 | 2.5 | 3.2 | 3.7 | 4.4 | 5.3 | 6.0 |
| 1250 | 20.83 | 3.037 | 1.9 | 2.5 | 3.2 | 3.7 | 4.4 | 5.2 | 6.0 |
| 1260 | 21.00 | 3.045 | 1.9 | 2.5 | 3.2 | 3.7 | 4.3 | 5.2 | 5.9 |
| 1270 | 21.17 | 3.052 | 1.9 | 2.5 | 3.2 | 3.7 | 4.3 | 5.2 | 5.9 |
| 1280 | 21.33 | 3.060 | 1.9 | 2.5 | 3.2 | 3.6 | 4.3 | 5.2 | 5.9 |
| 1290 | 21.50 | 3.068 | 1.9 | 2.4 | 3.2 | 3.6 | 4.3 | 5.1 | 5.8 |
| 1300 | 21.67 | 3.076 | 1.9 | 2.4 | 3.1 | 3.6 | 4.2 | 5.1 | 5.8 |
| 1310 | 21.83 | 3.083 | 1.9 | 2.4 | 3.1 | 3.6 | 4.2 | 5.1 | 5.8 |
| 1320 | 22.00 | 3.091 | 1.8 | 2.4 | 3.1 | 3.6 | 4.2 | 5.0 | 5.7 |
| 1330 | 22.17 | 3.099 | 1.8 | 2.4 | 3.1 | 3.5 | 4.2 | 5.0 | 5.7 |
| 1340 | 22.33 | 3.106 | 1.8 | 2.4 | 3.1 | 3.5 | 4.1 | 5.0 | 5.7 |
| 1350 | 22.50 | 3.114 | 1.8 | 2.4 | 3.1 | 3.5 | 4.1 | 5.0 | 5.6 |
| 1360 | 22.67 | 3.121 | 1.8 | 2.4 | 3.0 | 3.5 | 4.1 | 4.9 | 5.6 |
| 1370 | 22.83 | 3.128 | 1.8 | 2.3 | 3.0 | 3.5 | 4.1 | 4.9 | 5.6 |
| 1380 | 23.00 | 3.135 | 1.8 | 2.3 | 3.0 | 3.5 | 4.0 | 4.9 | 5.5 |
| 1390 | 23.17 | 3.143 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.5 |
| 1400 | 23.33 | 3.150 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.5 |
| 1410 | 23.50 | 3.157 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.5 |
| 1420 | 23.67 | 3.164 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.4 |
| 1430 | 23.83 | 3.171 | 1.8 | 2.3 | 2.9 | 3.4 | 3.9 | 4.7 | 5.4 |
| 1440 | 24.00 | 3.178 | 1.7 | 2.3 | 2.9 | 3.3 | 3.9 | 4.7 | 5.4 |
| 1450 | 24.17 | 3.185 | 1.7 | 2.3 | 2.9 | 3.3 | 3.9 | 4.7 | 5.3 |
| 1460 | 24.33 | 3.192 | 1.7 | 2.3 | 2.9 | 3.3 | 3.9 | 4.7 | 5.3 |
| 1470 | 24.50 | 3.199 | 1.7 | 2.2 | 2.9 | 3.3 | 3.9 | 4.6 | 5.3 |
| 1480 | 24.67 | 3.205 | 1.7 | 2.2 | 2.9 | 3.3 | 3.8 | 4.6 | 5.3 |
| 1490 | 24.83 | 3.212 | 1.7 | 2.2 | 2.9 | 3.3 | 3.8 | 4.6 | 5.2 |
| 1500 | 25.00 | 3.219 | 1.7 | 2.2 | 2.8 | 3.3 | 3.8 | 4.6 | 5.2 |
| 1510 | 25.17 | 3.226 | 1.7 | 2.2 | 2.8 | 3.2 | 3.8 | 4.6 | 5.2 |
| 1520 | 25.33 | 3.232 | 1.7 | 2.2 | 2.8 | 3.2 | 3.8 | 4.5 | 5.1 |
| 1530 | 25.50 | 3.239 | 1.7 | 2.2 | 2.8 | 3.2 | 3.8 | 4.5 | 5.1 |
| 1540 | 25.67 | 3.245 | 1.7 | 2.2 | 2.8 | 3.2 | 3.7 | 4.5 | 5.1 |
| 1550 | 25.83 | 3.252 | 1.7 | 2.2 | 2.8 | 3.2 | 3.7 | 4.5 | 5.1 |
| 1560 | 26.00 | 3.258 | 1.7 | 2.2 | 2.8 | 3.2 | 3.7 | 4.4 | 5.0 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 1570 | 26.17 | 3.264 | 1.6 | 2.1 | 2.8 | 3.1 | 3.7 | 4.4 | 5.0 |
| 1580 | 26.33 | 3.271 | 1.6 | 2.1 | 2.7 | 3.1 | 3.7 | 4.4 | 5.0 |
| 1590 | 26.50 | 3.277 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.4 | 5.0 |
| 1600 | 26.67 | 3.283 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.4 | 4.9 |
| 1610 | 26.83 | 3.290 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 1620 | 27.00 | 3.296 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 1630 | 27.17 | 3.302 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 1640 | 27.33 | 3.308 | 1.6 | 2.1 | 2.7 | 3.0 | 3.6 | 4.3 | 4.9 |
| 1650 | 27.50 | 3.314 | 1.6 | 2.1 | 2.7 | 3.0 | 3.5 | 4.3 | 4.8 |
| 1660 | 27.67 | 3.320 | 1.6 | 2.1 | 2.6 | 3.0 | 3.5 | 4.2 | 4.8 |
| 1670 | 27.83 | 3.326 | 1.6 | 2.1 | 2.6 | 3.0 | 3.5 | 4.2 | 4.8 |
| 1680 | 28.00 | 3.332 | 1.6 | 2.1 | 2.6 | 3.0 | 3.5 | 4.2 | 4.8 |
| 1690 | 28.17 | 3.338 | 1.6 | 2.0 | 2.6 | 3.0 | 3.5 | 4.2 | 4.7 |
| 1700 | 28.33 | 3.344 | 1.6 | 2.0 | 2.6 | 3.0 | 3.5 | 4.2 | 4.7 |
| 1710 | 28.50 | 3.350 | 1.6 | 2.0 | 2.6 | 3.0 | 3.5 | 4.1 | 4.7 |
| 1720 | 28.67 | 3.356 | 1.6 | 2.0 | 2.6 | 2.9 | 3.4 | 4.1 | 4.7 |
| 1730 | 28.83 | 3.362 | 1.5 | 2.0 | 2.6 | 2.9 | 3.4 | 4.1 | 4.6 |
| 1740 | 29.00 | 3.367 | 1.5 | 2.0 | 2.6 | 2.9 | 3.4 | 4.1 | 4.6 |
| 1750 | 29.17 | 3.373 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 4.1 | 4.6 |
| 1760 | 29.33 | 3.379 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 4.0 | 4.6 |
| 1770 | 29.50 | 3.384 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 4.0 | 4.6 |
| 1780 | 29.67 | 3.390 | 1.5 | 2.0 | 2.5 | 2.9 | 3.3 | 4.0 | 4.5 |
| 1790 | 29.83 | 3.396 | 1.5 | 2.0 | 2.5 | 2.9 | 3.3 | 4.0 | 4.5 |
| 1800 | 30.00 | 3.401 | 1.5 | 2.0 | 2.5 | 2.8 | 3.3 | 4.0 | 4.5 |
| 1810 | 30.17 | 3.407 | 1.5 | 2.0 | 2.5 | 2.8 | 3.3 | 4.0 | 4.5 |
| 1820 | 30.33 | 3.412 | 1.5 | 1.9 | 2.5 | 2.8 | 3.3 | 3.9 | 4.5 |
| 1830 | 30.50 | 3.418 | 1.5 | 1.9 | 2.5 | 2.8 | 3.3 | 3.9 | 4.4 |
| 1840 | 30.67 | 3.423 | 1.5 | 1.9 | 2.5 | 2.8 | 3.3 | 3.9 | 4.4 |
| 1850 | 30.83 | 3.429 | 1.5 | 1.9 | 2.4 | 2.8 | 3.3 | 3.9 | 4.4 |
| 1860 | 31.00 | 3.434 | 1.5 | 1.9 | 2.4 | 2.8 | 3.2 | 3.9 | 4.4 |
| 1870 | 31.17 | 3.439 | 1.5 | 1.9 | 2.4 | 2.8 | 3.2 | 3.9 | 4.4 |
| 1880 | 31.33 | 3.445 | 1.5 | 1.9 | 2.4 | 2.8 | 3.2 | 3.8 | 4.4 |
| 1890 | 31.50 | 3.450 | 1.5 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1900 | 31.67 | 3.455 | 1.5 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1910 | 31.83 | 3.461 | 1.4 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1920 | 32.00 | 3.466 | 1.4 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1930 | 32.17 | 3.471 | 1.4 | 1.9 | 2.4 | 2.7 | 3.1 | 3.8 | 4.3 |
| 1940 | 32.33 | 3.476 | 1.4 | 1.9 | 2.4 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1950 | 32.50 | 3.481 | 1.4 | 1.9 | 2.4 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1960 | 32.67 | 3.486 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1970 | 32.83 | 3.491 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1980 | 33.00 | 3.497 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1990 | 33.17 | 3.502 | 1.4 | 1.8 | 2.3 | 2.6 | 3.1 | 3.7 | 4.2 |
| 2000 | 33.33 | 3.507 | 1.4 | 1.8 | 2.3 | 2.6 | 3.1 | 3.7 | 4.1 |
| 2010 | 33.50 | 3.512 | 1.4 | 1.8 | 2.3 | 2.6 | 3.1 | 3.6 | 4.1 |
| 2020 | 33.67 | 3.517 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2030 | 33.83 | 3.521 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2040 | 34.00 | 3.526 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2050 | 34.17 | 3.531 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2060 | 34.33 | 3.536 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.0 |
| 2070 | 34.50 | 3.541 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.0 |
| 2080 | 34.67 | 3.546 | 1.4 | 1.8 | 2.2 | 2.6 | 3.0 | 3.5 | 4.0 |
| 2090 | 34.83 | 3.551 | 1.4 | 1.8 | 2.2 | 2.5 | 3.0 | 3.5 | 4.0 |
| 2100 | 35.00 | 3.555 | 1.4 | 1.8 | 2.2 | 2.5 | 3.0 | 3.5 | 4.0 |
| 2110 | 35.17 | 3.560 | 1.4 | 1.8 | 2.2 | 2.5 | 2.9 | 3.5 | 4.0 |
| 2120 | 35.33 | 3.565 | 1.4 | 1.8 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2130 | 35.50 | 3.570 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2140 | 35.67 | 3.574 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2150 | 35.83 | 3.579 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2160 | 36.00 | 3.584 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.9 |
| 2170 | 36.17 | 3.588 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.9 |
| 2180 | 36.33 | 3.593 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.9 |
| 2190 | 36.50 | 3.597 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.8 |
| 2200 | 36.67 | 3.602 | 1.3 | 1.7 | 2.2 | 2.4 | 2.8 | 3.4 | 3.8 |
| 2210 | 36.83 | 3.606 | 1.3 | 1.7 | 2.2 | 2.4 | 2.8 | 3.4 | 3.8 |
| 2220 | 37.00 | 3.611 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.4 | 3.8 |
| 2230 | 37.17 | 3.615 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.4 | 3.8 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 2240 | 37.33 | 3.620 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.8 |
| 2250 | 37.50 | 3.624 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.8 |
| 2260 | 37.67 | 3.629 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2270 | 37.83 | 3.633 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2280 | 38.00 | 3.638 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2290 | 38.17 | 3.642 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2300 | 38.33 | 3.646 | 1.3 | 1.7 | 2.1 | 2.4 | 2.7 | 3.3 | 3.7 |
| 2310 | 38.50 | 3.651 | 1.3 | 1.7 | 2.1 | 2.4 | 2.7 | 3.3 | 3.7 |
| 2320 | 38.67 | 3.655 | 1.3 | 1.6 | 2.1 | 2.4 | 2.7 | 3.2 | 3.7 |
| 2330 | 38.83 | 3.659 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.7 |
| 2340 | 39.00 | 3.664 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2350 | 39.17 | 3.668 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2360 | 39.33 | 3.672 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2370 | 39.50 | 3.676 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2380 | 39.67 | 3.681 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2390 | 39.83 | 3.685 | 1.2 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2400 | 40.00 | 3.689 | 1.2 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2410 | 40.17 | 3.693 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.2 | 3.6 |
| 2420 | 40.33 | 3.697 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2430 | 40.50 | 3.701 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2440 | 40.67 | 3.705 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2450 | 40.83 | 3.709 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2460 | 41.00 | 3.714 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2470 | 41.17 | 3.718 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2480 | 41.33 | 3.722 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2490 | 41.50 | 3.726 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2500 | 41.67 | 3.730 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.4 |
| 2510 | 41.83 | 3.734 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.0 | 3.4 |
| 2520 | 42.00 | 3.738 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.0 | 3.4 |
| 2530 | 42.17 | 3.742 | 1.2 | 1.6 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2540 | 42.33 | 3.746 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2550 | 42.50 | 3.750 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2560 | 42.67 | 3.753 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2570 | 42.83 | 3.757 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2580 | 43.00 | 3.761 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2590 | 43.17 | 3.765 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.3 |
| 2600 | 43.33 | 3.769 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.3 |
| 2610 | 43.50 | 3.773 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 3.0 | 3.3 |
| 2620 | 43.67 | 3.777 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2630 | 43.83 | 3.780 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2640 | 44.00 | 3.784 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2650 | 44.17 | 3.788 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2660 | 44.33 | 3.792 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.3 |
| 2670 | 44.50 | 3.795 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.3 |
| 2680 | 44.67 | 3.799 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2690 | 44.83 | 3.803 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2700 | 45.00 | 3.807 | 1.1 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2710 | 45.17 | 3.810 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2720 | 45.33 | 3.814 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2730 | 45.50 | 3.818 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2740 | 45.67 | 3.821 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2750 | 45.83 | 3.825 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2760 | 46.00 | 3.829 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2770 | 46.17 | 3.832 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2780 | 46.33 | 3.836 | 1.1 | 1.5 | 1.8 | 2.0 | 2.4 | 2.8 | 3.2 |
| 2790 | 46.50 | 3.839 | 1.1 | 1.4 | 1.8 | 2.0 | 2.4 | 2.8 | 3.1 |
| 2800 | 46.67 | 3.843 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2810 | 46.83 | 3.847 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2820 | 47.00 | 3.850 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2830 | 47.17 | 3.854 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2840 | 47.33 | 3.857 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2850 | 47.50 | 3.861 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 |
| 2860 | 47.67 | 3.864 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 |
| 2870 | 47.83 | 3.868 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 |
| **2880** | **48.00** | **3.871** | **1.1** | **1.4** | **1.8** | **2.0** | **2.3** | **2.7** | **3.1** |
| 2890 | 48.17 | 3.875 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2900 | 48.33 | 3.878 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.0 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 2910 | 48.50 | 3.882 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2920 | 48.67 | 3.885 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2930 | 48.83 | 3.888 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2940 | 49.00 | 3.892 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2950 | 49.17 | 3.895 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2960 | 49.33 | 3.899 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.7 | 3.0 |
| 2970 | 49.50 | 3.902 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.7 | 3.0 |
| 2980 | 49.67 | 3.905 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 3.0 |
| 2990 | 49.83 | 3.909 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 3.0 |
| 3000 | 50.00 | 3.912 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 3.0 |
| 3010 | 50.17 | 3.915 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3020 | 50.33 | 3.919 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3030 | 50.50 | 3.922 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3040 | 50.67 | 3.925 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3050 | 50.83 | 3.929 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3060 | 51.00 | 3.932 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3070 | 51.17 | 3.935 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3080 | 51.33 | 3.938 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3090 | 51.50 | 3.942 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3100 | 51.67 | 3.945 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3110 | 51.83 | 3.948 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3120 | 52.00 | 3.951 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.5 | 2.9 |
| 3130 | 52.17 | 3.954 | 1.0 | 1.3 | 1.7 | 1.9 | 2.1 | 2.5 | 2.8 |
| 3140 | 52.33 | 3.958 | 1.0 | 1.3 | 1.6 | 1.9 | 2.1 | 2.5 | 2.8 |
| 3150 | 52.50 | 3.961 | 1.0 | 1.3 | 1.6 | 1.9 | 2.1 | 2.5 | 2.8 |
| 3160 | 52.67 | 3.964 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3170 | 52.83 | 3.967 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3180 | 53.00 | 3.970 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3190 | 53.17 | 3.973 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3200 | 53.33 | 3.977 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3210 | 53.50 | 3.980 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3220 | 53.67 | 3.983 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3230 | 53.83 | 3.986 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3240 | 54.00 | 3.989 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3250 | 54.17 | 3.992 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3260 | 54.33 | 3.995 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3270 | 54.50 | 3.998 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3280 | 54.67 | 4.001 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3290 | 54.83 | 4.004 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3300 | 55.00 | 4.007 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3310 | 55.17 | 4.010 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3320 | 55.33 | 4.013 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3330 | 55.50 | 4.016 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3340 | 55.67 | 4.019 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3350 | 55.83 | 4.022 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3360 | 56.00 | 4.025 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3370 | 56.17 | 4.028 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3380 | 56.33 | 4.031 | 1.0 | 1.3 | 1.6 | 1.7 | 2.0 | 2.4 | 2.7 |
| 3390 | 56.50 | 4.034 | 1.0 | 1.3 | 1.6 | 1.7 | 2.0 | 2.4 | 2.7 |
| 3400 | 56.67 | 4.037 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.7 |
| 3410 | 56.83 | 4.040 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.6 |
| 3420 | 57.00 | 4.043 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.6 |
| 3430 | 57.17 | 4.046 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3440 | 57.33 | 4.049 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3450 | 57.50 | 4.052 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3460 | 57.67 | 4.055 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3470 | 57.83 | 4.058 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3480 | 58.00 | 4.060 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3490 | 58.17 | 4.063 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3500 | 58.33 | 4.066 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3510 | 58.50 | 4.069 | 1.0 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3520 | 58.67 | 4.072 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3530 | 58.83 | 4.075 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3540 | 59.00 | 4.078 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3550 | 59.17 | 4.080 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3560 | 59.33 | 4.083 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3570 | 59.50 | 4.086 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 3580 | 59.67 | 4.089 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3590 | 59.83 | 4.092 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3600 | 60.00 | 4.094 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3610 | 60.17 | 4.097 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.2 | 2.5 |
| 3620 | 60.33 | 4.100 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.2 | 2.5 |
| 3630 | 60.50 | 4.103 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3640 | 60.67 | 4.105 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3650 | 60.83 | 4.108 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3660 | 61.00 | 4.111 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3670 | 61.17 | 4.114 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3680 | 61.33 | 4.116 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3690 | 61.50 | 4.119 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3700 | 61.67 | 4.122 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3710 | 61.83 | 4.124 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3720 | 62.00 | 4.127 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3730 | 62.17 | 4.130 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.4 |
| 3740 | 62.33 | 4.132 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3750 | 62.50 | 4.135 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3760 | 62.67 | 4.138 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3770 | 62.83 | 4.140 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3780 | 63.00 | 4.143 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3790 | 63.17 | 4.146 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3800 | 63.33 | 4.148 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3810 | 63.50 | 4.151 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3820 | 63.67 | 4.154 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3830 | 63.83 | 4.156 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3840 | 64.00 | 4.159 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3850 | 64.17 | 4.161 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3860 | 64.33 | 4.164 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3870 | 64.50 | 4.167 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3880 | 64.67 | 4.169 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3890 | 64.83 | 4.172 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3900 | 65.00 | 4.174 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3910 | 65.17 | 4.177 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3920 | 65.33 | 4.180 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3930 | 65.50 | 4.182 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3940 | 65.67 | 4.185 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3950 | 65.83 | 4.187 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3960 | 66.00 | 4.190 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3970 | 66.17 | 4.192 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3980 | 66.33 | 4.195 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3990 | 66.50 | 4.197 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.1 | 2.3 |
| 4000 | 66.67 | 4.200 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.1 | 2.3 |
| 4010 | 66.83 | 4.202 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.1 | 2.3 |
| 4020 | 67.00 | 4.205 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4030 | 67.17 | 4.207 | 0.9 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4040 | 67.33 | 4.210 | 0.9 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4050 | 67.50 | 4.212 | 0.9 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4060 | 67.67 | 4.215 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4070 | 67.83 | 4.217 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4080 | 68.00 | 4.220 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4090 | 68.17 | 4.222 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4100 | 68.33 | 4.224 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4110 | 68.50 | 4.227 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4120 | 68.67 | 4.229 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4130 | 68.83 | 4.232 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4140 | 69.00 | 4.234 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4150 | 69.17 | 4.237 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4160 | 69.33 | 4.239 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4170 | 69.50 | 4.241 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4180 | 69.67 | 4.244 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4190 | 69.83 | 4.246 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4200 | 70.00 | 4.248 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4210 | 70.17 | 4.251 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4220 | 70.33 | 4.253 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4230 | 70.50 | 4.256 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 2.0 | 2.2 |
| 4240 | 70.67 | 4.258 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 2.0 | 2.2 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 4250 | 70.83 | 4.260 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 2.0 | 2.2 |
| 4260 | 71.00 | 4.263 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 1.9 | 2.2 |
| 4270 | 71.17 | 4.265 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4280 | 71.33 | 4.267 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4290 | 71.50 | 4.270 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4300 | 71.67 | 4.272 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4310 | 71.83 | 4.274 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| **4320** | **72.00** | **4.277** | **0.8** | **1.0** | **1.3** | **1.4** | **1.6** | **1.9** | **2.2** |

# APPENDIX E: Pre-Development Catchement Data

**Catchment: A**
**Mainstream Parameters**

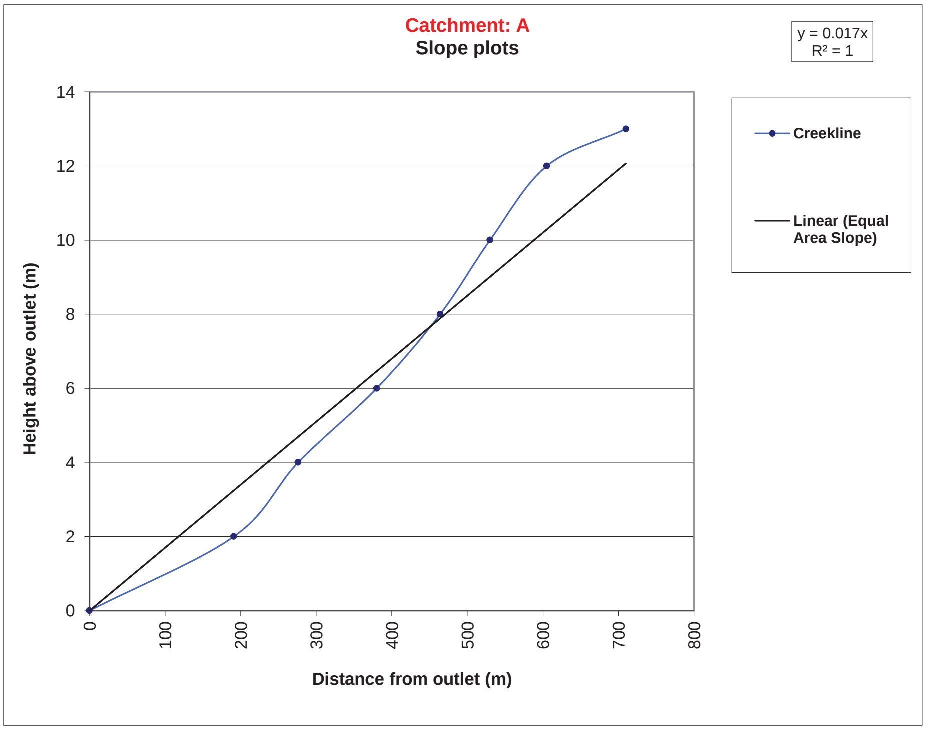
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 191 |
| 191 | 2 | 255 |
| 276 | 4 | 520 |
| 380 | 6 | 588 |
| 464 | 8 | 594 |
| 530 | 10 | 825 |
| 605 | 12 | 1,313 |
| 710 | 13 | **4,286** |

| | | |
|---|---|---|
| Δ L | 0.710 | km |

| | | |
|---|---|---|
| Area | 317,134 | $m^2$ |

| | | |
|---|---|---|
| Se (EQUAL AREA SLOPE) | 17.00 | m/km |
| | 1.7% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 710 | 12 |



**Catchment: B**
**Mainstream Parameters**

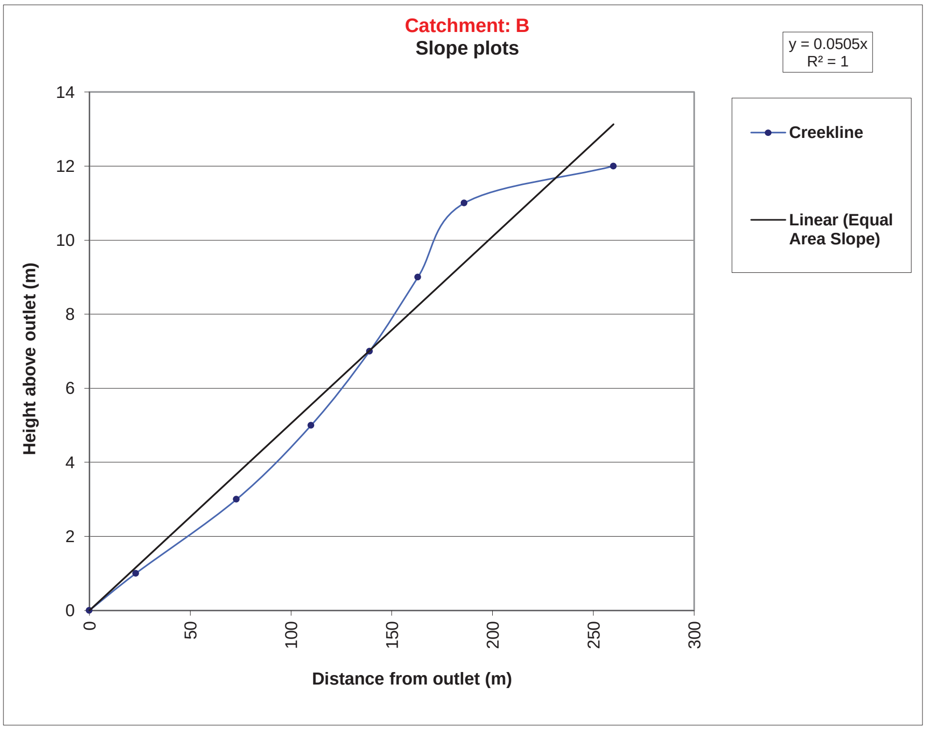
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 12 |
| 23 | 1 | 100 |
| 73 | 3 | 148 |
| 110 | 5 | 174 |
| 139 | 7 | 192 |
| 163 | 9 | 230 |
| 186 | 11 | 851 |
| 260 | 12 | **1,707** |

| | | |
|---|---|---|
| Δ L | 0.260 | km |

| | | |
|---|---|---|
| Area | 85,582 | $m^2$ |

| | | |
|---|---|---|
| Se<br>(EQUAL AREA SLOPE) | 50.49 | m/km |
| | 5.0% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 260 | 13 |



Catchment: C
Mainstream Parameters

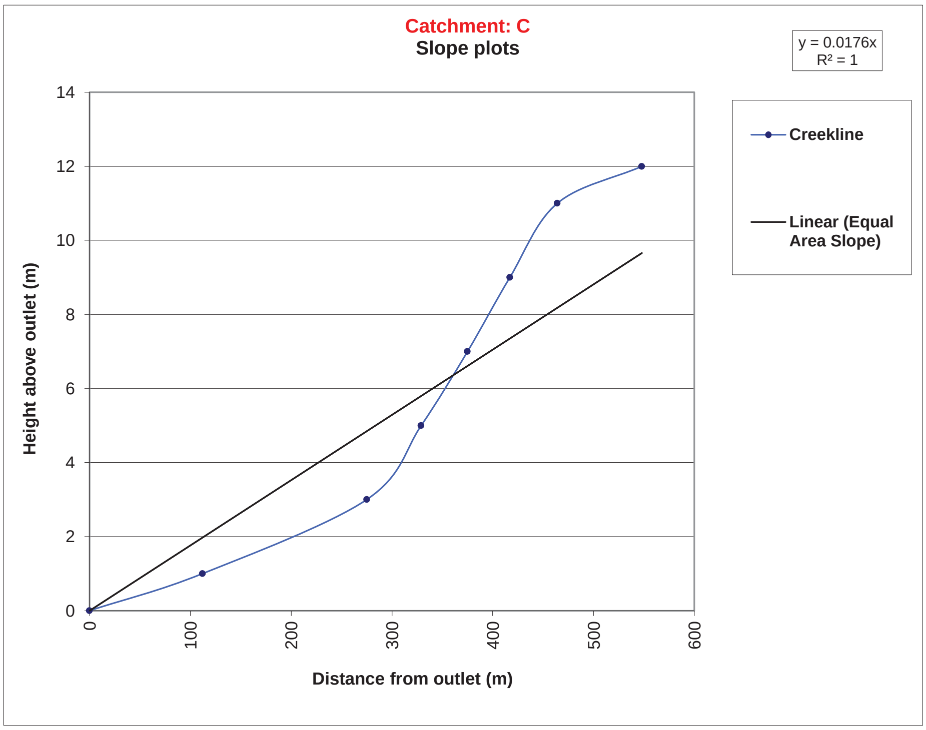
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 56 |
| 112 | 1 | 326 |
| 275 | 3 | 216 |
| 329 | 5 | 276 |
| 375 | 7 | 336 |
| 417 | 9 | 470 |
| 464 | 11 | 966 |
| 548 | 12 | 2,646 |

| | | |
|---|---|---|
| Δ L | 0.548 | km |

| | | |
|---|---|---|
| Area | 171,838 | $m^2$ |

| | | |
|---|---|---|
| Se (EQUAL AREA SLOPE) | 17.62 | m/km |
| | 1.8% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 548 | 10 |



Catchment: D
Mainstream Parameters

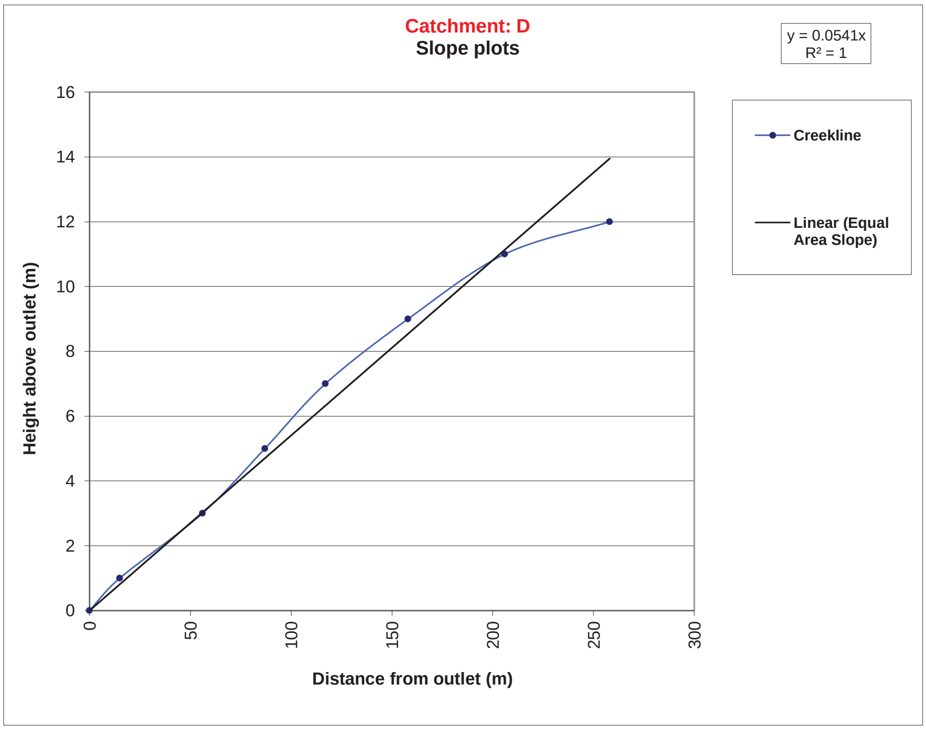
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 8 |
| 15 | 1 | 82 |
| 56 | 3 | 124 |
| 87 | 5 | 180 |
| 117 | 7 | 328 |
| 158 | 9 | 480 |
| 206 | 11 | 598 |
| 258 | 12 | **1,800** |

| | | |
|---|---|---|
| Δ L | 0.258 | km |

| | | |
|---|---|---|
| Area | 50,187 | $m^2$ |

| | | |
|---|---|---|
| Se (EQUAL AREA SLOPE) | 54.07 | m/km |
| | 5.4% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 258 | 14 |



# APPENDIX F: Pre-Development Analysis, Basin Storage & Sizing Calculations

**Civil Technology**
**15 Charles Street, South Perth**
**Ph: 9367 2533 Fax: 9367 8046 Email ian@civiltech.com.au**

**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

**PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS** **DATE:** **26/08/2014**

**IFD data for Bonniefield 1 in 1 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |

| CATCHEMNT A | | CATCHMENT A1 + E1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.73 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 2.39 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 31.71 | Catchment area - Lots ha | 28.98 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 1.5855 | Impervious area - ha | 3.4840 |
| Length of flow - m | 710.0 | Length of flow - m | 900.0 |
| Catchment top RL | 20.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 8.0 | Catchment Base RL | 8.0 |
| Ground slope to culvert S | 0.017 | Ground slope to culvert S | 0.029 |
| Time - min | 68.03 | Time - min | 55.56 |
| Intensity - mm/hr | 15 | Intensity - mm/hr | 17 |
| Inflow - litres/sec | 64.4 | Inflow - litres/sec | 161.7 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

| SOAKAGE/STORAGE/SIZING - COPAS FORMULA<br>Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 1 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.14 | 3.0 | 70.0 | 6.0 | 335.46 | 161.7 | 0.160 | 53.67 | 64.4 | 118.0 | 1.37 | 3.24 | 1.00 | 62.74 | 38.08 |
| 0.15 | 3.0 | 70.0 | 6.0 | 344.64 | 161.7 | 0.180 | 62.04 | 64.4 | 126.4 | 1.28 | 2.44 | 1.00 | 47.36 | 41.48 |
| 0.16 | 3.0 | 70.0 | 6.0 | 353.85 | 161.7 | 0.180 | 63.69 | 64.4 | 128.1 | 1.26 | 2.30 | 1.00 | 44.55 | 44.96 |
| 0.17 | 3.0 | 70.0 | 6.0 | 363.08 | 161.7 | 0.180 | 65.35 | 64.4 | 129.7 | 1.25 | 2.16 | 1.00 | 41.81 | 48.54 |
| 0.18 | 3.0 | 70.0 | 6.0 | 372.35 | 161.7 | 0.180 | 67.02 | 64.4 | 131.4 | 1.23 | 2.02 | 1.00 | 39.12 | 52.20 |
| 0.19 | 3.0 | 70.0 | 6.0 | 381.64 | 161.7 | 0.180 | 68.69 | 64.4 | 133.1 | 1.21 | 1.88 | 1.00 | 36.49 | 55.96 |
| 0.20 | 3.0 | 70.0 | 6.0 | 390.96 | 161.7 | 0.180 | 70.37 | 64.4 | 134.7 | 1.20 | 1.75 | 1.00 | 33.92 | 59.81 |

**IFD data for Bonniefield 1 in 5 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |

| CATCHEMNT A | | CATCHMENT A1 + E1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.73 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 2.39 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 31.71 | Catchment area - Lots ha | 28.98 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 1.5855 | Impervious area - ha | 3.4840 |
| Length of flow - m | 710.0 | Length of flow - m | 900.0 |
| Catchment top RL | 20.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 8.0 | Catchment Base RL | 8.0 |
| Ground slope to culvert S | 0.017 | Ground slope to culvert S | 0.029 |
| Time - min | 53.00 | Time - min | 43.14 |
| Intensity - mm/hr | 28 | Intensity - mm/hr | 32 |
| Inflow - litres/sec | 123.8 | Inflow - litres/sec | 310.3 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

| SOAKAGE/STORAGE/SIZING - COPAS FORMULA<br>Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 5 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.30 | 3.0 | 70.0 | 6.0 | 485.76 | 310.3 | 0.180 | 87.44 | 123.8 | 211.3 | 1.47 | 4.11 | 1.50 | 107.25 | 103.39 |
| 0.31 | 3.0 | 70.0 | 6.0 | 495.40 | 310.3 | 0.180 | 89.17 | 123.8 | 213.0 | 1.46 | 4.00 | 1.50 | 104.52 | 108.26 |
| 0.32 | 3.0 | 70.0 | 6.0 | 505.07 | 310.3 | 0.180 | 90.91 | 123.8 | 214.7 | 1.44 | 3.90 | 1.50 | 101.81 | 113.23 |
| 0.33 | 3.0 | 70.0 | 6.0 | 514.76 | 310.3 | 0.180 | 92.66 | 123.8 | 216.5 | 1.43 | 3.80 | 1.50 | 99.15 | 118.29 |
| 0.34 | 3.0 | 70.0 | 6.0 | 524.49 | 310.3 | 0.180 | 94.41 | 123.8 | 218.2 | 1.42 | 3.69 | 1.50 | 96.52 | 123.45 |
| 0.35 | 3.0 | 70.0 | 6.0 | 534.24 | 310.3 | 0.180 | 96.16 | 123.8 | 220.0 | 1.41 | 3.59 | 1.50 | 93.92 | 128.70 |
| 0.36 | 3.0 | 70.0 | 6.0 | 544.02 | 310.3 | 0.180 | 97.92 | 123.8 | 221.8 | 1.40 | 3.50 | 1.50 | 91.36 | 134.04 |

**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

**PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS** DATE: 26/08/2014

**IFD data for Bonniefield 1 in 50 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |

| CATCHEMNT A | | CATCHMENT A1 + E1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.73 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 2.39 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 31.71 | Catchment area - Lots ha | 28.98 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 1.5855 | Impervious area - ha | 3.4840 |
| Length of flow - m | 710.0 | Length of flow - m | 900.0 |
| Catchment top RL | 20.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 8.0 | Catchment Base RL | 8.0 |
| Ground slope to culvert S | 0.017 | Ground slope to culvert S | 0.029 |
| Time - min | 45.50 | Time - min | 37.31 |
| Intensity - mm/hr | 41 | Intensity - mm/hr | 46 |
| Inflow - litres/sec | 179.6 | Inflow - litres/sec | 447.4 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 20 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.37 | 3.0 | 70.0 | 6.0 | 553.83 | 447.4 | 0.180 | 99.69 | 179.6 | 279.3 | 1.60 | 5.98 | 1.90 | 186.81 | 139.49 |
| 0.38 | 3.0 | 70.0 | 6.0 | 563.67 | 447.4 | 0.180 | 101.46 | 179.6 | 281.1 | 1.59 | 5.83 | 1.90 | 182.14 | 145.02 |
| 0.39 | 3.0 | 70.0 | 6.0 | 573.54 | 447.4 | 0.180 | 103.24 | 179.6 | 282.9 | 1.58 | 5.68 | 1.90 | 177.44 | 150.66 |
| 0.40 | 3.0 | 70.0 | 6.0 | 583.44 | 447.4 | 0.180 | 105.02 | 179.6 | 284.7 | 1.57 | 5.53 | 1.90 | 172.72 | 156.38 |
| 0.41 | 3.0 | 70.0 | 6.0 | 593.37 | 447.4 | 0.180 | 106.81 | 179.6 | 286.4 | 1.56 | 5.38 | 1.90 | 167.98 | 162.21 |
| 0.42 | 3.0 | 70.0 | 6.0 | 603.32 | 447.4 | 0.180 | 108.60 | 179.6 | 288.2 | 1.55 | 5.23 | 1.90 | 163.22 | 168.13 |
| 0.43 | 3.0 | 70.0 | 6.0 | 613.31 | 447.4 | 0.180 | 110.40 | 179.6 | 290.0 | 1.54 | 5.08 | 1.90 | 158.44 | 174.15 |

**IFD data for Bonniefield 1 in 100 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

| CATCHEMNT A | | CATCHMENT A1 + E1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.73 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 2.39 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 31.71 | Catchment area - Lots ha | 28.98 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 1.5855 | Impervious area - ha | 3.4840 |
| Length of flow - m | 710.0 | Length of flow - m | 900.0 |
| Catchment top RL | 20.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 8.0 | Catchment Base RL | 8.0 |
| Ground slope to culvert S | 0.017 | Ground slope to culvert S | 0.029 |
| Time - min | 38.81 | Time - min | 31.72 |
| Intensity - mm/hr | 61 | Intensity - mm/hr | 69 |
| Inflow - litres/sec | 267.5 | Inflow - litres/sec | 666.9 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

## Sheet 2 of 2

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 100 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.54 | 3.0 | 70.0 | 6.0 | 725.03 | 666.9 | 0.180 | 130.51 | 267.5 | 398.0 | 1.68 | 7.02 | 2.35 | 250.36 | 246.79 |
| 0.55 | 3.0 | 70.0 | 6.0 | 735.36 | 666.9 | 0.180 | 132.36 | 267.5 | 399.8 | 1.67 | 6.92 | 2.35 | 246.65 | 253.98 |
| 0.56 | 3.0 | 70.0 | 6.0 | 745.72 | 666.9 | 0.180 | 134.23 | 267.5 | 401.7 | 1.66 | 6.81 | 2.35 | 242.93 | 261.28 |
| 0.57 | 3.0 | 70.0 | 6.0 | 756.11 | 666.9 | 0.180 | 136.10 | 267.5 | 403.6 | 1.65 | 6.71 | 2.35 | 239.19 | 268.67 |
| 0.58 | 3.0 | 70.0 | 6.0 | 766.52 | 666.9 | 0.180 | 137.97 | 267.5 | 405.4 | 1.64 | 6.60 | 2.35 | 235.44 | 276.17 |
| 0.59 | 3.0 | 70.0 | 6.0 | 776.97 | 666.9 | 0.180 | 139.85 | 267.5 | 407.3 | 1.64 | 6.50 | 2.35 | 231.67 | 283.76 |
| 0.60 | 3.0 | 70.0 | 6.0 | 787.44 | 666.9 | 0.180 | 141.74 | 267.5 | 409.2 | 1.63 | 6.39 | 2.35 | 227.88 | 291.46 |

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## PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield

## PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS

**DATE:** 26/08/2014

**IFD data for Bonniefield 1 in 1 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |

| CATCHMENT B | | CATCHMENT B1 (POS BUFFER) | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.00 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.00 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 8.56 | Catchment area - Lots ha | 6.73 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.4280 | Impervious area - ha | 0.3365 |
| Length of flow - m | 260.0 | Length of flow - m | 360.0 |
| Catchment top RL | 23.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 10.0 | Catchment Base RL | 10.0 |
| Ground slope to culvert S | 0.050 | Ground slope to culvert S | 0.067 |
| Time - min | 20.38 | Time - min | 19.62 |
| Intensity - mm/hr | 30 | Intensity - mm/hr | 31 |
| Inflow - litres/sec | 36.1 | Inflow - litres/sec | 29.0 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 1 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 6.0 | 0.00 | 29.0 | 0.180 | 0.00 | 36.1 | 36.1 | 0.80 | -1.73 | 1.00 | 0.00 | 0.00 |
| 0.01 | 0.0 | 0.0 | 6.0 | 0.01 | 29.0 | 0.180 | 0.00 | 36.1 | 36.1 | 0.80 | -1.73 | 1.00 | 0.00 | 0.00 |
| 0.02 | 0.0 | 0.0 | 6.0 | 0.06 | 29.0 | 0.180 | 0.01 | 36.1 | 36.1 | 0.80 | -1.73 | 1.00 | 0.00 | 0.00 |
| 0.03 | 0.0 | 0.0 | 6.0 | 0.13 | 29.0 | 0.180 | 0.02 | 36.1 | 36.1 | 0.80 | -1.74 | 1.00 | 0.00 | 0.00 |
| 0.04 | 0.0 | 0.0 | 6.0 | 0.23 | 29.0 | 0.180 | 0.04 | 36.1 | 36.2 | 0.80 | -1.74 | 1.00 | 0.00 | 0.00 |
| 0.05 | 0.0 | 0.0 | 6.0 | 0.36 | 29.0 | 0.180 | 0.06 | 36.1 | 36.2 | 0.80 | -1.74 | 1.00 | 0.00 | 0.00 |
| 0.06 | 0.0 | 0.0 | 6.0 | 0.52 | 29.0 | 0.180 | 0.09 | 36.1 | 36.2 | 0.80 | -1.75 | 1.00 | 0.00 | 0.01 |

**IFD data for Bonniefield 1 in 5 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |

| CATCHMENT B | | CATCHMENT B1 (POS BUFFER) | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.00 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.00 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 8.56 | Catchment area - Lots ha | 6.73 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.4280 | Impervious area - ha | 0.3365 |
| Length of flow - m | 260.0 | Length of flow - m | 360.0 |
| Catchment top RL | 23.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 10.0 | Catchment Base RL | 10.0 |
| Ground slope to culvert S | 0.050 | Ground slope to culvert S | 0.067 |
| Time - min | 15.66 | Time - min | 15.17 |
| Intensity - mm/hr | 58 | Intensity - mm/hr | 59 |
| Inflow - litres/sec | 68.7 | Inflow - litres/sec | 54.9 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 5 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 6.0 | 0.00 | 54.9 | 0.180 | 0.00 | 68.7 | 68.7 | 0.80 | -1.76 | 1.50 | 0.00 | 0.00 |
| 0.01 | 0.0 | 0.0 | 6.0 | 0.01 | 54.9 | 0.180 | 0.00 | 68.7 | 68.7 | 0.80 | -1.76 | 1.50 | 0.00 | 0.00 |
| 0.02 | 0.0 | 0.0 | 6.0 | 0.06 | 54.9 | 0.180 | 0.01 | 68.7 | 68.7 | 0.80 | -1.76 | 1.50 | 0.00 | 0.00 |
| 0.03 | 0.0 | 0.0 | 6.0 | 0.13 | 54.9 | 0.180 | 0.02 | 68.7 | 68.7 | 0.80 | -1.76 | 1.50 | 0.00 | 0.00 |
| 0.04 | 0.0 | 0.0 | 6.0 | 0.23 | 54.9 | 0.180 | 0.04 | 68.7 | 68.7 | 0.80 | -1.76 | 1.50 | 0.00 | 0.00 |
| 0.05 | 0.0 | 0.0 | 6.0 | 0.36 | 54.9 | 0.180 | 0.06 | 68.7 | 68.7 | 0.80 | -1.76 | 1.50 | 0.00 | 0.00 |
| 0.06 | 0.0 | 0.0 | 6.0 | 0.52 | 54.9 | 0.180 | 0.09 | 68.7 | 68.8 | 0.80 | -1.77 | 1.50 | 0.00 | 0.01 |

**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

**PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS** **DATE:** **26/08/2014**

**IFD data for Bonniefield 1 in 50 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |

| **CATCHMENT B** | | **CATCHMENT B1 (POS BUFFER)** | |
|---|---|---|---|
| **Predevelopment** | | **Post development** | |
| **Catchment area - Rds ha** | 0.00 | **Catchment area - Rds ha** | 0.00 |
| **Runoff Coefficient % Rds** | 90.0 | **Runoff Coefficient % Rds** | 90.0 |
| **Catchment area - Verges ha** | 0.00 | **Catchment area - Verges ha** | 0.00 |
| **Runoff Coefficient % Verges** | 20.0 | **Runoff Coefficient % Verges** | 20.0 |
| **Catchment area - Lots ha** | 8.56 | **Catchment area - Lots ha** | 6.73 |
| **Runoff Coefficient % Lots** | 5.0 | **Runoff Coefficient % Lots** | 5.0 |
| **Impervious area - ha** | 0.4280 | **Impervious area - ha** | 0.3365 |
| **Length of flow - m** | 260.0 | **Length of flow - m** | 360.0 |
| **Catchment top RL** | 23.0 | **Catchment top RL** | 34.0 |
| **Catchment Base RL** | 10.0 | **Catchment Base RL** | 10.0 |
| **Ground slope to culvert S** | 0.050 | **Ground slope to culvert S** | 0.067 |
| **Time - min** | 13.56 | **Time - min** | 13.23 |
| **Intensity - mm/hr** | 83 | **Intensity - mm/hr** | 84 |
| **Inflow - litres/sec** | 98.5 | **Inflow - litres/sec** | 78.4 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 20 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 6.0 | 0.00 | 78.4 | 0.180 | 0.00 | 98.5 | 98.5 | 0.80 | -1.78 | 1.90 | 0.00 | 0.00 |
| 0.01 | 0.0 | 0.0 | 6.0 | 0.01 | 78.4 | 0.180 | 0.00 | 98.5 | 98.5 | 0.80 | -1.78 | 1.90 | 0.00 | 0.00 |
| 0.02 | 0.0 | 0.0 | 6.0 | 0.06 | 78.4 | 0.180 | 0.01 | 98.5 | 98.5 | 0.80 | -1.78 | 1.90 | 0.00 | 0.00 |
| 0.03 | 0.0 | 0.0 | 6.0 | 0.13 | 78.4 | 0.180 | 0.02 | 98.5 | 98.5 | 0.80 | -1.78 | 1.90 | 0.00 | 0.00 |
| 0.04 | 0.0 | 0.0 | 6.0 | 0.23 | 78.4 | 0.180 | 0.04 | 98.5 | 98.5 | 0.80 | -1.79 | 1.90 | 0.00 | 0.00 |
| 0.05 | 0.0 | 0.0 | 6.0 | 0.36 | 78.4 | 0.180 | 0.06 | 98.5 | 98.6 | 0.80 | -1.79 | 1.90 | 0.00 | 0.00 |
| 0.06 | 0.0 | 0.0 | 6.0 | 0.52 | 78.4 | 0.180 | 0.09 | 98.5 | 98.6 | 0.80 | -1.79 | 1.90 | 0.00 | 0.01 |

**IFD data for Bonniefield 1 in 100 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

| **CATCHMENT B** | | **CATCHMENT B1 (POS BUFFER)** | |
|---|---|---|---|
| **Predevelopment** | | **Post development** | |
| **Catchment area - Rds ha** | 0.00 | **Catchment area - Rds ha** | 0.00 |
| **Runoff Coefficient % Rds** | 90.0 | **Runoff Coefficient % Rds** | 90.0 |
| **Catchment area - Verges ha** | 0.00 | **Catchment area - Verges ha** | 0.00 |
| **Runoff Coefficient % Verges** | 20.0 | **Runoff Coefficient % Verges** | 20.0 |
| **Catchment area - Lots ha** | 8.56 | **Catchment area - Lots ha** | 6.73 |
| **Runoff Coefficient % Lots** | 5.0 | **Runoff Coefficient % Lots** | 5.0 |
| **Impervious area - ha** | 0.4280 | **Impervious area - ha** | 0.3365 |
| **Length of flow - m** | 260.0 | **Length of flow - m** | 360.0 |
| **Catchment top RL** | 23.0 | **Catchment top RL** | 34.0 |
| **Catchment Base RL** | 10.0 | **Catchment Base RL** | 10.0 |
| **Ground slope to culvert S** | 0.050 | **Ground slope to culvert S** | 0.067 |
| **Time - min** | 11.63 | **Time - min** | 11.27 |
| **Intensity - mm/hr** | 122 | **Intensity - mm/hr** | 124 |
| **Inflow - litres/sec** | 145.3 | **Inflow - litres/sec** | 116.0 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.



**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 100 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.0 | 0.0 | 6.0 | 0.00 | 116.0 | 0.180 | 0.00 | 145.3 | 145.3 | 0.80 | -1.76 | 2.35 | 0.00 | 0.00 |
| 0.01 | 0.0 | 0.0 | 6.0 | 0.01 | 116.0 | 0.180 | 0.00 | 145.3 | 145.3 | 0.80 | -1.76 | 2.35 | 0.00 | 0.00 |
| 0.02 | 0.0 | 0.0 | 6.0 | 0.06 | 116.0 | 0.180 | 0.01 | 145.3 | 145.3 | 0.80 | -1.76 | 2.35 | 0.00 | 0.00 |
| 0.03 | 0.0 | 0.0 | 6.0 | 0.13 | 116.0 | 0.180 | 0.02 | 145.3 | 145.3 | 0.80 | -1.76 | 2.35 | 0.00 | 0.00 |
| 0.04 | 0.0 | 0.0 | 6.0 | 0.23 | 116.0 | 0.180 | 0.04 | 145.3 | 145.3 | 0.80 | -1.76 | 2.35 | 0.00 | 0.00 |
| 0.05 | 0.0 | 0.0 | 6.0 | 0.36 | 116.0 | 0.180 | 0.06 | 145.3 | 145.3 | 0.80 | -1.77 | 2.35 | 0.00 | 0.00 |
| 0.06 | 0.0 | 0.0 | 6.0 | 0.52 | 116.0 | 0.180 | 0.09 | 145.3 | 145.4 | 0.80 | -1.77 | 2.35 | 0.00 | 0.01 |

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## PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield

## PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS

**DATE:** **26/08/2014**

**IFD data for Bonniefield 1 in 1 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |

| CATCHMENT C | | CATCHMENT C1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.36 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 1.88 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 17.18 | Catchment area - Lots ha | 18.01 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.8590 | Impervious area - ha | 2.5005 |
| Length of flow - m | 550.0 | Length of flow - m | 830.0 |
| Catchment top RL | 19.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 9.0 |
| Ground slope to culvert S | 0.018 | Ground slope to culvert S | 0.030 |
| Time - min | 54.31 | Time - min | 52.26 |
| Intensity - mm/hr | 17 | Intensity - mm/hr | 17 |
| Inflow - litres/sec | 40.4 | Inflow - litres/sec | 120.7 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 1 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.23 | 3.0 | 30.0 | 10.0 | 262.96 | 120.7 | 0.180 | 47.33 | 40.4 | 87.8 | 1.38 | 3.29 | 1.00 | 48.40 | 39.37 |
| 0.24 | 3.0 | 30.0 | 10.0 | 271.44 | 120.7 | 0.180 | 48.86 | 40.4 | 89.3 | 1.35 | 3.08 | 1.00 | 45.36 | 41.99 |
| 0.25 | 3.0 | 30.0 | 10.0 | 280.00 | 120.7 | 0.180 | 50.40 | 40.4 | 90.8 | 1.33 | 2.88 | 1.00 | 42.41 | 44.69 |
| 0.26 | 3.0 | 30.0 | 10.0 | 288.64 | 120.7 | 0.180 | 51.96 | 40.4 | 92.4 | 1.31 | 2.68 | 1.00 | 39.52 | 47.47 |
| 0.27 | 3.0 | 30.0 | 10.0 | 297.36 | 120.7 | 0.180 | 53.52 | 40.4 | 94.0 | 1.28 | 2.49 | 1.00 | 36.71 | 50.33 |
| 0.28 | 3.0 | 30.0 | 10.0 | 306.16 | 120.7 | 0.180 | 55.11 | 40.4 | 95.6 | 1.26 | 2.31 | 1.00 | 33.96 | 53.27 |
| 0.29 | 3.0 | 30.0 | 10.0 | 315.04 | 120.7 | 0.180 | 56.71 | 40.4 | 97.2 | 1.24 | 2.12 | 1.00 | 31.28 | 56.29 |

**IFD data for Bonniefield 1 in 5 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |

| CATCHMENT C | | CATCHMENT C1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.36 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 1.88 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 17.18 | Catchment area - Lots ha | 18.01 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.8590 | Impervious area - ha | 2.5005 |
| Length of flow - m | 550.0 | Length of flow - m | 830.0 |
| Catchment top RL | 19.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 9.0 |
| Ground slope to culvert S | 0.018 | Ground slope to culvert S | 0.030 |
| Time - min | 41.65 | Time - min | 39.61 |
| Intensity - mm/hr | 33 | Intensity - mm/hr | 34 |
| Inflow - litres/sec | 78.2 | Inflow - litres/sec | 234.9 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 5 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.40 | 3.0 | 30.0 | 10.0 | 418.00 | 234.9 | 0.180 | 75.24 | 78.2 | 153.4 | 1.53 | 4.89 | 1.50 | 96.86 | 95.20 |
| 0.41 | 3.0 | 30.0 | 10.0 | 427.84 | 234.9 | 0.180 | 77.01 | 78.2 | 155.2 | 1.51 | 4.60 | 1.50 | 91.13 | 99.27 |
| 0.42 | 3.0 | 30.0 | 10.0 | 437.76 | 234.9 | 0.180 | 78.80 | 78.2 | 157.0 | 1.50 | 4.35 | 1.50 | 86.13 | 103.42 |
| 0.43 | 3.0 | 30.0 | 10.0 | 447.76 | 234.9 | 0.180 | 80.60 | 78.2 | 158.8 | 1.48 | 4.20 | 1.50 | 83.18 | 107.67 |
| 0.44 | 3.0 | 30.0 | 10.0 | 457.84 | 234.9 | 0.180 | 82.41 | 78.2 | 160.6 | 1.46 | 4.05 | 1.50 | 80.28 | 112.01 |
| 0.45 | 3.0 | 30.0 | 10.0 | 468.00 | 234.9 | 0.180 | 84.24 | 78.2 | 162.4 | 1.45 | 3.91 | 1.50 | 77.42 | 116.44 |
| 0.46 | 3.0 | 30.0 | 10.0 | 478.24 | 234.9 | 0.180 | 86.08 | 78.2 | 164.3 | 1.43 | 3.77 | 1.50 | 74.61 | 120.96 |

**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

**PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS** **DATE: 26/08/2014**

**IFD data for Bonniefield 1 in 50 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |

| CATCHMENT C | | CATCHMENT C1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.36 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 1.88 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 17.18 | Catchment area - Lots ha | 18.01 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.8590 | Impervious area - ha | 2.5005 |
| Length of flow - m | 550.0 | Length of flow - m | 830.0 |
| Catchment top RL | 19.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 9.0 |
| Ground slope to culvert S | 0.018 | Ground slope to culvert S | 0.030 |
| Time - min | 36.16 | Time - min | 34.22 |
| Intensity - mm/hr | 47 | Intensity - mm/hr | 49 |
| Inflow - litres/sec | 112.5 | Inflow - litres/sec | 338.8 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

| SOAKAGE/STORAGE/SIZING - COPAS FORMULA | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 20 ys | Post Develop Storage required m3 | Storage available at depth m3 |
| 0.48 | 3.0 | 30.0 | 10.0 | 498.96 | 338.8 | 0.180 | 89.81 | 112.5 | 202.3 | 1.67 | 7.01 | 1.90 | 166.49 | 130.29 |
| 0.49 | 3.0 | 30.0 | 10.0 | 509.44 | 338.8 | 0.180 | 91.70 | 112.5 | 204.2 | 1.66 | 6.80 | 1.90 | 161.55 | 135.10 |
| 0.50 | 3.0 | 30.0 | 10.0 | 520.00 | 338.8 | 0.180 | 93.60 | 112.5 | 206.1 | 1.64 | 6.59 | 1.90 | 156.56 | 140.00 |
| 0.51 | 3.0 | 30.0 | 10.0 | 530.64 | 338.8 | 0.180 | 95.52 | 112.5 | 208.0 | 1.63 | 6.38 | 1.90 | 151.52 | 145.00 |
| 0.52 | 3.0 | 30.0 | 10.0 | 541.36 | 338.8 | 0.180 | 97.44 | 112.5 | 209.9 | 1.61 | 6.16 | 1.90 | 146.42 | 150.09 |
| 0.53 | 3.0 | 30.0 | 10.0 | 552.16 | 338.8 | 0.180 | 99.39 | 112.5 | 211.9 | 1.60 | 5.95 | 1.90 | 141.28 | 155.28 |
| 0.54 | 3.0 | 30.0 | 10.0 | 563.04 | 338.8 | 0.180 | 101.35 | 112.5 | 213.8 | 1.58 | 5.73 | 1.90 | 136.08 | 160.57 |

**IFD data for Bonniefield 1 in 100 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

| CATCHMENT C | | CATCHMENT C1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 1.36 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 1.88 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 17.18 | Catchment area - Lots ha | 18.01 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.8590 | Impervious area - ha | 2.5005 |
| Length of flow - m | 550.0 | Length of flow - m | 830.0 |
| Catchment top RL | 19.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 9.0 |
| Ground slope to culvert S | 0.018 | Ground slope to culvert S | 0.030 |
| Time - min | 30.83 | Time - min | 29.34 |
| Intensity - mm/hr | 70 | Intensity - mm/hr | 72 |
| Inflow - litres/sec | 167.4 | Inflow - litres/sec | 502.3 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.



| SOAKAGE/STORAGE/SIZING - COPAS FORMULA | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 100 ys | Post Develop Storage required m3 | Storage available at depth m3 |
| 0.59 | 3.0 | 30.0 | 10.0 | 618.64 | 502.3 | 0.180 | 111.36 | 167.4 | 278.7 | 1.80 | 8.57 | 2.35 | 232.52 | 188.51 |
| 0.60 | 3.0 | 30.0 | 10.0 | 630.00 | 502.3 | 0.180 | 113.40 | 167.4 | 280.8 | 1.79 | 8.42 | 2.35 | 228.48 | 194.40 |
| 0.61 | 3.0 | 30.0 | 10.0 | 641.44 | 502.3 | 0.180 | 115.46 | 167.4 | 282.8 | 1.78 | 8.27 | 2.35 | 224.41 | 200.39 |
| 0.62 | 3.0 | 30.0 | 10.0 | 652.96 | 502.3 | 0.180 | 117.53 | 167.4 | 284.9 | 1.76 | 8.12 | 2.35 | 220.30 | 206.48 |
| 0.63 | 3.0 | 30.0 | 10.0 | 664.56 | 502.3 | 0.180 | 119.62 | 167.4 | 287.0 | 1.75 | 7.96 | 2.35 | 216.15 | 212.68 |
| 0.64 | 3.0 | 30.0 | 10.0 | 676.24 | 502.3 | 0.180 | 121.72 | 167.4 | 289.1 | 1.74 | 7.81 | 2.35 | 211.96 | 218.98 |
| 0.65 | 3.0 | 30.0 | 10.0 | 688.00 | 502.3 | 0.180 | 123.84 | 167.4 | 291.2 | 1.72 | 7.65 | 2.35 | 207.74 | 225.39 |

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**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

**PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS** **DATE:** **26/08/2014**

**IFD data for Bonniefield 1 in 1 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |

| CATCHMENT D | | CATCHMENT D1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.23 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.31 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 5.02 | Catchment area - Lots ha | 3.85 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.2510 | Impervious area - ha | 0.4615 |
| Length of flow - m | 260.0 | Length of flow - m | 270.0 |
| Catchment top RL | 21.0 | Catchment top RL | 20.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 10.0 |
| Ground slope to culvert S | 0.054 | Ground slope to culvert S | 0.037 |
| Time - min | 19.65 | Time - min | 19.69 |
| Intensity - mm/hr | 31 | Intensity - mm/hr | 31 |
| Inflow - litres/sec | 21.6 | Inflow - litres/sec | 39.7 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

SOAKAGE/STORAGE/SIZING - COPAS FORMULA

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 1 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.21 | 0.5 | 5.0 | 10.0 | 43.24 | 39.7 | 0.180 | 7.78 | 21.6 | 29.4 | 1.35 | 3.07 | 1.00 | 5.28 | 3.88 |
| 0.22 | 0.5 | 5.0 | 10.0 | 46.06 | 39.7 | 0.180 | 8.29 | 21.6 | 29.9 | 1.33 | 2.87 | 1.00 | 4.94 | 4.28 |
| 0.23 | 0.5 | 5.0 | 10.0 | 48.96 | 39.7 | 0.180 | 8.81 | 21.6 | 30.4 | 1.30 | 2.67 | 1.00 | 4.59 | 4.70 |
| 0.24 | 0.5 | 5.0 | 10.0 | 51.94 | 39.7 | 0.180 | 9.35 | 21.6 | 30.9 | 1.28 | 2.47 | 1.00 | 4.25 | 5.15 |
| 0.25 | 0.5 | 5.0 | 10.0 | 55.00 | 39.7 | 0.180 | 9.90 | 21.6 | 31.5 | 1.26 | 2.27 | 1.00 | 3.91 | 5.63 |
| 0.26 | 0.5 | 5.0 | 10.0 | 58.14 | 39.7 | 0.180 | 10.47 | 21.6 | 32.1 | 1.24 | 2.08 | 1.00 | 3.58 | 6.13 |
| 0.27 | 0.5 | 5.0 | 10.0 | 61.36 | 39.7 | 0.180 | 11.04 | 21.6 | 32.6 | 1.22 | 1.89 | 1.00 | 3.25 | 6.65 |

**IFD data for Bonniefield 1 in 5 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |

| CATCHMENT D | | CATCHMENT D1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.23 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.31 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 5.02 | Catchment area - Lots ha | 3.85 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.2510 | Impervious area - ha | 0.4615 |
| Length of flow - m | 260.0 | Length of flow - m | 270.0 |
| Catchment top RL | 21.0 | Catchment top RL | 20.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 10.0 |
| Ground slope to culvert S | 0.054 | Ground slope to culvert S | 0.037 |
| Time - min | 15.19 | Time - min | 15.33 |
| Intensity - mm/hr | 59 | Intensity - mm/hr | 58 |
| Inflow - litres/sec | 40.9 | Inflow - litres/sec | 74.9 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

SOAKAGE/STORAGE/SIZING - COPAS FORMULA

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 5 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.29 | 0.5 | 5.0 | 10.0 | 68.04 | 74.9 | 0.180 | 12.25 | 40.9 | 53.2 | 1.41 | 3.58 | 1.50 | 8.36 | 7.79 |
| 0.30 | 0.5 | 5.0 | 10.0 | 71.50 | 74.9 | 0.180 | 12.87 | 40.9 | 53.8 | 1.39 | 3.44 | 1.50 | 8.03 | 8.40 |
| 0.31 | 0.5 | 5.0 | 10.0 | 75.04 | 74.9 | 0.180 | 13.51 | 40.9 | 54.4 | 1.38 | 3.29 | 1.50 | 7.69 | 9.04 |
| 0.32 | 0.5 | 5.0 | 10.0 | 78.66 | 74.9 | 0.180 | 14.16 | 40.9 | 55.1 | 1.36 | 3.15 | 1.50 | 7.36 | 9.71 |
| 0.33 | 0.5 | 5.0 | 10.0 | 82.36 | 74.9 | 0.180 | 14.82 | 40.9 | 55.7 | 1.34 | 3.01 | 1.50 | 7.03 | 10.41 |
| 0.34 | 0.5 | 5.0 | 10.0 | 86.14 | 74.9 | 0.180 | 15.51 | 40.9 | 56.4 | 1.33 | 2.87 | 1.50 | 6.70 | 11.14 |
| 0.35 | 0.5 | 5.0 | 10.0 | 90.00 | 74.9 | 0.180 | 16.20 | 40.9 | 57.1 | 1.31 | 2.72 | 1.50 | 6.37 | 11.90 |

**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

**PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS** **DATE:** 26/08/2014

IFD data for Bonniefield 1 in 50 year event

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |

| CATCHMENT D | | CATCHMENT D1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.23 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.31 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 5.02 | Catchment area - Lots ha | 3.85 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.2510 | Impervious area - ha | 0.4615 |
| Length of flow - m | 260.0 | Length of flow - m | 270.0 |
| Catchment top RL | 21.0 | Catchment top RL | 20.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 10.0 |
| Ground slope to culvert S | 0.054 | Ground slope to culvert S | 0.037 |
| Time - min | 13.19 | Time - min | 13.22 |
| Intensity - mm/hr | 84 | Intensity - mm/hr | 84 |
| Inflow - litres/sec | 58.6 | Inflow - litres/sec | 107.6 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

SOAKAGE/STORAGE/SIZING - COPAS FORMULA

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 20 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.32 | 0.5 | 5.0 | 10.0 | 78.66 | 107.6 | 0.180 | 14.16 | 58.6 | 72.8 | 1.48 | 4.20 | 1.90 | 11.79 | 9.71 |
| 0.33 | 0.5 | 5.0 | 10.0 | 82.36 | 107.6 | 0.180 | 14.82 | 58.6 | 73.4 | 1.47 | 4.08 | 1.90 | 11.46 | 10.41 |
| 0.34 | 0.5 | 5.0 | 10.0 | 86.14 | 107.6 | 0.180 | 15.51 | 58.6 | 74.1 | 1.45 | 3.96 | 1.90 | 11.13 | 11.14 |
| 0.35 | 0.5 | 5.0 | 10.0 | 90.00 | 107.6 | 0.180 | 16.20 | 58.6 | 74.8 | 1.44 | 3.85 | 1.90 | 10.79 | 11.90 |
| 0.36 | 0.5 | 5.0 | 10.0 | 93.94 | 107.6 | 0.180 | 16.91 | 58.6 | 75.5 | 1.43 | 3.73 | 1.90 | 10.46 | 12.69 |
| 0.37 | 0.5 | 5.0 | 10.0 | 97.96 | 107.6 | 0.180 | 17.63 | 58.6 | 76.2 | 1.41 | 3.61 | 1.90 | 10.13 | 13.52 |
| 0.38 | 0.5 | 5.0 | 10.0 | 102.06 | 107.6 | 0.180 | 18.37 | 58.6 | 77.0 | 1.40 | 3.49 | 1.90 | 9.80 | 14.38 |

IFD data for Bonniefield 1 in 100 year event

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

| CATCHMENT D | | CATCHMENT D1 | |
|---|---|---|---|
| Predevelopment | | Post development | |
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.23 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.31 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 5.02 | Catchment area - Lots ha | 3.85 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.2510 | Impervious area - ha | 0.4615 |
| Length of flow - m | 260.0 | Length of flow - m | 270.0 |
| Catchment top RL | 21.0 | Catchment top RL | 20.0 |
| Catchment Base RL | 9.0 | Catchment Base RL | 10.0 |
| Ground slope to culvert S | 0.054 | Ground slope to culvert S | 0.037 |
| Time - min | 11.29 | Time - min | 11.31 |
| Intensity - mm/hr | 124 | Intensity - mm/hr | 124 |
| Inflow - litres/sec | 86.5 | Inflow - litres/sec | 158.9 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.



SOAKAGE/STORAGE/SIZING - COPAS FORMULA

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 100 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.34 | 0.5 | 5.0 | 10.0 | 86.14 | 158.9 | 0.180 | 15.51 | 86.5 | 102.0 | 1.56 | 5.32 | 2.35 | 17.10 | 11.14 |
| 0.35 | 0.5 | 5.0 | 10.0 | 90.00 | 158.9 | 0.180 | 16.20 | 86.5 | 102.7 | 1.55 | 5.15 | 2.35 | 16.57 | 11.90 |
| 0.36 | 0.5 | 5.0 | 10.0 | 93.94 | 158.9 | 0.180 | 16.91 | 86.5 | 103.4 | 1.54 | 4.98 | 2.35 | 16.02 | 12.69 |
| 0.37 | 0.5 | 5.0 | 10.0 | 97.96 | 158.9 | 0.180 | 17.63 | 86.5 | 104.1 | 1.53 | 4.80 | 2.35 | 15.46 | 13.52 |
| 0.38 | 0.5 | 5.0 | 10.0 | 102.06 | 158.9 | 0.180 | 18.37 | 86.5 | 104.8 | 1.52 | 4.63 | 2.35 | 14.88 | 14.38 |
| 0.39 | 0.5 | 5.0 | 10.0 | 106.24 | 158.9 | 0.180 | 19.12 | 86.5 | 105.6 | 1.50 | 4.44 | 2.35 | 14.30 | 15.27 |
| 0.40 | 0.5 | 5.0 | 10.0 | 110.50 | 158.9 | 0.180 | 19.89 | 86.5 | 106.4 | 1.49 | 4.32 | 2.35 | 13.91 | 16.20 |

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## PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield

## PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS

**DATE:** 26/08/2014

**IFD data for Bonniefield 1 in 1 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |

**CATCHEMENT E1**

| Predevelopment | | Post development | |
|---|---|---|---|
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.09 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.13 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 1.34 | Catchment area - Lots ha | 1.12 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.0670 | Impervious area - ha | 0.1630 |
| Length of flow - m | 200.0 | Length of flow - m | 200.0 |
| Catchment top RL | 34.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 22.0 | Catchment Base RL | 22.0 |
| Ground slope to culvert S | 0.060 | Ground slope to culvert S | 0.060 |
| Time - min | 15.50 | Time - min | 13.12 |
| Intensity - mm/hr | 35 | Intensity - mm/hr | 38 |
| Inflow - litres/sec | 6.5 | Inflow - litres/sec | 17.2 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 1 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.33 | 1.0 | 1.0 | 6.0 | 24.60 | 17.2 | 0.160 | 3.94 | 6.5 | 10.5 | 1.65 | 6.65 | 1.00 | 4.33 | 2.93 |
| 0.34 | 1.0 | 1.0 | 6.0 | 25.81 | 17.2 | 0.180 | 4.65 | 6.5 | 11.2 | 1.54 | 5.10 | 1.00 | 3.32 | 3.14 |
| 0.35 | 1.0 | 1.0 | 6.0 | 27.04 | 17.2 | 0.180 | 4.87 | 6.5 | 11.4 | 1.51 | 4.60 | 1.00 | 3.00 | 3.36 |
| 0.36 | 1.0 | 1.0 | 6.0 | 28.30 | 17.2 | 0.180 | 5.09 | 6.5 | 11.6 | 1.48 | 4.24 | 1.00 | 2.76 | 3.59 |
| 0.37 | 1.0 | 1.0 | 6.0 | 29.59 | 17.2 | 0.180 | 5.33 | 6.5 | 11.8 | 1.46 | 3.99 | 1.00 | 2.59 | 3.84 |
| 0.38 | 1.0 | 1.0 | 6.0 | 30.91 | 17.2 | 0.180 | 5.56 | 6.5 | 12.1 | 1.43 | 3.74 | 1.00 | 2.43 | 4.09 |
| 0.39 | 1.0 | 1.0 | 6.0 | 32.26 | 17.2 | 0.180 | 5.81 | 6.5 | 12.3 | 1.40 | 3.49 | 1.00 | 2.27 | 4.35 |

**IFD data for Bonniefield 1 in 5 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |

**CATCHEMENT E1**

| Predevelopment | | Post development | |
|---|---|---|---|
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.09 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.13 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 1.34 | Catchment area - Lots ha | 1.12 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.0670 | Impervious area - ha | 0.1630 |
| Length of flow - m | 200.0 | Length of flow - m | 200.0 |
| Catchment top RL | 34.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 22.0 | Catchment Base RL | 22.0 |
| Ground slope to culvert S | 0.060 | Ground slope to culvert S | 0.060 |
| Time - min | 12.03 | Time - min | 10.16 |
| Intensity - mm/hr | 66 | Intensity - mm/hr | 72 |
| Inflow - litres/sec | 12.3 | Inflow - litres/sec | 32.5 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

**SOAKAGE/STORAGE/SIZING - COPAS FORMULA**

| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | Post develop basin Inflow l/sec | Soil head loss lit/sec/m2 | Outflow loss infiltration l/sec | Ouflow piped to pre-dev flow l/sec | Outflow total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 5 ys | Post Develop Storage required m3 | Storage available at depth m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.44 | 1.0 | 1.0 | 6.0 | 39.44 | 32.5 | 0.180 | 7.10 | 12.3 | 19.4 | 1.67 | 6.99 | 1.50 | 6.19 | 5.83 |
| 0.45 | 1.0 | 1.0 | 6.0 | 40.96 | 32.5 | 0.180 | 7.37 | 12.3 | 19.7 | 1.65 | 6.68 | 1.50 | 5.91 | 6.16 |
| 0.46 | 1.0 | 1.0 | 6.0 | 42.51 | 32.5 | 0.180 | 7.65 | 12.3 | 19.9 | 1.63 | 6.36 | 1.50 | 5.62 | 6.50 |
| 0.47 | 1.0 | 1.0 | 6.0 | 44.09 | 32.5 | 0.180 | 7.94 | 12.3 | 20.2 | 1.60 | 6.03 | 1.50 | 5.33 | 6.86 |
| 0.48 | 1.0 | 1.0 | 6.0 | 45.70 | 32.5 | 0.180 | 8.23 | 12.3 | 20.5 | 1.58 | 5.69 | 1.50 | 5.03 | 7.23 |
| 0.49 | 1.0 | 1.0 | 6.0 | 47.33 | 32.5 | 0.180 | 8.52 | 12.3 | 20.8 | 1.56 | 5.34 | 1.50 | 4.73 | 7.61 |
| 0.50 | 1.0 | 1.0 | 6.0 | 49.00 | 32.5 | 0.180 | 8.82 | 12.3 | 21.1 | 1.54 | 4.99 | 1.50 | 4.41 | 8.00 |

**PROJECT: Subdivision of Lots 4, 5 & 10 Francisco Road, Bonnoefield**

## PRE-DEVELOPMENT ANALYSIS AND MAIN BASIN STORAGE AND SIZING CALCULATIONS

**DATE:** **26/08/2014**

**IFD data for Bonniefield 1 in 50 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |

**CATCHEMENT E1**

| Predevelopment | | Post development | |
|---|---|---|---|
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.09 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.13 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 1.34 | Catchment area - Lots ha | 1.12 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.0670 | Impervious area - ha | 0.1630 |
| Length of flow - m | 200.0 | Length of flow - m | 200.0 |
| Catchment top RL | 34.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 22.0 | Catchment Base RL | 22.0 |
| Ground slope to culvert S | 0.060 | Ground slope to culvert S | 0.060 |
| Time - min | 10.40 | Time - min | 8.80 |
| Intensity - mm/hr | 95 | Intensity - mm/hr | 103 |
| Inflow - litres/sec | 17.6 | Inflow - litres/sec | 46.4 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.

| SOAKAGE/STORAGE/SIZING - COPAS FORMULA | | | | | Post develop | | Outflow | Ouflow | Outflow | | | | Post Develop | Storage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | basin Inflow l/sec | Soil head loss lit/sec/m2 | loss infiltration l/sec | piped to pre-dev flow l/sec | total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 20 ys | Storage required m3 | available at depth m3 |
| 0.46 | 1.0 | 1.0 | 6.0 | 42.51 | 46.4 | 0.180 | 7.65 | 17.6 | 25.3 | 1.84 | 8.94 | 1.90 | 9.49 | 6.50 |
| 0.47 | 1.0 | 1.0 | 6.0 | 44.09 | 46.4 | 0.180 | 7.94 | 17.6 | 25.6 | 1.82 | 8.72 | 1.90 | 9.26 | 6.86 |
| 0.48 | 1.0 | 1.0 | 6.0 | 45.70 | 46.4 | 0.180 | 8.23 | 17.6 | 25.9 | 1.80 | 8.49 | 1.90 | 9.01 | 7.23 |
| 0.49 | 1.0 | 1.0 | 6.0 | 47.33 | 46.4 | 0.180 | 8.52 | 17.6 | 26.1 | 1.78 | 8.26 | 1.90 | 8.77 | 7.61 |
| 0.50 | 1.0 | 1.0 | 6.0 | 49.00 | 46.4 | 0.180 | 8.82 | 17.6 | 26.4 | 1.75 | 8.02 | 1.90 | 8.52 | 8.00 |
| 0.51 | 1.0 | 1.0 | 6.0 | 50.69 | 46.4 | 0.180 | 9.12 | 17.6 | 26.8 | 1.73 | 7.78 | 1.90 | 8.26 | 8.41 |
| 0.52 | 1.0 | 1.0 | 6.0 | 52.42 | 46.4 | 0.180 | 9.44 | 17.6 | 27.1 | 1.72 | 7.53 | 1.90 | 8.00 | 8.83 |

**IFD data for Bonniefield 1 in 100 year event**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

**CATCHEMENT E1**

| Predevelopment | | Post development | |
|---|---|---|---|
| Catchment area - Rds ha | 0.00 | Catchment area - Rds ha | 0.09 |
| Runoff Coefficient % Rds | 90.0 | Runoff Coefficient % Rds | 90.0 |
| Catchment area - Verges ha | 0.00 | Catchment area - Verges ha | 0.13 |
| Runoff Coefficient % Verges | 20.0 | Runoff Coefficient % Verges | 20.0 |
| Catchment area - Lots ha | 1.34 | Catchment area - Lots ha | 1.12 |
| Runoff Coefficient % Lots | 5.0 | Runoff Coefficient % Lots | 5.0 |
| Impervious area - ha | 0.0670 | Impervious area - ha | 0.1630 |
| Length of flow - m | 200.0 | Length of flow - m | 200.0 |
| Catchment top RL | 34.0 | Catchment top RL | 34.0 |
| Catchment Base RL | 22.0 | Catchment Base RL | 22.0 |
| Ground slope to culvert S | 0.060 | Ground slope to culvert S | 0.060 |
| Time - min | 7.89 | Time - min | 7.57 |
| Intensity - mm/hr | 147 | Intensity - mm/hr | 150 |
| Inflow - litres/sec | 27.4 | Inflow - litres/sec | 68.0 |

Kinematic wave equation - Use n =0.05 for predevelopment n = 0.04 for post development)
The roughness coefficient for the pre development was chosen to be 0.05 because of the presence of sparse vegetation throughout the subject site
The roughness coefficient for the post development was chosen to be 0.04. this is because even though there will be the construction of impermeable surfaces within the subject site, when compared to the amount of permeable soils still remaining is quite insignificant, also it was chosen to include the added lag effect of the proposed weirs located within the roadside swales.



| SOAKAGE/STORAGE/SIZING - COPAS FORMULA | | | | | Post develop | | Outflow | Ouflow | Outflow | | | | Post Develop | Storage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of water in basin m | Basin width m | Basin length m | Basin side slope 1 in x | Wetted area m2 | basin Inflow l/sec | Soil head loss lit/sec/m2 | loss infiltration l/sec | piped to pre-dev flow l/sec | total l/sec | Ratio Inflow / Outflow | K | $F_y$ for 1 in 100 ys | Storage required m3 | available at depth m3 |
| 0.54 | 1.0 | 1.0 | 6.0 | 55.95 | 68.0 | 0.180 | 10.07 | 27.4 | 37.5 | 1.81 | 8.69 | 2.35 | 10.34 | 9.71 |
| 0.55 | 1.0 | 1.0 | 6.0 | 57.76 | 68.0 | 0.180 | 10.40 | 27.4 | 37.8 | 1.80 | 8.51 | 2.35 | 10.13 | 10.17 |
| 0.56 | 1.0 | 1.0 | 6.0 | 59.60 | 68.0 | 0.180 | 10.73 | 27.4 | 38.1 | 1.78 | 8.33 | 2.35 | 9.92 | 10.65 |
| 0.57 | 1.0 | 1.0 | 6.0 | 61.47 | 68.0 | 0.180 | 11.06 | 27.4 | 38.5 | 1.77 | 8.15 | 2.35 | 9.70 | 11.14 |
| 0.58 | 1.0 | 1.0 | 6.0 | 63.36 | 68.0 | 0.180 | 11.41 | 27.4 | 38.8 | 1.75 | 7.97 | 2.35 | 9.48 | 11.64 |
| 0.59 | 1.0 | 1.0 | 6.0 | 65.29 | 68.0 | 0.180 | 11.75 | 27.4 | 39.2 | 1.74 | 7.78 | 2.35 | 9.26 | 12.16 |
| 0.60 | 1.0 | 1.0 | 6.0 | 67.24 | 68.0 | 0.180 | 12.10 | 27.4 | 39.5 | 1.72 | 7.59 | 2.35 | 9.03 | 12.70 |

# APPENDIX G: Open Channel Flow Calculation Sheet

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## DETAILED OPEN CHANNEL FLOW CALCULATION SHEET

## PROJECT: Francisco Road, Bonniefield

**SECTION:** Catchment A1 + E1
**DATE:** 29.08.2014

| | | | |
|---|---|---|---|
| **Catchment area lots - m2** | 289800.0 | **1 in 100 year** | |
| **Runoff Coefficient** | 0.05 | | |
| **Catchment area roads - m2** | 17300.0 | | |
| **Runoff Coefficient** | 0.9 | | |
| **Catchment area verges - m2** | 23900.0 | | |
| **Runoff Coefficient** | 0.2 | | |
| **Impervious area - m2** | 34840.0 | | |
| **Length of overland flow - m** | 900.0 | | |
| **Catchment top RL** | 34.0 | | |
| **Catchment Base RL** | 9.0 | | |
| **Ground slope to culvert S** | 0.028 | | |
| **Time overland - min** | 32.48 | (Kinematic wave equation for open paddock Flow + retardation time in V-Drains which includes weirs) | |
| **Intensity - mm/hr** | 68 | (ARR polynomial formula) | **n= 0.04** |
| **Flow - litres/sec** | 657.3 | | |

**IFD data for Bonniefield area**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8267 | -0.6494 | -0.0114 | 0.0105 | -0.0025 | -0.0005 | 0.0001 |

| V-Drain FLOW ANALYSIS - MANNING FORMULA | | | | | Flow | Wetted | Hydraulic | V-Drain | Gutter Flow | Gutter Flow | Gutter Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of flow | Left side | Right side | Flow width | Manning's | section area | perimeter | radius | S | Q | Q | Velocity |
| mm | % | % | m | n | a | p | a/p = r | % | m3/sec | litres/sec | m/sec |
| 400 | 33.33 | 33.33 | 2.400 | 0.04 | 0.4800 | 2.5298 | 0.1897 | 2.000 | 0.560 | 560.3 | 1.167 |
| 410 | 33.33 | 33.33 | 2.460 | 0.04 | 0.5043 | 2.5931 | 0.1945 | 2.000 | 0.598 | 598.5 | 1.187 |
| 420 | 33.33 | 33.33 | 2.520 | 0.04 | 0.5292 | 2.6563 | 0.1992 | 2.000 | 0.638 | 638.2 | 1.206 |
| 430 | 33.33 | 33.33 | 2.580 | 0.04 | 0.5547 | 2.7196 | 0.2040 | 2.000 | 0.680 | 679.5 | 1.225 |
| 440 | 33.33 | 33.33 | 2.640 | 0.04 | 0.5808 | 2.7828 | 0.2087 | 2.000 | 0.722 | 722.5 | 1.244 |
| 450 | 33.33 | 33.33 | 2.700 | 0.04 | 0.6075 | 2.8460 | 0.2135 | 2.000 | 0.767 | 767.1 | 1.263 |

**SECTION:** Catchment C1

| | | | |
|---|---|---|---|
| **Catchment area lots - m2** | 180100.0 | | |
| **Runoff Coefficient** | 0.05 | | |
| **Catchment area roads - m2** | 13600.0 | **1 in 100 year** | |
| **Runoff Coefficient** | 0.9 | | |
| **Catchment area verges - m2** | 18800.0 | | |
| **Runoff Coefficient** | 0.2 | | |
| **Impervious area - m2** | 25005.0 | | |
| **Length of flow - m** | 495.0 | | |
| **Catchment top RL** | 24.0 | | |
| **Catchment Base RL** | 9.0 | | |
| **Ground slope to culvert S** | 0.030 | | |
| **Time - min** | 19.47 | (Kinematic wave equation) | **n= 0.04** |
| **Intensity - mm/hr** | 92 | (ARR polynomial formula) | |
| **Flow - litres/sec** | 641.3 | | |

**IFD data for Bonniefield area**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8267 | -0.6494 | -0.0114 | 0.0105 | -0.0025 | -0.0005 | 0.0001 |

| ROAD GUTTER FLOW ANALYSIS - MANNING FORMULA | | | | | Flow | Wetted | Hydraulic | V drain | V-Drain | V-Drain | V-Drain |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of flow | V drain | V drain | Flow width | Manning's | section area | perimeter | radius | Slope | Q | Q | Velocity |
| mm | x-fall LHS % | x-fall RHS % | m | n | a | p | a/p = r | % | m3/sec | litres/sec | m/sec |
| 430 | 33.33 | 33.33 | 2.580 | 0.04 | 0.5547 | 2.7196 | 0.2040 | 2.000 | 0.680 | 679.5 | 1.225 |
| 440 | 33.33 | 33.33 | 2.640 | 0.04 | 0.5808 | 2.7828 | 0.2087 | 1.400 | 0.604 | 604.5 | 1.041 |
| 450 | 33.33 | 33.33 | 2.700 | 0.04 | 0.6075 | 2.8460 | 0.2135 | 1.400 | 0.642 | 641.8 | 1.056 |
| 460 | 33.33 | 33.33 | 2.760 | 0.04 | 0.6348 | 2.9093 | 0.2182 | 1.400 | 0.681 | 680.5 | 1.072 |
| 470 | 33.33 | 33.33 | 2.820 | 0.04 | 0.6627 | 2.9725 | 0.2229 | 1.400 | 0.721 | 720.7 | 1.088 |
| 480 | 33.33 | 33.33 | 2.880 | 0.04 | 0.6912 | 3.0358 | 0.2277 | 1.400 | 0.762 | 762.3 | 1.103 |

# DETAILED OPEN CHANNEL FLOW CALCULATION SHEET

## PROJECT: Francisco Road, Bonniefield

**SECTION:** **Catchment D1**

**IFD data for Bonniefield area**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| 3.8267 | -0.6494 | -0.0114 | 0.0105 | -0.0025 | -0.0005 | 0.0001 |

| | | |
|---|---|---|
| **Catchment area lots - m2** | 38500.0 | |
| **Runoff Coefficient** | 0.05 | |
| **Catchment area roads - m2** | 2300.0 | **1 in 100 year** |
| **Runoff Coefficient** | 0.9 | |
| **Catchment area verges - m2** | 3100.0 | |
| **Runoff Coefficient** | 0.2 | |
| **Impervious area - m2** | 4615.0 | |
| **Length of flow - m** | 80.0 | |
| **Catchment top RL** | 20.0 | **n= 0.04** |
| **Catchment Base RL** | 10.0 | |
| **Ground slope to culvert S** | 0.125 | |
| **Time - min** | 3.02 | (Kinematic wave equation) |
| **Intensity - mm/hr** | 218 | (ARR polynomial formula) |
| **Flow - litres/sec** | 279.5 | |

| ROAD GUTTER FLOW ANALYSIS - MANNING FORMULA | | | | | Flow | Wetted | Hydraulic | V drain | V-Drain | V-Drain | V-Drain |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of flow | V drain | V drain | Flow width | Manning's | section area | perimeter | radius | Slope | Q | Q | Velocity |
| mm | x-fall LHS % | x-fall RHS % | m | n | a | p | a/p = r | % | m3/sec | litres/sec | m/sec |
| 310 | 33.33 | 33.33 | 1.860 | 0.04 | 0.2883 | 1.9606 | 0.1470 | 2.000 | 0.284 | 283.9 | 0.985 |
| 320 | 33.33 | 33.33 | 1.920 | 0.04 | 0.3072 | 2.0239 | 0.1518 | 1.400 | 0.259 | 258.6 | 0.842 |
| 330 | 33.33 | 33.33 | 1.980 | 0.04 | 0.3267 | 2.0871 | 0.1565 | 1.400 | 0.281 | 280.7 | 0.859 |
| 340 | 33.33 | 33.33 | 2.040 | 0.04 | 0.3468 | 2.1503 | 0.1613 | 1.400 | 0.304 | 303.9 | 0.876 |
| 350 | 33.33 | 33.33 | 2.100 | 0.04 | 0.3675 | 2.2136 | 0.1660 | 1.400 | 0.328 | 328.4 | 0.893 |
| 360 | 33.33 | 33.33 | 2.160 | 0.04 | 0.3888 | 2.2768 | 0.1708 | 1.400 | 0.354 | 354.0 | 0.910 |

A48 32586
fA 635951

CLE
TOWN PLANNING + DESIGN

Attention: Johan Gildenhuys

DEPARTMENT OF PLANNING
16 JUN 2014
FILE ~~801-3-9-2~~
SPN/0659


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WITH COMPLIMENTS

Our Reference: 2172Ltr105
Enquiries: Phillida Rodic

CLE TOWN PLANNING + DESIGN

12 June 2014

Chief Executive Officer
Shire of Irwin
PMB 21
DONGARA WA 6525

**Attention: Ms Suzette van Aswegen & Mr Doug Fotheringham**

Dear Suzette & Doug,

**RE: LOTS 4, 5 & 10 BRAND HIGHWAY LOCAL STRUCTURE PLAN LODGEMENT**

Thank you, once again, for your early input into the development of the Lots 4, 5 and 10 Brand Highway (previously Francisco Road) Local Structure Plan. Following incorporation of your most recent comments (email of 27th May 2014), we are now pleased to formally submit the Structure Plan for the Shire's formal assessment and approval. We trust that the time we have spent developing up the proposal will assist in a smooth assessment and reporting process. Should the Shire believe there is value in our presenting the plan to the Council, we would be very pleased to do so.

In relation to the assessment fee payable, our client will submit this directly to you shortly.

Should you have any queries or wish to discuss this matter further, please do not hesitate to contact either Phillida Rodic or Tony Lambert of this office on 9382 1233.

Yours faithfully,

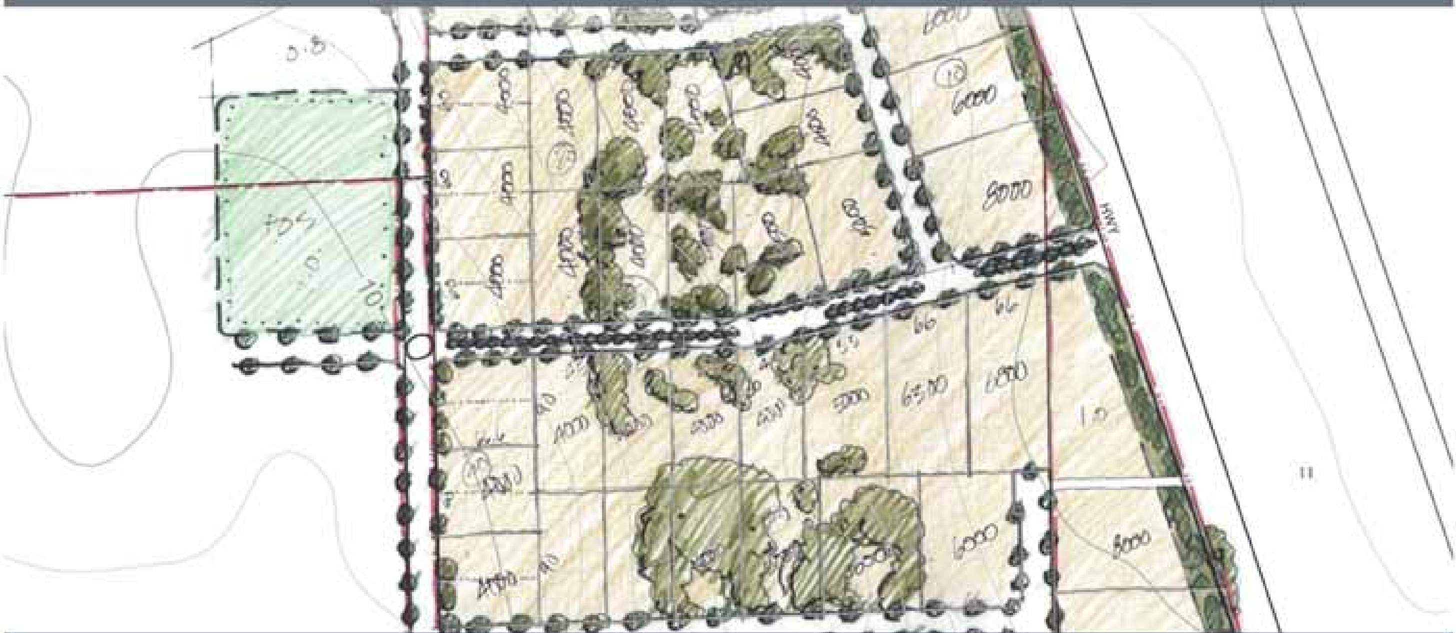
P. Rodic

**Phillida Rodic**
**Senior Associate**
**CLE Town Planning + Design**

Cc: Ben Clarke
Ian McKellar & Chris Elms - Civil Tech
Paul van der Moezel - PGV Environmental
Jonathan Riley - Traffic Consultant
Roger Underwood - Gum York Services
Johan Gildenhuys - Department of Planning

Enc: Lots 4, 5 and 10 Brand Hwy, Bonniefield, Dongara Local Structure Plan - 2172Rep87C

# LOCAL STRUCTURE PLAN



Lots 4, 5 and 10 Brand Highway, Bonniefield
Dongara

June 2014

CLE
TOWN PLANNING + DESIGN

# LOTS 4, 5 AND 10 BRAND HIGHWAY,

# BONNIEFIELD, DONGARA

# LOCAL STRUCTURE PLAN

Prepared by:

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2187Rep87C

June 2014

**PART 1**

## 1. STRUCTURE PLAN AREA

This Structure Plan shall apply to lots 4, 5 and 10 Brand Highway, Bonniefield being the land contained within the inner edge of the broken black line shown on the Structure Plan Map.

## 2. STRUCTURE PLAN CONTENT

This Structure Plan comprises the:

a) Statutory section (Part 1);
b) Explanatory section (Part 2); and
c) Appendices to Part 2 – Technical reports.

Part 1 includes the Structure Plan Map and provisions which require statutory effect.

Part 2 (and its appendices) justifies and explains the provisions contained in Part 1, and should be used as a reference guide to interpret and implement Part 1. It does not hold statutory effect.

## 3. INTERPRETATIONS AND SCHEME RELATIONSHIP

This Structure Plan has been prepared under Clause 5.35.6 of the Shire of Irwin Local Planning Scheme No.5 ('the Scheme').

The words and expressions used in this part of the Structure Plan shall have the respective meanings given to them in the Scheme.

Land use permissibility for each zone within the Structure Plan shall be in accordance with the Scheme, except as specifically varied by this structure plan.

The provisions, standards and requirements specified under Part 1 of this Structure Plan shall have the same force and effect as if it were a provision, standard or requirement of the Scheme.

In accordance with sub-clause 5.35.12.2 of the Scheme, in the event of there being any inconsistencies or conflict between the provisions of the Scheme and the provisions of this Structure Plan, then the provisions of the Scheme shall prevail to the extent of the inconsistency.

Part 2 of this Structure Plan and the Technical Appendices are to be used as a reference only to clarify and guide interpretation and implementation of Part 1.

## 4. OPERATION

In accordance with the sub-clause 5.35.12.1 of the Scheme, this Structure Plan shall come into operation when it is certified by the Commission pursuant to sub-clause 5.35.12.1 (a).

## 5. LAND USE AND SUBDIVISION REQUIREMENTS

Subdivision and development shall be generally in accordance with the Structure Plan Map.

Prior to the creation of any lot in excess of 20 lots within the Structure Plan area, the Boulevard Entry Road access from Brand Highway shall be provided and / or upgraded to the specification of the WAPC, on the advice of Main Roads WA.

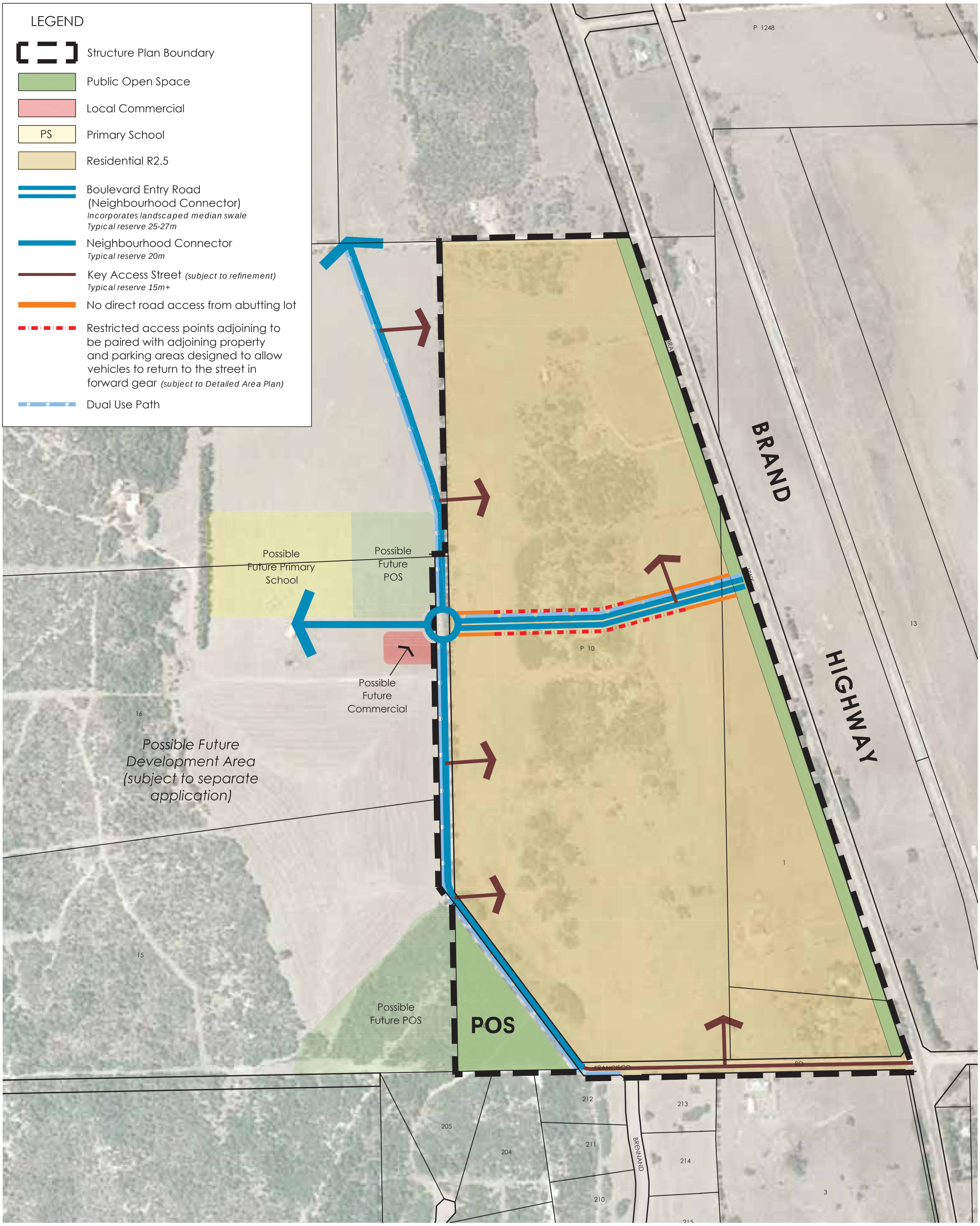
The Boulevard Entry Road shall be provided with a road reserve of 25-27m in order to accommodate a landscaped central median swale to capture stormwater and manage potential future traffic. The precise road layout and treatment of the verges and median shall be determined as a condition of subdivision in consultation with the Shire of Irwin.

Access to the Boulevard Entry Road from abutting lots shall be restricted though application of a Detailed Area Plan which limits access points and requires the placement and design of parking areas to allow vehicles to return to the street in forward gear.

## 6. DEVELOPMENT REQUIREMENTS

Development of lots abutting or immediately opposite the triangular public open space in the south-west corner of the structure plan area are to be subject to Australian Standards ASA 3959-2009 ("Construction of Houses in Bushfire-prone Areas") and all lots are to be provided with a 20m Bushfire Protection Zone to any habitable building.

A Detailed Area Plan prepared over lots abutting the Boulevard Entry Road to limit access to this as detailed above shall apply to development of the subject lots.




# DRAFT LOCAL STRUCTURE PLAN

Francisco Road, Dongara

2172-88C-01 (18.03.2014), nts

**PART 2**

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# 1.0 PLANNING BACKGROUND

## 1.1 Introduction and Purpose

This Local Structure Plan (LSP) has been prepared on behalf of the owners of Lots 4, 5 and 10, Brand Highway, Bonniefield, and is lodged with the Shire of Irwin pursuant to clause 5.35.4 of the Scheme. The purpose of this LSP is to guide the subdivision and development of the subject area in a coordinated fashion. Development of the LSP area will assist provide for the anticipated demand for residential lots within Dongara-Port Denson in an integrated and sustainable manner. The urban expansion that the LSP facilitates will support coordinated and ongoing growth as envisaged by the Shire of Irwin's *Strategic Community Plan 2012 – 2013.*

The LSP draws on the current strategic planning framework, and refines the level of detail in order to ensure that relevant environmental, social, economic and infrastructure issues are addressed, and that a clear and robust statutory framework is provided to enable subdivision and development of the structure plan area. The timeframe for the subdivision and development of the LSP area will be guided by land sales and market demand, anticipated to run over the course of the next 5 – 10 years.

Preparation of this LSP and the Development Concept from which it has been developed has involved consultation with the Shire of Irwin, Department of Planning, Main Roads WA, environmental agencies and relevant service authorities. The consultation early on in the process has ensured that the LSP addresses all matters raised by the various agencies prior to lodgement.

## 1.2 Land Description

### *1.2.1 Location*

The LSP area is located immediately north of the Dongara townsite, within the suburb of Bonniefield. It is bounded by Francisco Road to the south, Brand Highway to the east, existing farming land to the north, and existing farming land to the west, which abuts foreshore reserves and the Indian Ocean. The LSP area is approximately 3km north of the Dongara town centre and 1.5km from the ocean.

A location plan showing the LSP area within the broader district context is provided at Figure 1.

### *1.2.2 Area and Land Use*

The LSP area is approximately 59ha in total, and comprises 3 freehold lots. The majority of the land is used for farming, and a child care centre is understood to operate from the dwelling at Lot 4. A detailed site plan and orthophoto is Figure 2.

#### *1.2.3 Legal Description and Ownership*

The LSP area includes all of lots 4, 5 and 10 Brand Highway. All three land parcels are privately owned, with the owners of Lot 10 the principal proponents of this plan. Table 1 provides the legal description and ownership of the subject land.

**Table 1 – Land Ownership and Legal Description**

| Lot No | Certificate of Title* | Owner | Area (ha) |
|---|---|---|---|
| 4 | 2046/796 | Paul Bender & Brenda Kretschmer-Bender | 2.4 |
| 5 | 2046-797 | Gary & Jose Norrish | 8.6 |
| 10 | 2072/286 | Lundy Pty Ltd & Texas Property Development Pty Ltd | 48.2 |
| **Total** | | | **59.2** |

* Refer Appendix 1

### 1.3 Planning Framework

#### *1.3.1 Zoning and Reservations*

The site was recently rezoned to 'Development' under the Shire of Irwin's Local Planning Scheme No 5 (LPS5) via Amendment 15, which was prepared by the proponents of this proposal.

The purpose of the 'Development' zone is to provide for the comprehensive planning and coordinated subdivision and development of land, in accordance with an approved structure plan.

Land to the north, east and west is zoned 'General Farming'. The Race Course estate to the south is zoned 'Rural Residential', and is largely developed for this purpose, with the areas immediately south and west of this being zoned 'Residential'.

Brand Highway, abutting the LSP area to the east, is reserved for 'Major Road or Highway'.

The coastal corridor to the west forms a Local Reserve, whilst Reserve 23600, a 50ha (approximately) block of land diagonally south-west of the site is reserved for conservation.

A plan depicting the current zonings under LSP5 is provided at Figure 3.

### *1.3.2 Regional and Sub-Regional Structure Plan*

The Shire has commissioned a District Structure Plan (DSP) for the Dongara – Port Denison area which has recently been released as a draft for public comment (refer Figure 4). This identifies the LSP land and the adjoining land to the west as '*Future Urban / Residential'* and more specifically, as the 'Francisco Road North Precinct'. This reflects the stated intentions of the landowners. In relation to this LSP area, the draft DSP acknowledges that it is likely to be developed in the short to mid-term for low density residential purposes with future development including a neighbourhood centre and public purpose reserve (a primary school) shown immediately to the west of the LSP area, within the heart of the development precinct. The proposed LSP is consistent with the provisions of the draft DSP and will serve as a catalyst for the future development of the land identified within the 'Francisco Road North Precinct' in accordance with the provisions of the plan.

Adjoining land to the south is also identified for future urban development, with land to the north of the LSP area indicated as future 'Rural Living'.

### *1.3.3 Planning Strategies*

A number of planning strategies apply to the region, though with limited direct implications for the site. The WAPC's draft Mid West Regional Planning and Infrastructure Framework 2011, for example, recognizes Dongara's role as a regional centre, and acknowledges and responds to the high level of activity in the region which supports growth of such centres and hence their residential expansion.

More pertinently, the Shire's draft Local Planning Strategy identifies specific areas for urban expansion of the town, including a growth precinct running up to the boundary of this site (Policy Area B). The rezoning proposal for the site successfully demonstrated the rationale for incorporating the LSP area within area B and supporting its urban development as part of the town's growth strategy. This position is reinforced through its identification in the subsequently prepared draft District Structure Plan for the town.

As has been noted above, the Shire's Strategic Community Plan 2012-2022 identifies the need for future urban land to accommodated planned growth of the Dongara Port Denison towns.

### *1.3.4 Policies*

A number of state planning policies and guidelines are relevant to the LSP, including the WAPC's:

- Liveable Neighbourhoods (Edition 3, 2007);
- Development Control Policy 2.3 - Public Open Space in Residential Areas;
- Planning for Bush Fire Protection Guidelines (Edition 2, 2010);
- Better Urban Water Management Guidelines (2008) and the Department of Water's Best Practice Stormwater Management for WA document; and
- Structure Plan Preparation Guidelines (2012).

The structure plan and its supporting documents respond to and generally accord with the provisions and principles of these operational policies and guidelines, as discussed further in Part 3 of this report.

In particular, the design of the plan and associated Development Concept reflect the 'new urbanist' design principles underpinning Liveable Neighbourhoods through:

- Consolidating development in an accessible and amenable location, with good access to services, employment and amenities;
- Structuring development upon a 'modified grid' road layout which facilitates ease of movement, choice of routes, legibility and good accessible for all modes of transport;
- Planned provision of local services, within the next phase of the development, to supplement those already available within 3km, in the town;
- Provision of local open space, providing for both local amenity and environmental conservation; and
- Integration of storm water management within the design, allowing disposal at or close to source, utilisation of run off to support green spaces, and sustainable water practices.

### *1.3.5 Other Approvals and Decisions*

In considering broader issues relating to Dongara, the WAPC in 2011 identified the subject site (and 145ha of adjoining land to the west) as suitable for urban development. This has been reflected in the Shire's draft DSP as the Francisco Road North Precinct.

The original rezoning proposal for the subject site incorporated this larger area, much of which is within the same ownership as the majority of the subject site. A consolidated urban residential development of up 1500-2000 lots was envisaged, as conceptually illustrated in Figure 5, to be progressively developed over the longer term. In considering this proposal at a number of briefing sessions in 2012, a number of Councillors present expressed concern at both the extent of the development site, and the residential density on the periphery of town. For this reason, the amendment area was modified to restrict it to the subject site, and the notional layout amended to accommodate larger lots which might eventually integrate into a more urban residential area to the west. This discussion process did not involve a formal decision by Council but very much affected the extent and form of the development concept which secured Council's support for the rezoning, and forms the basis of this proposal.

Future development of land to the west of the site cannot be assumed by the proposal, as it requires additional statutory decisions and processes, however it should be accommodated and planned for, to allow it to occur in an integrated fashion, if and when this land is rezoned.

## 2.0 SITE CONDITIONS AND CONSTRAINTS (SITE ANALYSIS)

A summary of opportunities and constraints presented by the site is shown graphically in Figure 6 – Site Analysis. Its attributes are further discussed below.

### 2.1 Biodiversity and Natural Area Assets

The majority of the site is cleared. Environmental investigations were undertaken as part of the LPS5 amendment process to rezone the land and prior investigations leading up to this incorporating the land to the west of the site. Based on this analysis, the Environmental Protection Authority resolved to not formally assess the rezoning proposal, on the basis that development of the amendment area would not have any significant environmental implications. A copy of the EPA's formal advice is Appendix 2, and positively notes the proposed retention of remnant vegetation in the south-west corner of the site.

The findings of the environmental investigations are documented in Appendices 3 and 4 to this report. These apply to the broader area then under review, and are summarized as follows:

- The flora and vegetation represents a low species richness associated with the Quindalup dune, largely due to the poor condition of the site;
- No Threatened (Declared Rare) or Priority Listed flora species were found;
- Four separate Vegetation Associations were identified on the site, (refer Figure 7) as follows:
    - Ar *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub: main vegetation type on site, ranging from 2 – 5m tall, standing typically on the lee side of the dunes and in the valleys. Sparsely vegetated understorey with extensive weed, most Ar areas have been classed 'Good' or 'Degraded' with the exception of one 'Very Good' area in the south west corner of the site;
    - ArAh *Acacia rostellifera / Alyogne hueglii* Open Heath: A narrow and of this vegetation type occurred on the top of the eastern ridge of the dunes on Lots 15 and 16 as well as a degraded part on the eastern side of Lot 1409. Overall, the vegetation type was dominated by weeds but was classified as being in Good condition;
    - MlAr *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland: This vegetation type occurs in two stands, one of around 5ha at the northern end of Lot 17 and a smaller one at the north-east corner of Lot 1409. Their conditions were assessed to be Very Good and Degraded, respectively. The larger area contained 13 specifies of which 10 were native;
    - EoAr *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub: A very small stand of EoAr occurred on the southeastern end of Lot 15 was assessed to be in Good condition although the quadrant contained only 2 of 7 species which were native.

- Overall, remnant vegetation condition is mainly 'Good' showing evidence of grazing and a dominance of weeds in the understorey, but with some pockets of vegetation in 'Very Good' condition;
- The dominant vegetation type *Acacia rostellifera* belows to Beard's Vegetation Community 431 of which 73.76% of its original extent of 4,460ha remains (Ecoscape, 2011 and WAPC, 2010 quoted in PGV Environmental, 2011). The reserved proportion is far lower at less than 1% however includes the 50ha Conservation Reserve 23600 abutting the southern boundary of the site. Given the extent and better condition of the Ar in the adjoining Reserve 23600, the vegetation of the subject site is not considered to have regional significance;
- The vegetation types attributed to the site under the Dongara to Cape Burney Coastal Vegetation Survey similarly suggest that it holds no regional significance;
- The *Acacia rostellifera* community is not considered to hold local significance, but the limited extent of *Melaleuca lanceolata* (Lot 17) suggests it may have some local significance. A portion of the 5ha 'Very Good' condition area of this vegetation type in the north of the site is therefore recommended within the public open space network proposed;
- The *Eucalyptus obtusiflora* in Lot 15 could also be considered to hold local significance given its rarity in the area. This area is also suggested for retention within open space, recognising that it is a very small area and in poor condition.

In terms of Fauna:

- There are four habitats on the site;
- The vegetated areas of Lots 10 (south west corner), 15, 16 and 17 is considered to be Good Fauna Habitat. The remainder of the site is considered to be Disturbed or Highly Degraded Fauna Habitat;
    - Of the conservation significant species identified through a review of relevant government databases, only one, the carpet python, is known to occur on the site, with four others (Peregrine Falcon, Fork-tailed Swift, Cattle Egret and Rainbow Bee-eater identified as potentially visiting the site. Of these latter species, only the Rainbow Bee-eater is considered likely to utilize the habitat of the site (rather than temporarily visit);
- It is considered highly unlikely that development of the site will cause a significant impact on any fauna species of conservation significance "*due to the low usage potential of the site by a few species and the presence of similar habitat in adjoining reserves and the wider Dongara area*" (p15-16, PGV, 2012).

Whilst much of the (reduced) area the subject of this LSP was not included in the detailed surveys, it was included in the broader Dongara to Cape Burney Coastal Vegetation Survey prepared by Ecoscape for the Northern Agricultural Catchment Council in 2010. This mapped vegetation on the site as follows:

- Vegetation condition: Degraded;
- Vegetation type: Unit 7 (as occurs on most of the remainder of the larger site area surveyed by PGV Environmental). Both Ecoscape and PGV concluded that this vegetation unit does not have any local or regional significance.

Given these conclusions and the fact that the majority of the site the subject of this Structure Plan is cleared, no environmental objection has been raised to its development, though retention of the vegetation in the south-west corner of the site has been supported by all parties. This reflects a positive environmental outcome, reducing the need for land-clearing to accommodate urban growth of the town, and allowing for consolidation of residential areas within 3km of the town centre, and within walking / cycling distance of the beach.

## 2.2 Landform and soils

A Land Capability and Geotechnical Assessment undertaken by Landform in 2005 (refer Appendix 5). This assessment supports the suitability of the site for the form of development proposed. The assessment described soils on the site as follows:

- The western Quindalup Dune soils are relative old and therefore contain a brown to cream brown sand with minor clay and calcareous materials;
- Eastern Tamala limestone soils (more prevalent in the rezoning area) are brown sands grading to earthy sands overlying limestone at variable depth;
- The coastal nature of the older Quindalup dunes makes them less susceptible to erosion than the younger phase Quindalup dunes. (Landform Research (2005) summarised in PGV Environmental, 2011)

The Landform report further notes that:

- The only areas of likely instability are the two high ridges in the south of the area;
- In general, the nature of the sands on the site is porous and permeability high;
- Some small amounts of clay may be present, but in general this gets washed down to lower levels of the soil profile; and
- A wind erosion risk exists if vegetation is removed and the soils are exposed to the wind.

This assessment supports the suitability of the site for the form of development proposed, and suggests excellent capacity for sustainable storm water management practices, including at-source disposal, and integration of stormwater swales for more severe events within public open space. More detailed geotechnical investigations will be required to support subdivision. Staged clearing and development, and its management during the development process, and the retention of the dune peak in the south should assist in addressing the erosion risk identified.

## 2.3 Groundwater and Surface Water

There are no surface water features such as creeklines, drainage lines or wetlands on the site.

PGV Environmental further noted that "*Groundwater occurs under the site at an average level of around 2m AHD (Landform Research, 2005) indicating a minimum depth to groundwater of around 10m*" (PGV Environmental, 2011). Ground water quality is noted in the Landform report as being suitable for stock, but not for horticulture. This conclusion was supported by the Local Water Management Strategy prepared for the site, discussed below.

## 2.4 Bushfire Hazard

A Bushfire Management Plan has been prepared for the site by Roger Underwood (refer Appendix 6) which assesses the site and proposes a management framework for bushfire risk. This recognizes that the cleared nature of much of the site and adjoining properties, and the management already in place moderates bushfire risk. It is generally supportive of the layout proposed in the Development Concept (provided at Figure 8) but recommends that lots abutting the proposed triangular public open space in the south (which has remnant vegetation) be subject to Australian Standards ASA 3959-2009 ("Construction of Houses in Bushfire-prone Areas") and that all lots be provided with a 20m Bushfire Protection Zone defined as follows:

- width: 20 metres measured from any external wall of the building;
- location: within the boundaries of the lot on which the building is situated, unless this zone overlaps with a BPZ on an adjoining property or within a road reserve;
- fuel load: reduced to and maintained at 2 tonnes per hectare;
- any trees planted within the BPZ to be a minimum of 10 metres apart and trees low pruned at least to a height of 2 metres;
- no native scrub to be located within 2 metres of a building (including windows) and no tree crowns overhanging the building;
- fences and sheds within the BPZ constructed using non-combustible materials (e.g. colourbond iron, brick, limestone);
- shrubs in the BPZ have no dead material within the plant and tall shrubs in the BPZ are not planted in clumps close to the building i.e. within 3 metres.

A standard requirement for installation of fire hydrants plus the provision of bushfire risk and management to lot purchasers represent other key recommendations.

## 2.5 Heritage

A search of the Department of Indigenous Affairs website shows no registered sites within the LSP area.

The LSP area is not known to contain places of either state or local heritage significance, with no portion listed on either the State Register or the Shire's Municipal Inventory of Heritage Places.

## 2.6 Coast and Foreshores

The LSP area does not abut the coastal reserve, and is located approximately 1.5km from the shoreline of the Indian Ocean. As and when rezoning and development occurring to the west of the site, formalization of access to the beach and management of the foreshore (through development and implementation of an approved Foreshore Management Plan) would be required as part of the planning process for the abutting area.

## 2.7 Context Analysis

The contextual opportunities and constraints presented by the site have been reviewed with the key ones incorporated into Figure 9. The context analysis has concluded that:

- Development of the LSP area represents a northern extension to the townsite, extending the general form of the Racecourse Estate across Francisco Road, albeit at slightly higher density;
- The LSP area has good access to the regional road network, although access to Brand Highway will require consideration of sight lines and road safety;
- Francisco Road and Brennand Road to the south of the site provide secondary access points. It is understood that some concerns exist as to the operation of the existing Francisco Road – Brand Highway intersection, and that modification to this or its closure have been touted as possibilities. In the event that this occurs, the access available directly from Brand Highway, and through Brennand Road remain quite sufficient;
- The LSP area has good access to both the Dongara town centre (3Km to the south) and Geraldton (65km to the north), providing for a range of retail, service, community, recreation and employment opportunities;
- Whilst the proposal works well in isolation, longer term, development of the areas to the west and north of the site has been provided for, with a notional concept for this provided in Figure 5. In the interim, the land to the west and north contains small rural landholdings which are principally used for grazing. The limited interface to the north restricts impact, as do the larger lot sizes proposed and the road alignment along most of the western boundary;
- There are opportunities to recognize and integrate existing landform within key areas of open space – particularly in the south western corner of the LSP area;

- Where fire protection and civil engineering requirements allow, mature vegetation can be retained within road reserves and private lots, as well as within public open space;
- Soil types and depth to groundwater provide opportunities for on-site infiltration, minimising the requirement for overland or piped conveyance of stormwater and providing for more sustainable water management.

Additional, more localized provision for retail and commercial services is planned within a future small scale Neighbourhood / Local Centre immediately to the west of the LSP site, proposed as part of the broader area planning and reflected within the draft DSP for Dongara - Port Denison. Its notional location will place it within the centre of the estate, with good road connections to it, maximizing its accessibility. Co-location with a future primary school should support its function and facilitate shared trips. This will provide local services and schools within about 800m of each lot within the LSP area. In the interim, the 3km distance into Dongara town centre is considered to provide very good accessibility to goods and services for future residents, particularly within the context of a regional town where critical mass and urban densities are developing. This is reflected within the draft DSP which acknowledges that the catchment radius' recommended by Liveable Neighbourhoods are not appropriate in subdivisions where large lots are proposed.

## 3.0 LAND USE AND SUBDIVISION REQUIREMENTS (INC DESIGN RATIONALE)

### 3.1 Land Use

The Structure Plan proposes residential development of the site at low (R2.5) densities, whilst maintaining the ability to increase densities (particularly along the western boundary) in the future, if and when sewer is extended to the site. This might occur in conjunction with future urban development anticipated west of the site, as envisaged by the Overall (Long Term Potential) Local Structure Plan Concept and reflected in the 'Francisco Road North Precinct' section of the draft DSP for Dongara – Port Denison.

This residential zoning facilitates expansion of the townsite and, based on the current Concept, provides for approximately 85 additional lots of between 1.5ha and 4000m$^2$. The precise number of lots and their sizes will be determined at subdivision, however the minimum lot sizes stipulated by the Residential Design Codes for R2.5 (4000m$^2$) will apply.

By designating the land as 'Residential' zone, the limited non-residential uses permissible in this zone under the Scheme also apply, allowing the operation of home based businesses, subject to Council approval.

Development of a commercial facility within the LSP area is not viable given its scale and proximity to Dongara town centre, however a future facility is proposed abutting the LSP area within future stages of development, should these be supported.

### 3.2 Integration with Surrounding Land

The location of the site means that it will provide a logical extension to the existing townsite. Larger lots within the rezoning area have been proposed to provide a transition in density and built form from the existing Rural Residential to the south, and along Brand Highway (which is still largely rural in nature at this location currently) to the (potential) remainder of the estate area, which maintains long term urban potential. Longer term, this will also provide a visual transition from future urban development to the south up to future rural living to the north (based on the draft District Structure Plan recommendations).

Some landscape screening between Brand Highway and the development is also proposed in the form of a vegetated open space strip of 20m. Fencing controls may be appropriate in some locations (eg along the northern boundary) to address the relationship between land uses, and manage visual impact.

Interconnection with the existing street network to the south is provided for, to provide interconnection of neighbourhoods and a secondary route into town. Future connections to the north and west are provided for to maintain the option for future longer term development of the neighbouring sites.

### 3.3 Open Space (Parkland Provision and Management)

The topography and visual prominence of the dune on the south-west corner of the site, and its covering of remnant vegetation have prompted its retention within the plan as a local park, along with a proposed future adjoining area in the possible future urban area to the west (this area is outside the LSP area by virtue of its location on a separate lot). A further linear strip (20m wide) is proposed along Brand Highway to provide screening to the highway, reducing noise and visual impact to the residential areas, and supporting at-source disposal of stormwater. Integration of a pathway and retention of some remnant trees may be possible within this area, as part of the POS treatment to be undertaken in accordance with Liveable Neighbourhoods. These areas provide local open space within 400m of every lot proposed, and supplement the district recreation facilities available within the existing townsite, and the reserves along the coast and Irwin River which are the focus of much recreation for Dongara residents. A further active recreation oval is anticipated as part of a shared facility with the future primary school immediately west of the site, if and when future staged development occurs.

The LSP provides a total of around 4.59ha, or 7.7% of the area as public open space. Given the large size of the lots proposed, and their proximity to the beach and facilities within Dongara, it is likely to be sufficient to support the development. However, in order to meet the 10% requirement specified by WAPC policy, an additional area (or cash in lieu) may be required. Following preliminary discussion options with the Shire, indications are that cash in lieu to meet the value of the shortfall in area is preferred.

Additional ‘greening’ of the site and improvement of the amenity offered by local streets (as a critical component of the public realm, and potential recreational network for walkers and cyclists) may also be achieved through street tree planting and landscaping.

Treatment and management of the public open space areas and streetscapes would be expected to be addressed in standard conditions of subdivision requiring preparation and implementation of public open space plans and civil works plans, consistent with WAPC policy. Utilisation of water wise, predominantly native species would be anticipated as a standard requirement as would use of storm water run-off to provide an additional irrigation source.

Maintenance of public open space areas by the developer is required for a period of two years following completion. Maintenance and management issues are also critical considerations in the development of landscape proposals, and will require the further, detailed input of the Shire at this stage of the process.

### 3.4 Residential

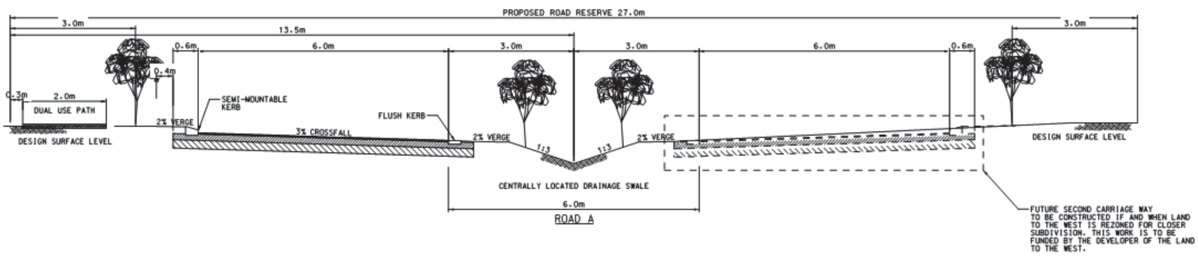
The plan proposes low density residential across the site. Densities have been kept low to reflect its location on the fringe of the town, and the preferences expressed by Councillors in briefing sessions undertaken in 2012, but are generally not of the traditional rural residential scale now discouraged by state planning policy. The preliminary Concept Plan (Figure 8) indicates approximately 85 lots ranging from 1.5ha in the south east corner, down to 4000m² internally. Lot sizes have been deliberately kept larger adjacent to Brand Highway to maintain a semi rural character at the entrance to the town, and to make efficient use of the land and infrastructure required to service it. Lot sizes then graduate down to the average 4000m² required at R2.5 along the western portions of the LSP area, providing a range of lot types and sizes. This interface allows for further potentially more diverse urban development to continue in future stages to the west, if and when rezoned.

### 3.5 Movement Network (Traffic Management and Safety)

The traffic planning for the site is detailed in the attached assessment undertaken by Jonathan Riley Consulting (refer Appendix 7).

Primary access to the site is proposed from a new entrance point from Brand Highway, approximately mid way up the site, supplemented by Francisco Road to the south (connecting into Brennand Road, which leads into town). The location of the new access point has been agreed in consultation with Main Roads WA to provide good visibility, and safe access onto the highway. Both the new entry road and Francisco Road extension are projected to carry low volumes of traffic associated with this structure plan, but are designated Neighbourhood Connectors by virtue of their function.

The new entry road has been designed to provide for access to a potentially larger area as a boulevard entry road, with a reserve of between 25 and 27m required to facilitate this and accommodate the boulevard style road and landscaped median swale. A notional short and long term section for the road is provided below.

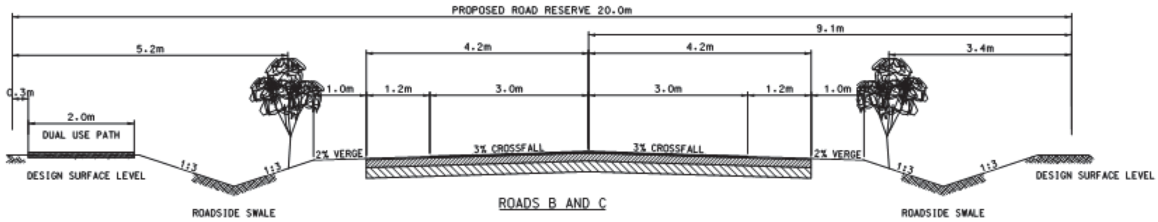


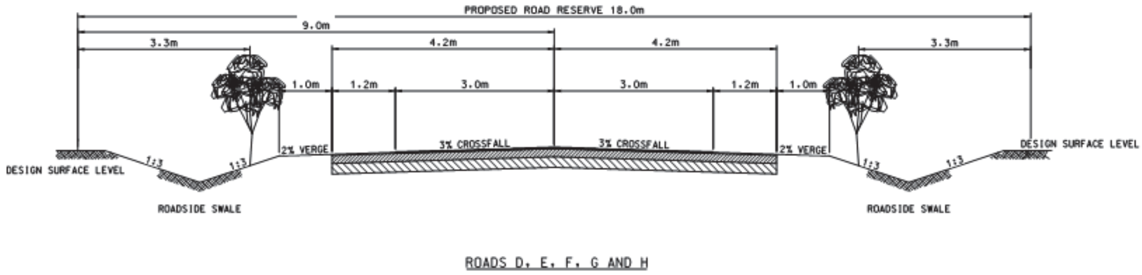

Source: Civil Technology Drawing 796-01-001

The precise long term treatment will in large part depend on the extent of development (and therefore traffic) which occurs to the west, with a conservative 'worst case scenario' adopted to ensure the robustness of the plan. Application of a requirement in the LSP for lots along the entry road to make provision for vehicles to return to the street in forward gear (either through circular driveways or turning areas) and collocation of driveways has been made to limit direct and reversing vehicle access to this road, in the event that its ultimate volumes require this. Any necessary changes to the entry road to accommodate any future development would be a cost attributable to that development and so would not fall upon the Shire.

The traffic assessment undertaken for the proposal indicates that the new Brand Highway connection will be required to be constructed prior to the creation of 24 lots to maintain safe and functional traffic access from the Highway. This figure has been reduced to 20 lots in Part 1 of the LSP to provide an additional safeguard. Construction of the intersection represents a substantial capital cost.

The road layout through the site reflects the modified grid advocated by the WAPC's design manual, Liveable Neighbourhoods, and provides direct and legible access to all lots. The planned north-south link on the western side of the site is notionally indicated to veer north-west across lot 17 as part of future development of this site, providing a more efficient layout for the northern part of Lot 10. The placement of the road also better provides for long term connection into Lot 1248 to the north, should this ever be required. This long term approach may require that development of some lots be held back at subdivision stage to coordinate in with this future stage, however this is considered appropriate, given the design benefits achieved. The precise details of local road alignment can be determined in consultation with approval agencies at subdivision, provided that the fundamental structure stipulated by the Structure Plan is maintained. Whilst minimum reserve widths required under policy are outlined in the traffic assessment, uniform widths of 18-20m are proposed for local road to reflect local conditions, character and expectation. This more generous reserve width also provides for the integration of open drainage swales / channels within verges proposed by the Local Water Management Strategy, should this be approved (refer example notional layouts below).




Source: Civil Technology Drawing 796-01-001

Traffic generated by the proposal is projected to be low. However, in order to future proof the proposal, the entry road and north-south boundary road connecting into Francisco Road are both recommended to be provided with larger road reserves, to ensure that they are capable of accommodating additional growth, should this be required.

A dual use / shared path (DUP) is proposed along the western boundary of the LSP land. The path will provide a pedestrian and bicycle connection to the Dongara town site to the south and will extend to the northern border of the LSP land to connect with future developments to the north. A further DUP along the Boulevard Entry Road will provided an off-road cycling environment along this street. It is expected that development of the pathways will be required as a condition of subdivision approval. The location of the pathways allows them to integrate with the future activity centre and primary school site planned immediately west of the site, and to utilize the more amenable and lower traffic volume environments of Francisco and Brennand Road to provide access to Dongara townsite, in preference to Brand Highway.

Local pedestrian and cycle movement on lower order streets can be accommodated on street, as it is throughout most of Dongara-Port Denison, given the generous road reserves and low traffic volumes of most streets. Provision of an access easement from the disconnected road shown parallel to Brand Highway on the Development Concept (Figure 8) across Lot 5 to provide direct pedestrian connection to the Highway from the southern portion of the subject site has been requested to be Shire, to maximize pedestrian accessibility. This would be secured through a condition of subdivision of that lot.

### 3.6 Urban Water Management

A Local Water Management Strategy (LWMS) has been prepared for the site (refer Appendix 8) responding to the Department of Water's Stormwater Management Manual 2004-07, the WAPC's Water Resources policy 2.9 and the Commission's supplementary Better Urban Water Management Guidelines. The Strategy sets out a number of water management objectives and design criteria, a management strategy, preliminary catchment details and calculations and monitoring recommendations. It indicates provision of drainage swales within a central median on the Boulevard Entry Road and within verges in lower order road reserves, as part of a landscaped treatment, in accordance with state and local government guidelines. Additional run off from the western portion of the land can continue to drain to the west based on natural land form, into temporary detention swales, pending development of this area (if approved) and integration of this within further swales. Run off volumes are anticipated to be very low, with the majority permeating into the soil within the road side swales before it reaches to the site boundary. Further details of this, supported by more detailed geotechnical analysis will be provided to support the Urban Water Management Plans required under standard conditions of subdivision approval. These will be required to be prepared to government standards and will involve close involvement by the Shire and Department of Water to ensure the detail of treatment is acceptable. The Strategy provides the framework to guide this process, and demonstrates the workability of the basic approach, subject to detailed design.

The LWMS concludes that the site is capable of accommodating stormwater run-off through the application of integrated urban water management principles, and that swales and bubble ups can permeate that water at or close to source, and 'harvest' it to support landscaping and the 'greening' of the site.

### 3.7 Education Facilities

The scale of the development does not warrant provision of an additional school or other education facilities, with the Department of Education verbally confirming that the existing Dongara District High School and Primary School having sufficient capacity to cater for the additional population generated by the LSP area. In the event that rezoning and development to the west is achieved in the future, provision for an additional primary school will be required, and is notionally shown in the conceptual structure plan for the larger area. This would provide a highly localized facility within walking and cycling distance of all lots proposed. Provision for good access to these facilities both by car, foot and cycle has been made in their location and the design of the surrounding road network.

### 3.8 Activity Centres and Employment

The LSP area is located within 3km of Dongara and 65km of Geraldton. These centres will provide for the commercial needs of the future population and, in conjunction with local agricultural, fishing and mining opportunities, are likely to provide for most of their employment.

A possible future Local Neighbourhood Centre is shown on the Long Term Potential Structure Plan Concept which would again provide a very localized and accessible resource to the site, should it be approved and developed. This would enhance the compliance of the proposal with the directions of Liveable Neighbourhoods, which strongly espouses provision of local facilities and reduced dependence on car travel, but cannot reasonably be expected to be provided within the limited area the subject of this structure plan.

### 3.9 Infrastructure Coordination, Servicing and Staging (Public Utilities)

A preliminary investigation of infrastructure and servicing requirements was undertaken in support of the rezoning proposal for the site. This investigation confirmed that provision of service infrastructure is not a constraint to residential development in this area, and concluded that:

- A desirable site grading for subdivision can be achieved with some earthworks. Site stabilisation will be a factor to be addressed in subdivision design and construction staging and management to avoid potential dust and ground erosion;
- The site's sandy soils provide opportunities to apply water sensitive stormwater design principles that encourage containment at source;
- A water main exists in Francisco Road which can provide a connection to the site;
- Under the LPS5, lots exceeding 4000m$^2$ in area (as proposed in the Development Concept) do not require connection to deep sewer. The preliminary findings of the investigation and prior Land Capability Assessment indicate the site's suitability for on-site disposal of waste water;
- Power infrastructure will need to be upgraded and extended to accommodate development of the site. Planning for this in conjunction with Western Power will be undertaken parallel to structure planning and connections secured in accordance with standard conditions of subdivision.

The LSP provides for sufficient verge widths to accommodate services within standard alignments.

Given that the large majority of the LSP area is under single ownership, initial costs for the provision of infrastructure necessary to service the LSP area will be borne by the proponent, with opportunities to recover costs from service authorities as part of standard agreements.

The release of lots is likely to be staged, depending on market demand, and is proposed to commence in the south-east of the site and more progressively north and west over a 5 -10 year period, depending on sales.

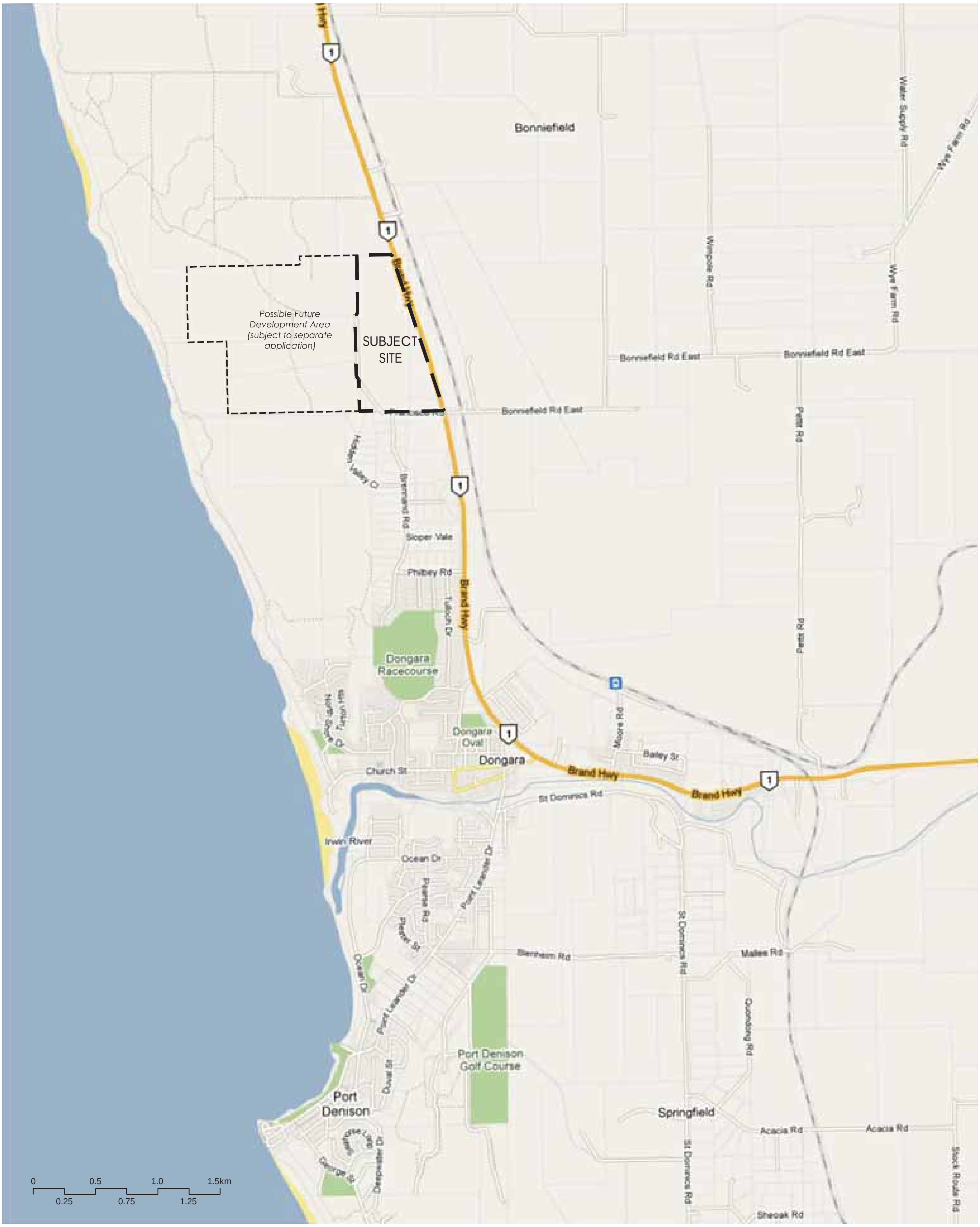
The design and alignment of service corridors and infrastructure will accord with standard agency requirements, with potential for common trenching to be investigated.

## 4.0 CONCLUSION & IMPLEMENTATION

In conclusion, this LSP outlines a subdivision and development proposal consistent with that negotiated with Council and incorporated in the rezoning documentation for the area, providing for the development of larger residential lots to provide for the continued growth of the town. The plan provides the potential to link into future development of land to the west and north of the area, but does not depend on this. The plan is supported by a range of technical studies which demonstrate its suitability for the development proposed, and outline how fire risk, traffic and water management, amongst other things, are most appropriately addressed.

Implementation of the plan is likely to be driven by the majority landowner (Lot 10). The initial developer will be required extend utilities to the site and develop the detail of road layouts, public open space and lot configuration under the direction of this plan, to facilitate subdivision. This will occur in consultation with the Shire, the WA Planning Commission and relevant other government agencies. The LSP layout allows for development of Lot 4 to occur independently, based on the street access available from Francisco Road. Development of Lot 5 is most likely to follow Lot 10, though the extension of additional internal road access however could occur separately under an access agreement. Progressive release of lots is likely to be lead by the market, with an estimated timeframe of 5 to 10 years for completion of the estate.

# FIGURES




*Source: Google Maps 2010*

2172-89-01 (26.11.2013), nts

# LOCATION PLAN

Francisco Road, Dongara: Figure 1

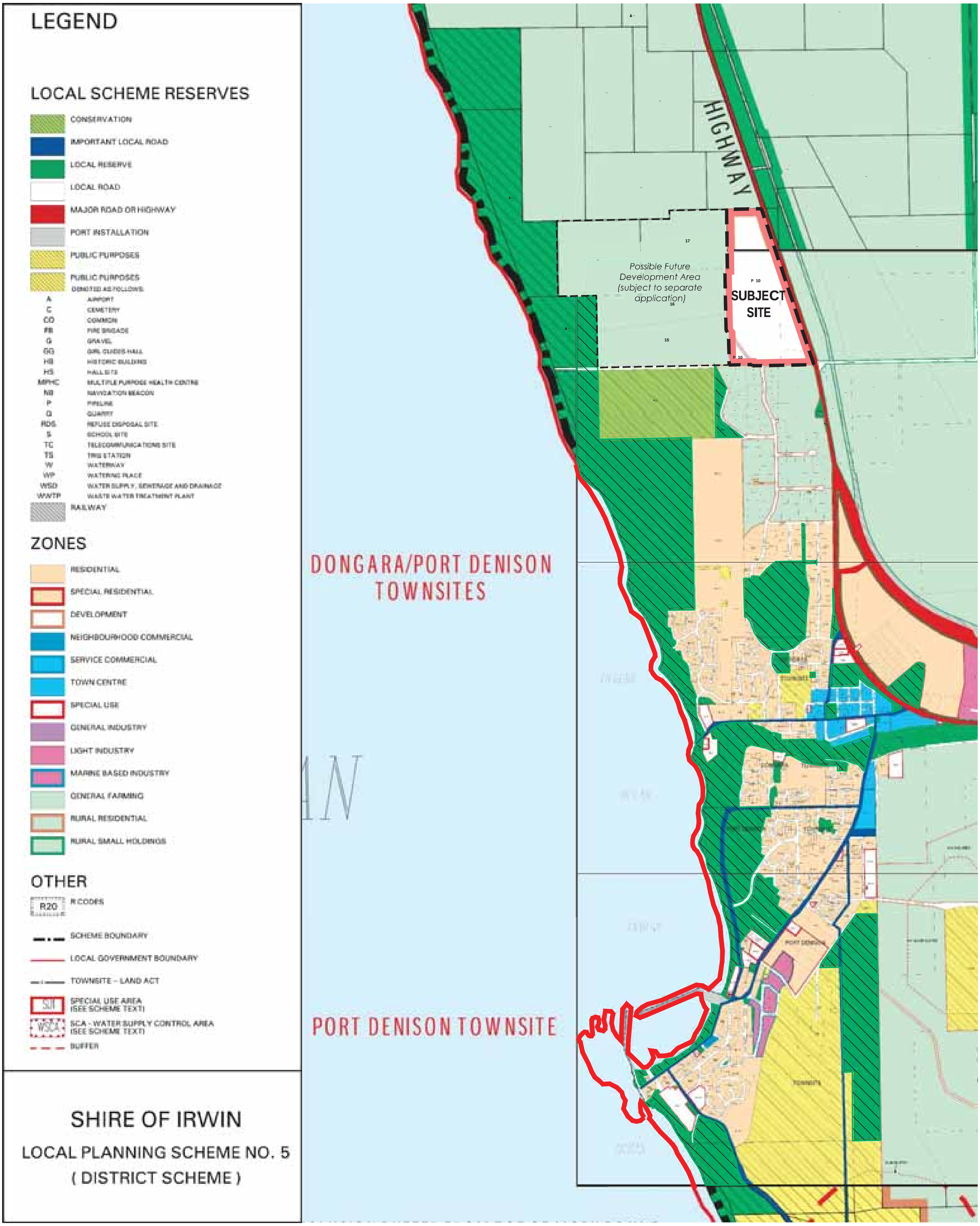
CLE
TOWN PLANNING + DESIGN


*Source: Landgate 2009*

# SITE PLAN

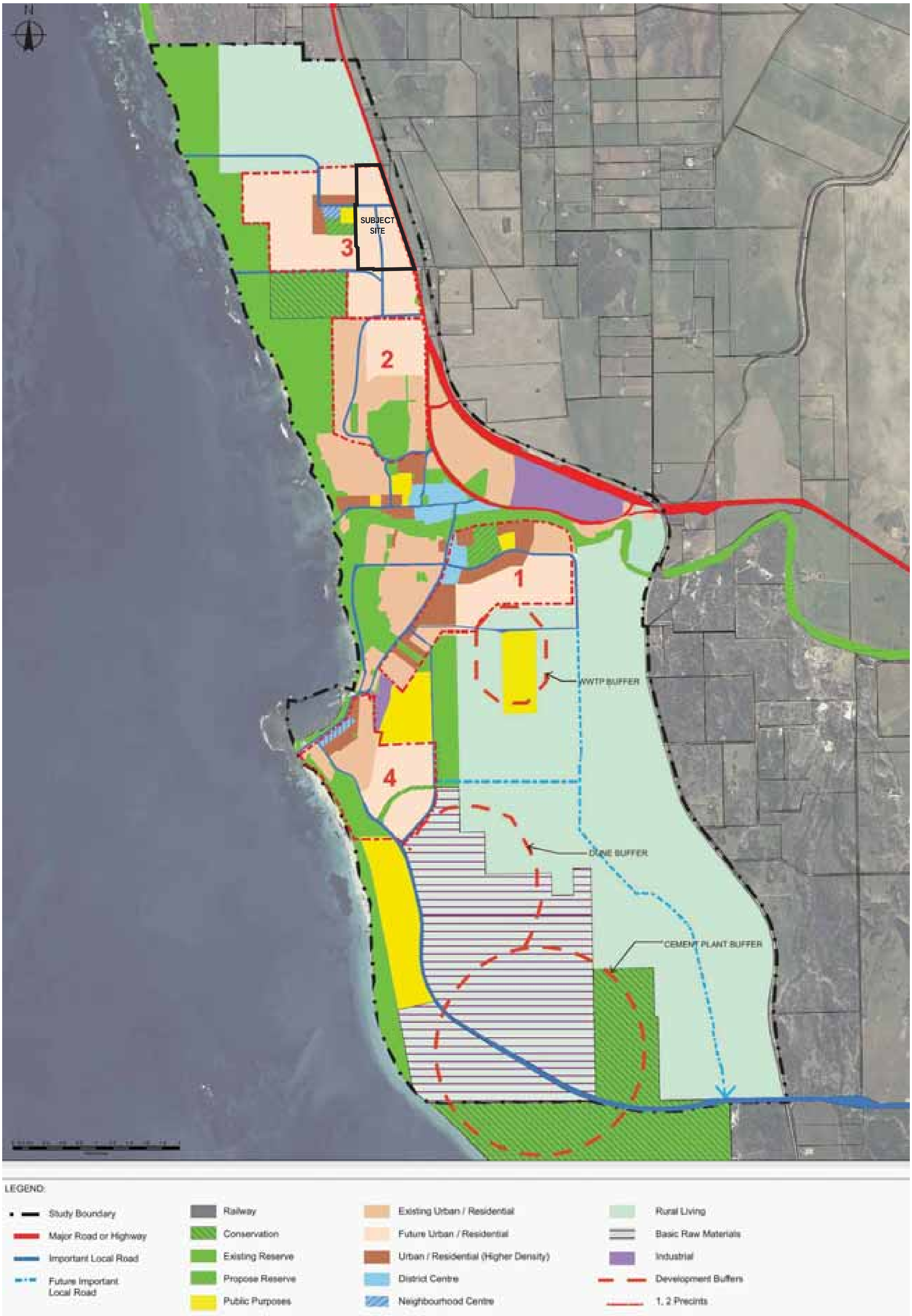
2172-90-01 (26.11.2013), nts

Francisco Road, Dongara: Figure 2




Source: WAPC

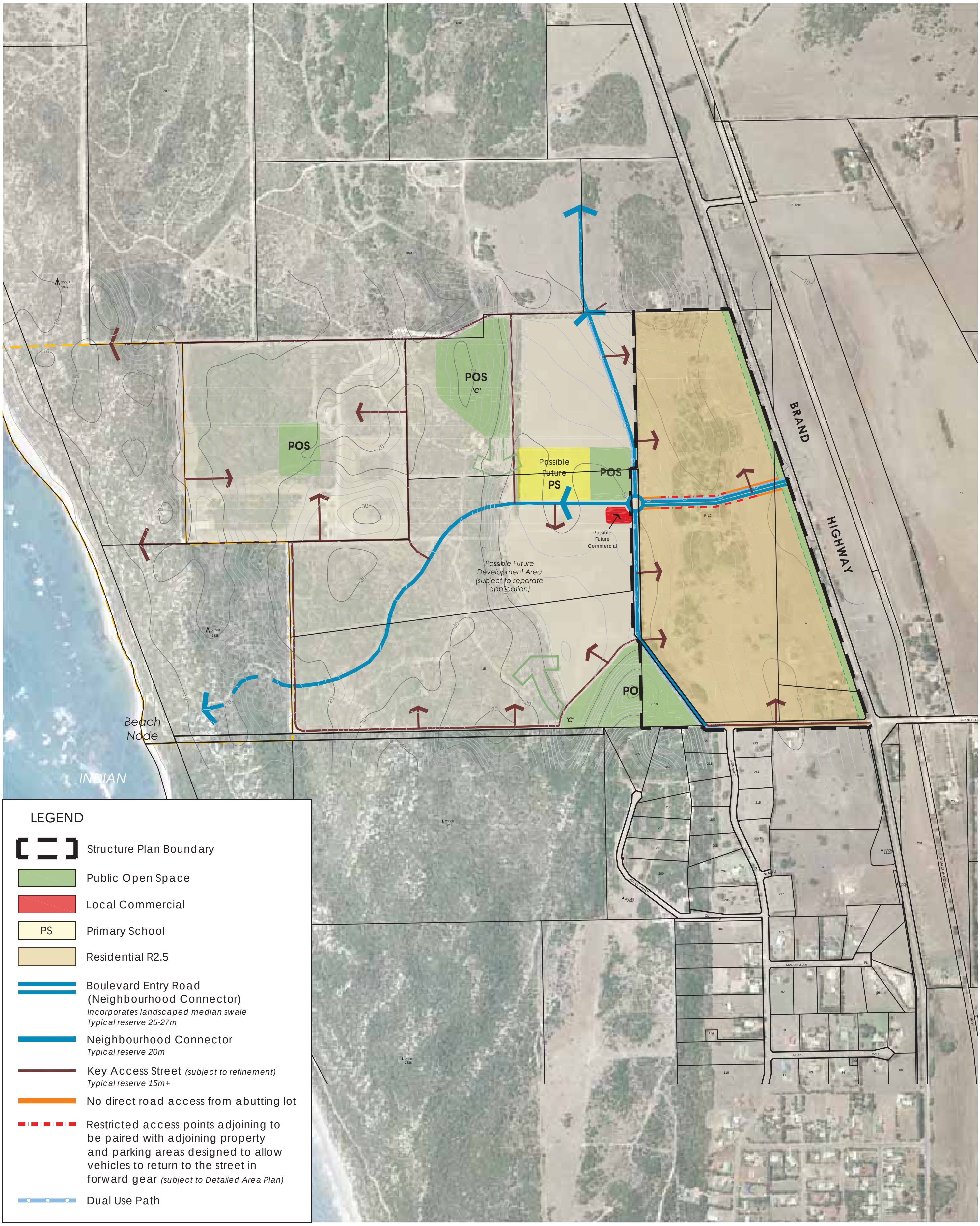
SHIRE OF IRWIN - TOWN PLANNING SCHEME No. 5




*Source: Shire of Irwin*

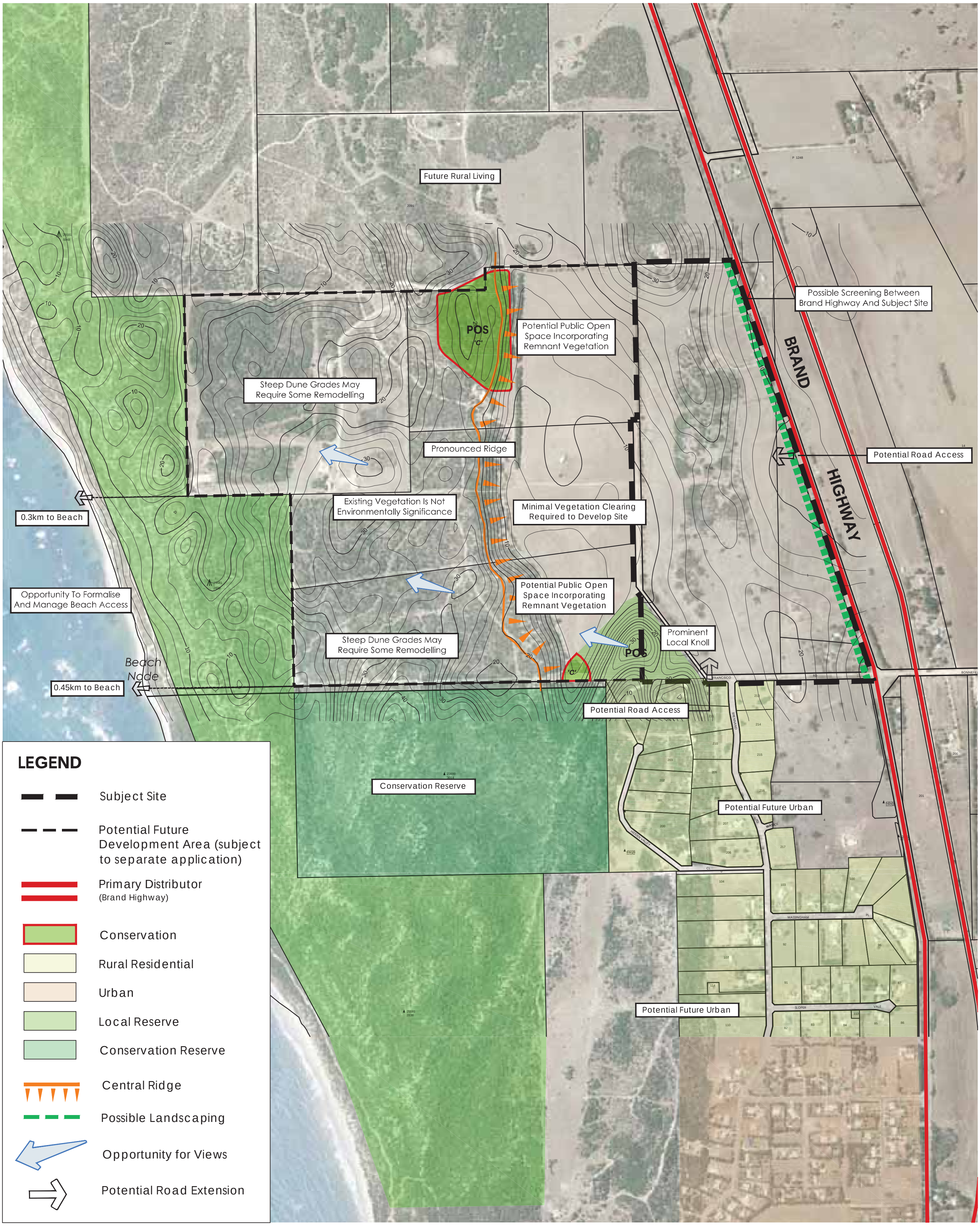
DONGARA - PORT DENISON DISTRICT STRUCTURE PLAN

CLE
TOWN PLANNING + DESIGN

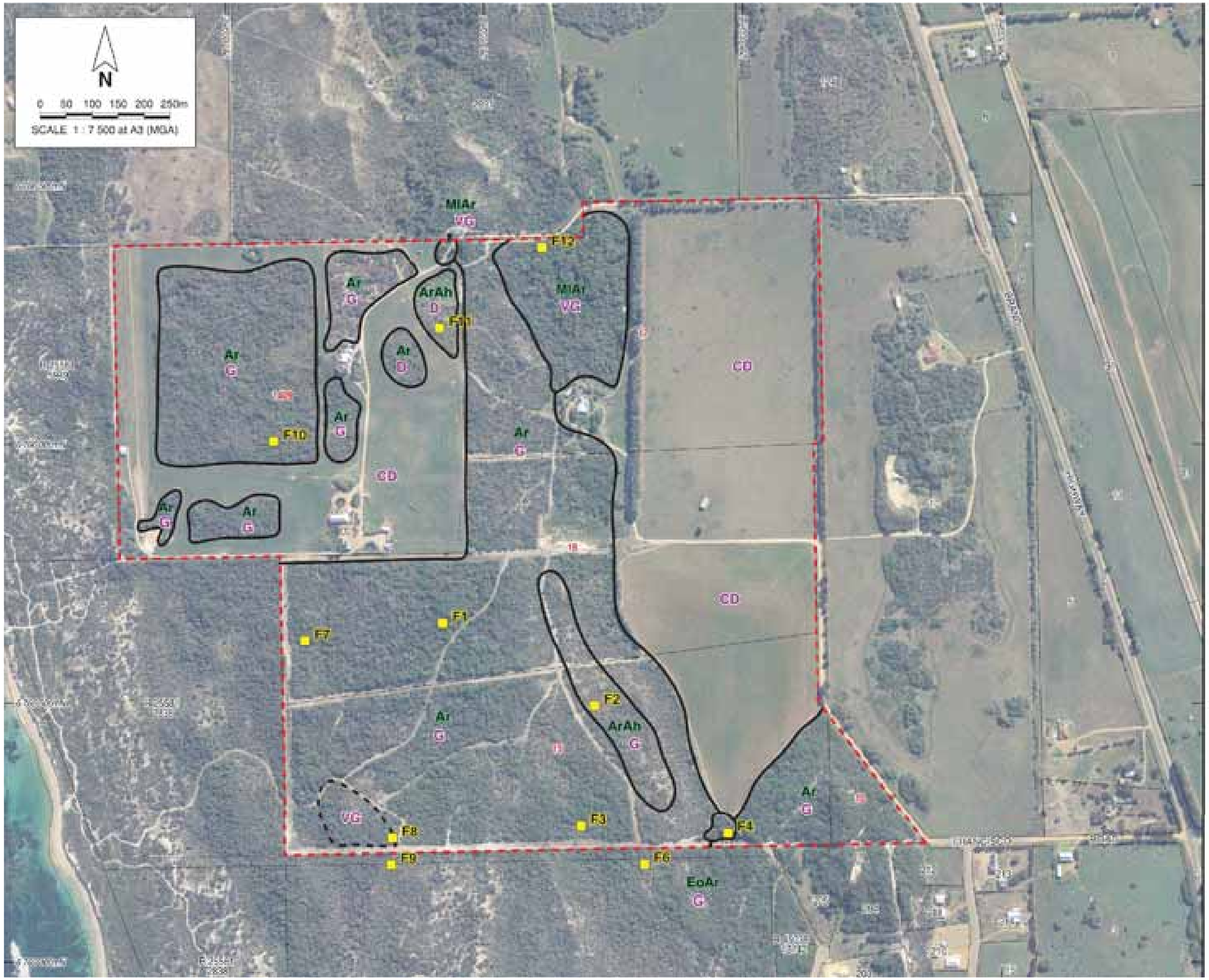



# OVERALL STRUCTURE PLAN CONCEPT

CLE TOWN PLANNING + DESIGN




SITE ANALYSIS PLAN




Legend

- Site Boundary
- Cadastral Boundary
- Quadrat Location
- Vegetation Type Boundary
- Vegetation Condition Boundary
- **Ar** Vegetation Type
- G Vegetation Condition

**Vegetation Legend**

**Ar** *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub

**ArAh** *Acacia rostellifera/Alyogyne huegelii* Open Heath

**MlAr** *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland

**EoAr** *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub

**Vegetation Condition Legend**
(Source: BUSH FOREVER Govt. of W.A., 2000)

**P - Pristine**
Pristine or nearly so, no obvious signs of disturbance.

**Ex - Excellent**
Vegetation structure intact, disturbance affecting individual species and weeds are non aggressive species.

**VG - 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.

**G - Good**
Vegetation structure significantly altered by very obvious signs of multiple disturbance. 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.

**D - 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.

**CD - Completely Degraded**
The structure of the vegetation is no longer intact and the areas is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora composing weed or crop species with isolated native trees or shrubs.

**Cl - Cleared**
No native vegetation remaining.

# VEGETATION TYPES AND CONDITION


DEVELOPMENT CONCEPT PLAN


Source: Google Maps 2010

CONTEXT ANALYSIS PLAN

# APPENDICES

# APPENDIX 1

## Certificates of Title

| REGISTER NUMBER | |
| --- | --- |
| **4/D88986** | |
| DUPLICATE EDITION | DATE DUPLICATE ISSUED |
| **2** | **10/12/2004** |

WESTERN AUSTRALIA

# RECORD OF CERTIFICATE OF TITLE

UNDER THE TRANSFER OF LAND ACT 1893

VOLUME **2046** FOLIO **796**

The person described in the first schedule is the registered proprietor of an estate in fee simple in the land described below subject to the reservations, conditions and depth limit contained in the original grant (if a grant issued) and to the limitations, interests, encumbrances and notifications shown in the second schedule.

B G Roberts

REGISTRAR OF TITLES

REGISTRAR OF TITLES WESTERN AUSTRALIA

**LAND DESCRIPTION:**

LOT 4 ON DIAGRAM 88986

**REGISTERED PROPRIETOR:**
(FIRST SCHEDULE)

PAUL REGINALD BENDER
BRENDA KRETSCHMER-BENDER
BOTH OF LOT 4 FRANCISCO ROAD, DONGARA
AS JOINT TENANTS

(T J859849 ) REGISTERED 3 AUGUST 2006

**LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:**
(SECOND SCHEDULE)

1. *J859850 MORTGAGE TO COMMONWEALTH BANK OF AUSTRALIA REGISTERED 3.8.2006.

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required.
* Any entries preceded by an asterisk may not appear on the current edition of the duplicate certificate of title.
Lot as described in the land description may be a lot or location.

--------------------------------------------------END OF CERTIFICATE OF TITLE--------------------------------------------------

**STATEMENTS:**

The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

| | |
| --- | --- |
| SKETCH OF LAND: | 2046-796 (4/D88986). |
| PREVIOUS TITLE: | 1530-936. |
| PROPERTY STREET ADDRESS: | 30701 BRAND HWY, BONNIEFIELD. |
| LOCAL GOVERNMENT AREA: | SHIRE OF IRWIN. |

NOTE 1: G754302 SECTION 138D TLA APPLIES TO CAVEAT G743704
NOTE 2: DUPLICATE CERTIFICATE OF TITLE NOT ISSUED AS REQUESTED BY DEALING J859850

| REGISTER NUMBER | |
|---|---|
| 5/D88986 | |
| DUPLICATE EDITION | DATE DUPLICATE ISSUED |
| 1 | 2/8/2001 |

WESTERN AUSTRALIA

# RECORD OF CERTIFICATE OF TITLE

UNDER THE TRANSFER OF LAND ACT 1893

VOLUME 2046 FOLIO 797

The person described in the first schedule is the registered proprietor of an estate in fee simple in the land described below subject to the reservations, conditions and depth limit contained in the original grant (if a grant issued) and to the limitations, interests, encumbrances and notifications shown in the second schedule.

BGRoberts

REGISTRAR OF TITLES

REGISTRAR OF TITLES WESTERN AUSTRALIA

**LAND DESCRIPTION:**

LOT 5 ON DIAGRAM 88986

**REGISTERED PROPRIETOR:**
(FIRST SCHEDULE)

GARY ANTHONY NORRISH
JOSE NORRISH
BOTH OF POST OFFICE BOX 35, PERENJORI
AS JOINT TENANTS

(T H027153 ) REGISTERED 15 FEBRUARY 1999

**LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:**
(SECOND SCHEDULE)

1. EASEMENT BURDEN CREATED UNDER SECTION 27A OF T. P. & D. ACT - SEE DIAGRAM 88986.
2. H823814 MORTGAGE TO BANK OF WESTERN AUSTRALIA LTD REGISTERED 30.7.2001.

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required.
* Any entries preceded by an asterisk may not appear on the current edition of the duplicate certificate of title.
Lot as described in the land description may be a lot or location.

----------------------------------------------------END OF CERTIFICATE OF TITLE----------------------------------------------------

**STATEMENTS:**

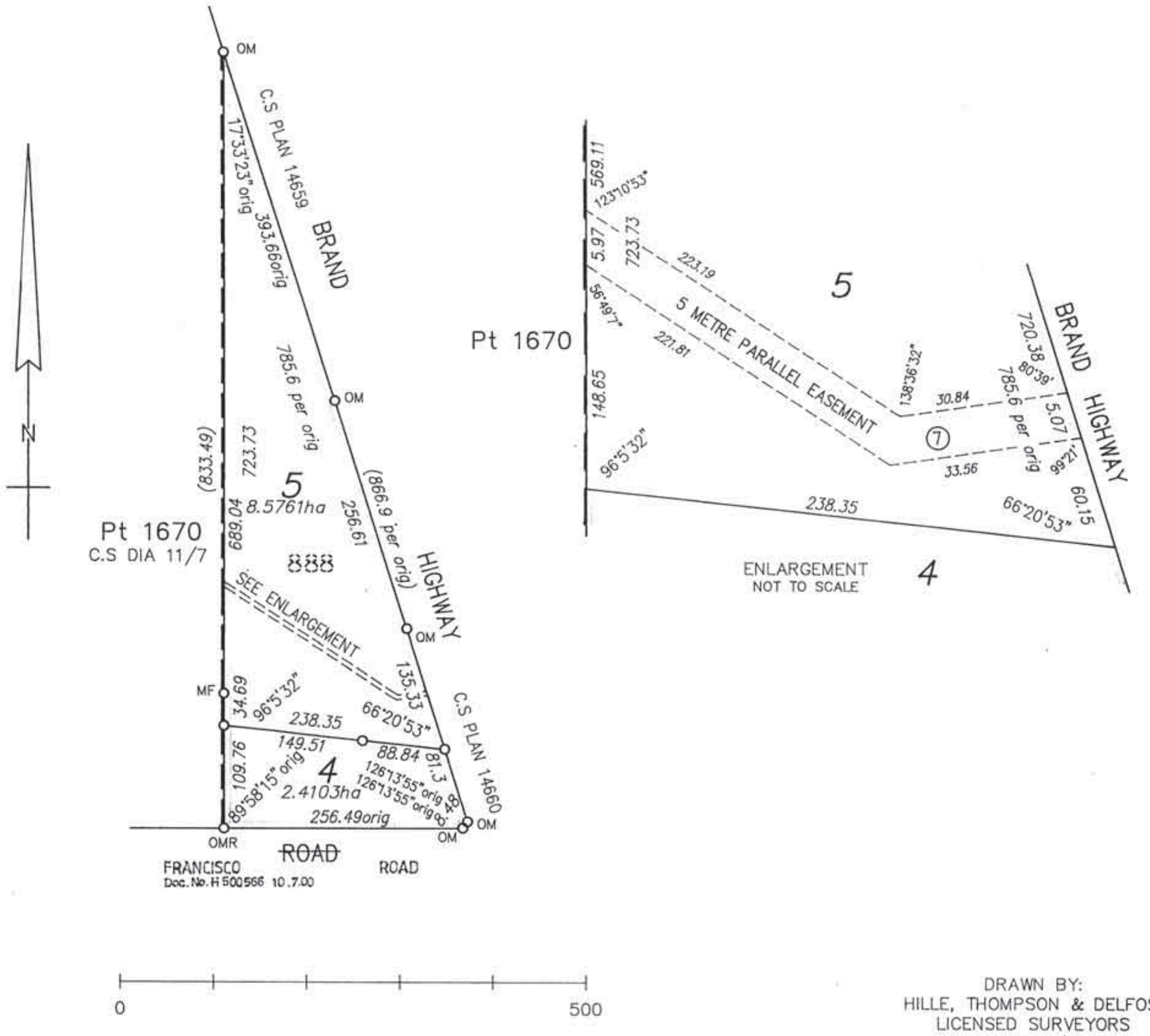
The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

| | |
|---|---|
| SKETCH OF LAND: | 2046-797 (5/D88986). |
| PREVIOUS TITLE: | 1530-936. |
| PROPERTY STREET ADDRESS: | 30721 BRAND HWY, BONNIEFIELD. |
| LOCAL GOVERNMENT AREA: | SHIRE OF IRWIN. |

| LAND DESCRIPTION | ON | CERTIFICATE OF TITLE | FIELD BOOK | DIA 88986 |
|---|---|---|---|---|
| PT LOT 1 OF PT VICTORIA LOCATION 888 | PLAN<br>DIAGRAM 55781<br>INDEX BOOKARA SE (25)<br>PUBLIC | VOLUME 1530 FOLIO 936 | 68631 | TOTAL AREA 10.9864ha |

LOCALITY: BONNIEFIELD
LOCAL AUTHORITY: SHIRE OF IRWIN

EASEMENT TO WESTERN POWER
(7) UNDER SEC 27A OF THE T.P.& D. ACT REG 7 (POWER)




DRAWN BY:
HILLE, THOMPSON & DELFOS.
LICENSED SURVEYORS
48 MARINE TERRACE
GERALDTON
380/94/1303

## SURVEYOR'S CERTIFICATE

REG 54: I A.G.THOMPSON hereby certify that:
(a) this plan of survey is a correct and accurate representation of the survey carried out by me personally/under my own personal supervision, inspection and field check, and recorded in field books lodged for the purposes of this plan of survey;
(b) the measurements are in strict accordance with the Licensed Surveyors (Guidance of Surveyors) Regulations 1961 and in particular regulations 23 and 34 of those regulations; and
(c) this survey and this plan of survey are in strict accordance with the requirements of the Licensed Surveyors (Guidance of Surveyors) Regulations 1961 and the relevant law in relation to which it is lodged.

A.G.Thompson 18/4/95
Licensed Surveyor Date

~~REG 55D I hereby certify that:~~
~~(a) this plan is correct and was prepared under my supervision and is the result of calculations from measurements made by me personally/under my own personal supervision, inspection and field check as recorded in the field books lodged for the purposes of this plan;~~
~~(b) the measurements are in strict accordance with the requirements of the Licensed Surveyors (Guidance of Surveyors) Regulations 1961 and in particular regulations 23 and 34 of those regulations; and~~
~~(c) this plan of survey conforms with the relevant law in relation to which it is lodged.~~

Licensed Surveyor Date

**APPROVED BY**
STATE PLANNING COMMISSION
FILE 96328
Eugene Ferraro
For Chairman
DATE 30.5.95
MINISTRY FOR PLANNING
25 MAY 1995
FILE 96328

**LODGED**
DATE 21.4.95
FEE PAID $253
ASSESSMENT NO 87910
EXAMINED (LEGALLY) J. Chernouski 10/5/95
DOCKET ~~PLAN~~/DIAGRAM 87573
(LEGALLY) CERTIFIED CORRECT J. Chernouski 10/5/95
F.S.C. No.
DOLA
Department of LAND ADMINISTRATION

**SCALE** 1: 5000
ALL DISTANCES ARE IN METRES
**IN ORDER FOR DEALINGS**
SUBJECT TO
SEC.27A OF T.P. & D. ACT
G.J. Brinton 1.6.95
For Inspector of Plans and Surveys Date
APPROVED 10.7.95
APPROVED Date
Inspector of Plans and Surveys

**OFFICE OF TITLES DIAGRAM**
88986

| REGISTER NUMBER | |
|---|---|
| 10/D90656 | |
| DUPLICATE EDITION | DATE DUPLICATE ISSUED |
| 1 | 15/12/2003 |

WESTERN AUSTRALIA

# RECORD OF CERTIFICATE OF TITLE

UNDER THE TRANSFER OF LAND ACT 1893

VOLUME 2072 FOLIO 286

The person described in the first schedule is the registered proprietor of an estate in fee simple in the land described below subject to the reservations, conditions and depth limit contained in the original grant (if a grant issued) and to the limitations, interests, encumbrances and notifications shown in the second schedule.

BGRoberts

REGISTRAR OF TITLES

REGISTRAR OF TITLES WESTERN AUSTRALIA

**LAND DESCRIPTION:**

LOT 10 ON DIAGRAM 90656

**REGISTERED PROPRIETOR:**
(FIRST SCHEDULE)

LUNDY NOMINEES PTY LTD
TEXAS PROPERTY DEVELOPMENT PTY LTD
BOTH OF 21 MORETON TERRACE, DONGARA
AS TENANTS IN COMMON IN EQUAL SHARES

(T I711524 ) REGISTERED 28 NOVEMBER 2003

**LIMITATIONS, INTERESTS, ENCUMBRANCES AND NOTIFICATIONS:**
(SECOND SCHEDULE)

1. E852131 EASEMENT BURDEN SEE SKETCH ON VOL 2072 FOL 286. REGISTERED 7.4.1992.

Warning: A current search of the sketch of the land should be obtained where detail of position, dimensions or area of the lot is required.
* Any entries preceded by an asterisk may not appear on the current edition of the duplicate certificate of title.
Lot as described in the land description may be a lot or location.

--------------------END OF CERTIFICATE OF TITLE--------------------

**STATEMENTS:**

The statements set out below are not intended to be nor should they be relied on as substitutes for inspection of the land and the relevant documents or for local government, legal, surveying or other professional advice.

| | |
|---|---|
| SKETCH OF LAND: | 2072-286 (10/D90656). |
| PREVIOUS TITLE: | 2006-40. |
| PROPERTY STREET ADDRESS: | 30799 BRAND HWY, BONNIEFIELD. |
| LOCAL GOVERNMENT AREA: | SHIRE OF IRWIN. |

LT. 37

ORIGINAL—NOT TO BE REMOVED FROM OFFICE OF TITLES

Application G155047

Volume 2006 Folio 40

WESTERN AUSTRALIA

REGISTER BOOK
VOL. FOL.
CT 2072 - 286

# CERTIFICATE OF TITLE

UNDER THE "TRANSFER OF LAND ACT, 1893" AS AMENDED

I certify that the person described in the First Schedule hereto is the registered proprietor of the undermentioned estate in the undermentioned land subject to the easements and encumbrances shown in the Second Schedule hereto.

Dated 18th April, 1996

G Sach
REGISTRAR OF TITLES

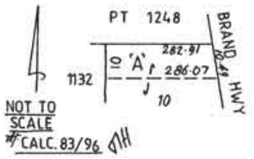
ESTATE AND LAND REFERRED TO

Estate in fee simple in portion of Victoria Location 1670 and being Lot 10 on Diagram 90656, delineated on the map in the Third Schedule hereto.

FIRST SCHEDULE (continued overleaf)

Rex David Tomsett and Pamela Mary Tomsett both of Post Office Box 10, Dongara.

SECOND SCHEDULE (continued overleaf)

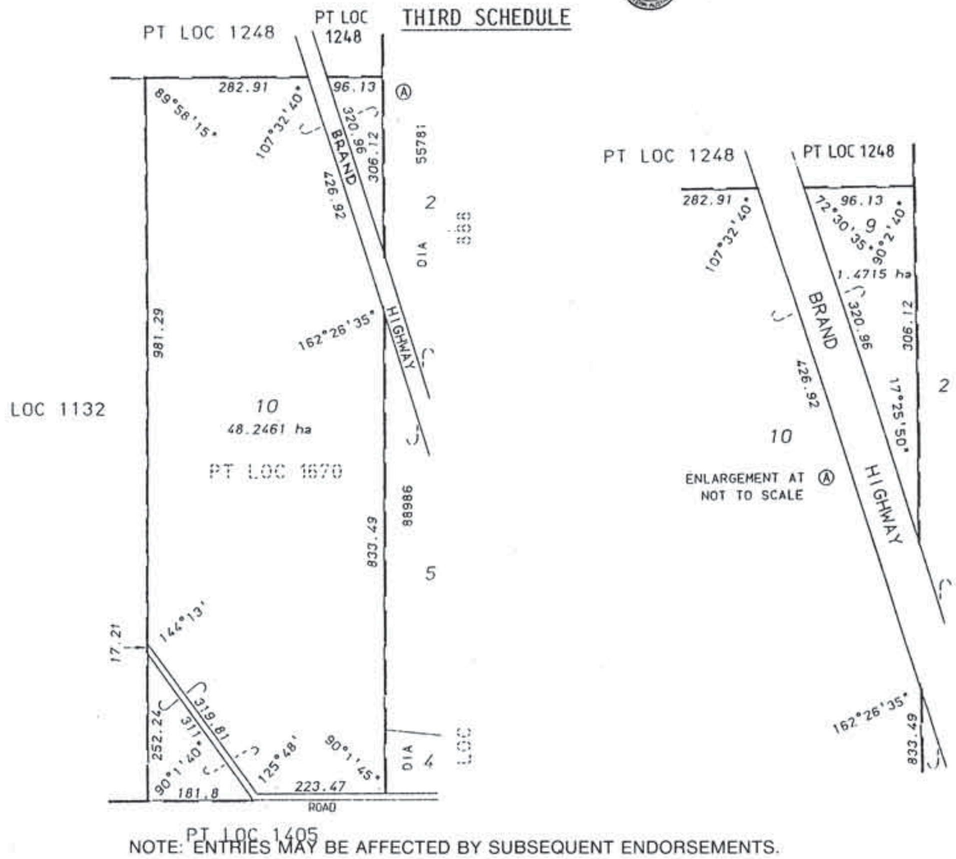



1. TRANSFER E852131. A right of carriageway over the portion of the within land marked 'A' on the map in the margin as set out in the said Transfer is granted to the proprietor or proprietors for the time being of Victoria Location 1409. Registered 7.4.92 at 9.04 hrs.

2. MORTGAGE F618037 to Westpac Banking Corporation. Registered 19.7.94 at 8.25 hrs.

3. ~~MORTGAGE F618038 to Westpac Banking Corporation. Registered 19.7.94 at 8.25 hrs.~~
Discharged G883426 24.8.98

THIRD SCHEDULE




NOTE: ENTRIES MAY BE AFFECTED BY SUBSEQUENT ENDORSEMENTS.

PERSONS ARE CAUTIONED AGAINST ALTERING OR ADDING TO THIS CERTIFICATE OR ANY NOTIFICATION HEREON

LT. 37

**FIRST SCHEDULE (continued)** NOTE: ENTRIES MAY BE AFFECTED BY SUBSEQUENT ENDORSEMENTS

| REGISTERED PROPRIETOR | INSTRUMENT | | REGISTERED | TIME | SEAL | CERT. OFFICER |
|---|---|---|---|---|---|---|
| | NATURE | NUMBER | | | | |

**SECOND SCHEDULE (continued)** NOTE: ENTRIES MAY BE AFFECTED BY SUBSEQUENT ENDORSEMENTS

| INSTRUMENT | | PARTICULARS | REGISTERED | TIME | SEAL | CERT. OFFICER | CANCELLATION | NUMBER | REGISTERED OR LODGED | SEAL | CERT. OFFICER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NATURE | NUMBER | | | | | | | | | | |

CERTIFICATE OF TITLE VOL. 2072 FOL. 286

# APPENDIX 2

## EPA Advice on Site Rezoning

GOVERNMENT OF WESTERN AUSTRALIA

# Environmental Protection Authority

The Atrium,
Level 8, 168 St Georges Terrace,
Perth, Western Australia 6000.
Telephone: (08) 6467 5000.
Facsimile: (08) 6467 5557.

Postal Address: Locked Bag 33,
Cloisters Square, Perth, Western Australia 6850.
Website: www.epa.wa.gov.au

Chief Executive Officer
Shire of Irwin
PMB 21
DONGARA WA 6525

*Our Ref* A569830
*Enquiries* Peta Hayward
*Phone* 6467 5304

ATTENTION:

Dear Sir/Madam

**DECISION UNDER SECTION 48A(1)(a)**
***Environmental Protection Act 1986***

| | |
|---|---|
| **SCHEME AMENDMENT TITLE:** | **Shire of Irwin Local Planning Scheme 5 Amendment 15 - Rezoning from General Farming to Development** |
| **LOCATION:** | **Lots 4, 5 and 10 Brand Highway** |
| **LOCALITY:** | **Bonniefield, Dongara** |
| **RESPONSIBLE AUTHORITY:** | **Shire of Irwin** |
| **DECISION:** | **Scheme Amendment Not Assessed – Advice Given (no appeals)** |

Thank you for referring the above scheme amendment to the Environmental Protection Authority (EPA).

After consideration of the information provided by you, the Environmental Protection Authority (EPA) considers that the proposed scheme amendment should not be assessed under Part IV Division 3 of the *Environmental Protection Act 1986* (EP Act) but nevertheless provides the following advice and recommendations.

**ADVICE AND RECOMMENDATIONS**

**1. Environmental Issues**

- Native Vegetation.

**2. Advice and recommendations regarding Environmental Issues**

The EPA considers that with the retention of the native vegetation in the south west corner of the amendment area as Public Open Space (outlined in the Draft Local Structure Plan) the amendment will not result in any significant environmental impacts.

The EPA notes the future proposal to develop properties to the west of the subject site. The EPA advises that the approval of this amendment does not preempt approval for future development which will require a separate referral under the EP Act.

### 3. General Advice

- For the purposes of Part IV of the EP Act, the scheme amendment is defined as an assessed scheme amendment. In relation to the implementation of the scheme amendment, please note the requirements of Part IV Division 4 of the EP Act.
- There is no appeal right in respect of the EPA's decision on the level of assessment of scheme amendments.
- A copy of this advice will be sent to relevant authorities and made available to the public on request.

Yours faithfully

A. Sutton

Anthony Sutton
Director
Assessment and Compliance Division

17 December 2012

# APPENDIX 3

## Flora and Vegetation Survey 2011 (PGV Environmental)

# LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

## FLORA AND VEGETATION SURVEY

| | |
|---|---|
| Prepared for: | BJ Clarke & Co Real Estate |
| Report Date: | 16 November 2011 |
| Version: | 2 |
| Report No. | 2011-27 |

pgv ENVIRONMENTAL

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Figure 1: Location

Figure 2: Vegetation Types and Condition


**Appendices**


Appendix 1: DEC Database Searches

Appendix 2: Quadrat Data

Appendix 3: Flora List

# 1 INTRODUCTION

## 1.1 Background

Lots 10, 15, 16, 17 and 1409 Francisco Road, Dongara (the site) are located adjacent to the coast approximately 3km north of the Dongara town centre. The site is currently being considered by the Department of Planning for its potential urban development to accommodate the future expansion of Dongara.

The owners of the lots are assisting the Department of Planning by undertaking planning and environmental work to investigate the opportunities and constraints to future urban development. This flora and vegetation survey has been commissioned by the landowners as part of those investigations.

## 1.2 Scope of Work

The flora and vegetation survey included the following tasks:

1. A Department of Environment and Conservation database search for potential Declared Rare Flora, Priority Flora and Threatened and Priority Ecological Communities that might occur on the site;
2. A review of any relevant flora and vegetation surveys undertaken in the vicinity of the site and the region in general;
3. A survey on the site to record the flora in permanent 10m x 10m quadrats;
4. A thorough site walkover of the site to record flora and vegetation outside of the sampled quadrats;
5. Compilation of a list of all flora species occurring at the time of survey;
6. A map of the vegetation types and condition; and
7. A description and GPS co-ordinates of any significant flora species or vegetation communities on the site.

# 2 EXISTING ENVIRONMENT

## 2.1 Land Use

Lot 10 west of Francisco Road currently consists of undeveloped native vegetation. The eastern portions of Lots 15, 16 and 17 have been cleared for agriculture while the western portions contain native vegetation. The native vegetation on these lots has been grazed in the past. A residential dwelling exists on Lot 17. Lot 1409 contains two residential dwellings, some cleared land for horse paddocks, and a central area of native vegetation.

The lots are zoned General Farming in the Shire of Irwin Town Planning Scheme No. 5.

Several tracks and firebreaks occur in the vegetated part of Lots 15, 16 and 17. Tracks lead down to the beach from Lot 15 and Lot 1409. The beach is located approximately 450m west of Lot 15 and 270m west of Lot 1409. The lots are separated from the coast by two Local Reserves (25581 5949 and 25581 2838) as well as a strip of Unallocated Crown Land.

Conservation Reserve 23600 abuts Lot 15 to the south and consists of native vegetation.

Private lots 205, 205 and 212 are located south of Lot 10 and a part of Lot 15 and contain native vegetation.

The balance of Lot 10 east of Francisco Rd abuts the eastern side of the site and has been predominantly cleared for agriculture.

Private Lots 2092, 2091 and 1248 occur to the north of the site and have been partially cleared for agriculture but retain native vegetation on the majority of the land.

## 2.2 Topography and Landform

The site is located close to the coast and includes undulating coastal Quindalup dunes on the western side and the flatter Tamala limestone landform on the eastern side. Generally the clearing for agriculture has occurred on the eastern Tamala limestone landform although some of the coastal soils on Lot 1409 have been cleared for horse paddocks.

The eastern cleared area is relatively flat from west to east but slopes generally from the north down to the south. Elevation on the eastern portion ranges from 32mAHD down to 9m AHD.

The western dunal area is undulating and ranges in elevation from 20m - 38m AHD on Lots 15-27 and 12m – 33m AHD on Lot 1409.

## 2.3 Geology and Soils

Soils on the site have been described by Landform Research (2005). The eastern Tamala limestone soils are brown sands grading to earthy sands overlying limestone at variable depth. The western Quindalup Dune soils are relatively old Quindalup dunes and therefore contain a brown to cream brown sand with minor clay and calcareous materials. The coarser nature of the older Quindalup

dunes makes them less susceptible to erosion than younger phase Quindalup dunes (Landform Research, 2005).

## 2.6 Hydrology

There are no surface water features such as creeklines, drainage lines or wetlands on the site.

Groundwater occurs under the site at an average level of around 2m AHD (Landform Research, 2005) indicating a minimum depth to groundwater of around 10m.

# 3 Vegetation and Flora

## 3.1 Methodology

A flora and vegetation survey of the site was conducted by Dr Paul van der Moezel on 20 and 21 September 2011. The survey was undertaken in accordance with the EPA's Guidance Statement No. 51 *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia*.

The survey included sampling from 10 permanent 10m x 10m quadrats on the site as well as a thorough walk over the area. Given the uniformity of the vegetation and overall low species diversity, the number of quadrats and site coverage during the field survey was considered high.

Each quadrat was marked with an aluminium dropper in the south-west and south-east corners of the quadrat. Hand-held GPS co-ordinates were taken from the position of the south-east dropper.

All plant species were either identified on site or collected for identification.

## 3.2 Department of Environment and Conservation Database Searches

A search of the DEC Threatened Flora Database and the WA Herbarium indicates that one Threatened (Declared Rare Flora) and 15Priority species are listed in the vicinity of the site but not on the site (Table 1).

**Table 1: List of Flora Species Identified from DEC Database Searches.**

| Species | Status under Wildlife Cons. Act | Status under EPBC Act | Flowering Period |
|---|---|---|---|
| *Acacia telmica* | P3 | | July - Sept |
| *Anthocercis intricata* | P3 | | June - Sept |
| *Banksia elegans* | P4 | | Oct - Nov |
| *Calytrix eneabbensis* | P4 | | July - Oct |
| *Comesperma rhadinocarpum* | P2 | | Oct - Nov |
| *Conostylis micrantha* | Threatened | Endangered | July - Aug |
| *Cryptandra pendula* | P1 | | July, Aug |
| *Dampiera tephrea* | P2 | | July |
| *Eucalyptus ebbanoensis* | P4 | | Jan - Mar |
| *Eucalyptus macrocarpa x pyriformis* | P3 | | - |
| *Eucalyptus zopherophloia* | P4 | | Nov - Jan |
| *Grevillea tenuiloba* | P3 | | Apr or July - Oct |
| *Haloragis foliosa* | P3 | | Oct |
| *Stylidium carnosum* subsp narrow leaves (JA Wege 490) | P1 | | Sept, Oct |
| *Stylidium pseudocaespitosum* | P2 | | Sept |

A search of the DEC's Threatened (TEC) and Priority Ecological Communities (PEC) database did not identify any known occurrences of TECs or PECs within 5km of the site.

## 3.3 Survey Conditions

The conditions that the survey was undertaken in are presented in Table 2 in order to assess the adequacy of the survey. In summary, there were no constraints to the survey.

**Table 2: Statement of Botanical Survey Conditions**

| ISSUE | CONSTRAINTS (YES/NO); SIGNIFICANT, MODERATE OR NEGLIGIBLE | COMMENT |
|---|---|---|
| Competency/experience of the consultant conducting the survey | No constraints | Dr Paul van der Moezel has extensive survey experience on the Swan Coastal Plain, including the Dongara and Geraldton areas. |
| Proportion of the flora identified | No constraints | The uniformity of the vegetation and timing of the survey in late September would have resulted in nearly all of the native species on the site being recorded. |
| Sources of information (historic/recent or new data) | No constraints | The flora of the Swan Coastal Plain and Geraldton area is relatively well documented, Dongara less so. |
| Proportion of the task achieved and further work that may need to be undertaken | No constraints | No follow-up survey required. |
| Timing/weather/season/cycle | No constraints | Generally average rainfall in winter 2011 on the Swan Coastal Plain. Late September survey ideal for identifying most species. No Threatened or Priority ephemeral species expected on the site requiring particular seasonal surveys outside of mid-Spring. |
| Intensity of survey (e.g. In retrospect was the intensity adequate) | No constraints | The network of tracks made access and coverage easy. Approximately 2 days spent walking and driving over the site. |
| Completeness (e.g. was relevant area fully surveyed) | No constraints | |
| Resources (e.g. degree of expertise available for plant identification) | No constraints | Experienced botanist undertook plant identifications mostly on site with some identification off-site using standard reference material. |
| Remoteness and/or access problems | No constraints | Easily accessible by vehicle and on foot. |
| Availability of contextual (e.g. bioregional) information for the study area. | No constraints | Geraldton Regional Flora and Vegetation Survey (WAPC, 2010) and Dongara to Cape Burney Vegetation Survey (Ecoscape, 2010) used for regional context. |

Fungi and nonvascular flora (e.g. algae, mosses and liverworts) were not specifically surveyed for during the survey.

## 3.4 Results

### 3.4.1 Flora

A total of 55 species were recorded during the 2011 spring flora survey (Appendix 3). This total consisted of 33 native species and 22 introduced species. The very low number of native species and high proportion of introduced species (40%) reflects the generally naturally low species richness of Quindalup dunes as well as the overall low condition of the site.

None of the species recorded was a Threatened (Declared Rare) or Priority listed flora.

### 3.4.2 Vegetation Types

Four separate Vegetation Associations were described and mapped on the site based on the structure and composition of the vegetation (Figure 2). However, one vegetation type, the *Acacia rostellifera* Tall Open to Closed Tall Scrub was by far the dominant vegetation type, representing about 90% of the native vegetation. The four vegetation types are described below.

**Ar** *Acacia rostellifera* **Tall Open Scrub to Closed Tall Scrub**

This is the main vegetation on the site. *Acacia rostellifera* ranges in height from 2-5m high with the taller stands typically on the lee side of the dunes and in the valleys. Density of *Acacia rostellifera* is high, ranging from 60-80%. As a result of the high canopy density, the understorey is sparsely vegetated. Most of the species are weeds with the main native species being *Rhagodia preissii* ssp *obovata* and the creeper *Clematis linearifolia.* Common weed species include *Sonchus asper, Sonchus oleraceus, Bromus diandrus* and *Euphorbia peplus.* The soil type was typically Brown-grey sand.

The quadrats surveyed in this area contained an average of 12.0 species (range 8-16). The quadrat in Very Good condition had a higher number of native species (13) than the other quadrats in Good condition (average 3.5, range 2-5) (Quadrats F1, F3, F7, F8, F10, Appendix 2).

**ArAh** *Acacia rostellifera/Alyogyne huegelii* **Open Heath**

A narrow band of this vegetation type occurred on the top of the eastern ridge in the Quindalup dunes on Lots 15 and 16 as well as a degraded part on the eastern side of Lot 1409. *Acacia rostellifera* was the dominant species but less dense (40%) and shorter (1.5-2m) than in the Ar vegetation above. *Alyogyne huegelii* was consistently dominant up to 2m high. Overall the vegetation type was dominated by weed species but was classified as being in Good condition. The soil type was yellow-grey sand.

The quadrats surveyed in this area contained an average of 13.5 species (range 13-14) of which 6 (range 4-8) were native (Quadrat F2, F11, Appendix 2).

**MlAr** *Melaleuca lanceolata* **Low Open Forest over** *Acacia rostellifera* **Tall Shrubland**

This vegetation type occurs in two stands, one large stand approximately 5ha in size at the northern end of Lot 17 and one smaller stand in the north-east corner of Lot 1409. The *Melaleuca lanceolata* (Rottnest Island Tea Tree) trees were up to 8m high and relatively dense with around a 50% canopy cover. The mid-storey of *Acacia rostellifera* was open (4m high and 20% cover) while the understorey iwas densely vegetated in ground covers. Native creepers *Zygophyllum fruticulosum* and *Clematis linearifolia* were common. The condition of the 5ha parcel of this vegetation type was mostly Very Good with the smaller parcel in Degraded condition. The soil type was Dark grey sand.

The quadrat surveyed in the larger stand contained 13 species of which 10 were native (Quadrat F12, Appendix 2).

**EoAr** *Eucalyptus obtusiflora* **Tree Mallee over** *Acacia rostellifera* **Tall Open Scrub**

A very small natural stand of *Eucalyptus obtusiflora* (Dongara Mallee) occurred on the southeastern end of Lot 15. Several *Eucalyptus obtusiflora* trees were present up to 6-7m high with an open mid-storey of *Acacia rostellifera* 2m high and a weedy understorey. The soil type was brown loamy sand.

The quadrat surveyed in the larger stand contained 7 species of which only 2 were native (Quadrat F4, Appendix 2).

### 3.4.3 Vegetation Condition

The condition of the vegetation was assessed according to the system devised by Keighery and described in *Bush Forever* (Government of Western Australia, 2000a). Keighery's condition rating scale ranges from Pristine (where the vegetation exhibits no visible signs of disturbance) to Completely Degraded (where the vegetation structure in no longer intact and without native plant species) (Table 1).

The vegetation condition of the site was mostly rated as Good (Figure 2). The rating of Good indicates that the upper *Acacia rostellifera* canopy was considered to be in its natural structure whereas the understorey was significantly altered. The dominance of weeds in the understorey may be due to past clearing of the whole site with subsequent re-growth of the *Acacia rostellifera* trees, or to grazing the understorey, or as a result of high frequency of fires. Examination of historical aerial photographs available on the Landgate website show that in 1998, only 13 years ago, the area of native vegetation on the western Quindalup dune area was more extensive, particularly on Lot 1409. The vegetation appears to be denser than in 2011 with less tracks and firebreaks. The condition of the vegetation therefore is considered to be more as a result of grazing the understorey.

The vegetation structure in some of the *Acacia rostellifera* vegetation on Lot 1409 has been reduced to an extent that the areas were rated as Degraded. The larger stand of Rottnest Island Tea Tree was assessed as being in Very Good condition. One area of *Acacia rostellifera* vegetation near the south-west corner of Lot 15 had a lower dominance of weed species and was rated as Very Good.

**Table 3: Vegetation Condition Rating Scale.**

| | |
|---|---|
| Pristine | Pristine or nearly so, no obvious signs of disturbance. |
| Excellent | Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species. |
| Very Good | Vegetation structure altered, obvious signs of disturbance.<br>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 disturbance. Retains basic vegetation structure or ability to regenerate it.<br>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.<br>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 are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs. |

Source: Government of Western Australia, 2000.

### 3.4.4 Conservation Significance of Vegetation and Flora

*Vegetation – Regional Significance using Beard Vegetation Community Types*

According to Beard (1976) the vegetation on the site belongs to Beard's Vegetation Community 431 (*Acacia rostellifera* open shrubland). Vegetation Community 431 is restricted to the Geraldton Sandplains bioregion between Kalbarri and Dongara.

The Beard Vegetation Community 431 has 73.76% of its original extent of 4,460ha remaining (Ecoscape 2011 and WAPC 2010). The percentage remaining is greater than 30%, which is the EPA's minimum target retention for vegetation communities. However, the proportion of Community 431 that is within conservation reserves is very low with less than 1% reserved, or 46.75ha (WAPC 2010).

Conservation Reserve 23600 abuts the southern boundary of the site. The Reserve contains native vegetation mapped as Beard Vegetation Community 431. As Reserve 23600 is approximately 50ha in size, it is reasonable to assume that the only area of Vegetation Community 431 that is protected is actually the reserve abutting the site.

The criteria used by the EPA for identifying areas of regional significance (EPA 2008 - Guidance Statement 33) is the Comprehensive, Adequate and Representative (CAR) system. According to the CAR system, it is desirable to have representative and viable areas of each vegetation type reserved throughout its distribution. Reserve 23600 to the south of the site would appear to satisfy the protection of Vegetation Community 431 in this part of the Community's distribution. Two quadrats surveyed in the Reserve as part of this flora and vegetation survey (F6 and F9 in Appendix 2) confirm that the vegetation in the Reserve is very similar to the dominant *Acacia rostellifera* vegetation on the site. Therefore, as Reserve 23600 is completely covered in native vegetation in better condition than on the subject site the Reserve could be considered to adequately protect a representative example of vegetation community 431 in the Dongara area.

The conclusion in this report is that on the basis of the Beard vegetation community types the vegetation on the site is not considered to be regionally significant.

*Vegetation – Regional Significance using Dongara to Cape Burney Vegetation Survey*

A survey of the coastal strip between Dongara and Cape Burney was initiated by the Department of Planning, the City of Geraldton-Greenough and the Shire of Irwin to provide guidance for future planning of the area. The survey undertaken by Ecoscape (2010) described and mapped the vegetation types and condition in a 6,400ha area between Dongara and Cape Burney and included the survey area the subject of this report. Following statistical analysis of the quadrat data, a total of nine plant communities were identified.

The Dongara to Cape Burney Coastal Vegetation Survey mapped two vegetation types on the site as follows:

> Community 7 – Taller Dune Slope *Acacia rostellifera, Alyxia buxifolia, Melaleuca depressa* and *Templetonia retusa* shrubland
>
> Community 8 – Dune Swale and Greenough Alluvial Flats *Melaleuca* Forest or tall shrubland.

Community type 7 matches the description of vegetation types Ar and ArAh mapped in this report (Figure 2). Community type 8 matches the description of vegetation type MlAr mapped in this report (Figure 2).

The Dongara to Cape Burney survey mapped another community type (Community 9 – Mallee *Eucalyptus obtusiflora* and *Eucalyptus oraria*) immediately to the north but not on the site. The more detailed survey undertaken for this report considers that this community also occurs in a very small part of the site, coinciding with the EoAr vegetation type on Figure 2.

The Dongara to Cape Burney survey did not consider any of the nine vegetation communities described and mapped for that area had regional significance.

*Vegetation - Local*

Vegetation can have local significance for a number of reasons including the retention of bushland with linkage value, aesthetic value, and the protection of local flora and fauna.

The Dongara to Cape Burney Coastal Vegetation Survey considered that seven of the nine plant communities identified in that survey had local significance due to their restricted extent in the Dongara to Cape Burney study area.

The *Acacia rostellifera* dominated vegetation of Community 7 was not one of the locally significant vegetation types as it was found to be the most widespread vegetation community in the region.

The condition of the *Acacia rostellifera* dominated vegetation on the site was mostly in Good condition and indicated that the upper *Acacia rostellifera* canopy retained its natural structure whereas the understorey was significantly altered and was dominated by weeds. This survey concludes that the *Acacia rostellifera* dominated vegetation is not likely to be floristically different from the *Acacia rostellifera* vegetation in the adjoining Conservation Reserve and is in poorer condition. Given the low significance of the vegetation type, and its local protection in the Conservation Reserve, the *Acacia rostellifera* vegetation on the site is not considered to be locally significant.

Community 8, which represents the *Melaleuca lanceolata* vegetation on the site, was considered locally significant in the Dongara to Cape Burney Coastal Vegetation Survey as it was only recorded from 174ha in the Dongara to Cape Burney area. The large stand of *Melaleuca lanceolata* on the site is mostly in Very Good condition and is of a size (around 5ha) and uniform shape that could retain its current environmental values in the long term. This report recommends protection of as much of the large stand of *Melaleuca lanceolata* in Public Open Space as possible.

Community 9, which represents the small area of *Eucalyptus obtusiflora* on the site, was also considered to be locally significant as it only occupied 33ha of the area and was one of the least represented of the plant communities in the Dongara to Cape Burney study area. The area of vegetation on the site containing *Eucalyptus obtusiflora* was very small and in poor condition. However, given that this vegetation type is uncommon in the Dongara area, retention of this stand is recommended. To make the vegetation a viable size, additional areas of native vegetation on the site could be retained alongside this area, or the area could be made contiguous with the Reserve immediately adjacent to the south.

*Flora*

The coastal strip between Dongara and Cape Burney has a very low number of conservation significant species (Ecoscape 2010) and this survey confirmed that no Declared Rare Flora or Priority listed flora were recorded on the. The site therefore does not have a high conservation significance for flora species.

# 4 SUMMARY AND CONCLUSIONS

The flora and vegetation survey of Lots 10, 15, 16, 17 and 1409 Francisco Road Dongara resulted in the following findings:

- A total of 55 species were recorded during the spring flora survey, consisting of 33 native species and 22 introduced species. The very low number of native species and high proportion of introduced species (40%) reflects the generally naturally low species richness of Quindalup dunes as well as the overall low condition of the site;
- None of the species is a Threatened (Declared Rare) or Priority listed flora;
- Four vegetation types were described and mapped for the site. The most dominant vegetation was *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub. Two areas containing *Melaleuca lanceolata* (Rottnest Island Tea Tree) including a 5ha stand in Very Good condition occurs on the site as does a very small stand containing the Dongara Mallee (*Eucalyptus obtusiflora*);
- The condition of the vegetation was mostly Good and reflected the high proportion of weeds in the understorey which was most likely due to past grazing on the site;
- None of the vegetation types is a Threatened or Priority Ecological Community;
- The vegetation is mapped as Beard Vegetation Complex 431 (*Acacia rostellifera* open shrubland). Vegetation Community 431 has nearly 73.76% of its original extent remaining, however only around 1% of it is in secure reserves. The reserve protecting this Complex is Conservation Reserve 23600 located immediately south of the site and protects around 50ha of Community 431 in very good condition. The vegetation on the site is therefore considered to not have regional significance;
- The *Acacia rostellifera* dominated vegetation is considered by the Dongara to Cape Burney Coastal Vegetation Survey to be widespread and not have local significance;
- The larger *Melaleuca lanceolata* (Rottnest Island Tea Tree) stand and the area containing the Dongara Mallee (*Eucalyptus obtusiflora*) are considered to be locally significant as they are not widespread in the Dongara area. These areas are recommended for protection in Public Open Space.

# 6 REFERENCES

Beard, J.S. (1976). *The vegetation of the Dongara area, Western Australia: map and explanatory memoir, 1:250,000 series.* Vegmap Publications, Perth.

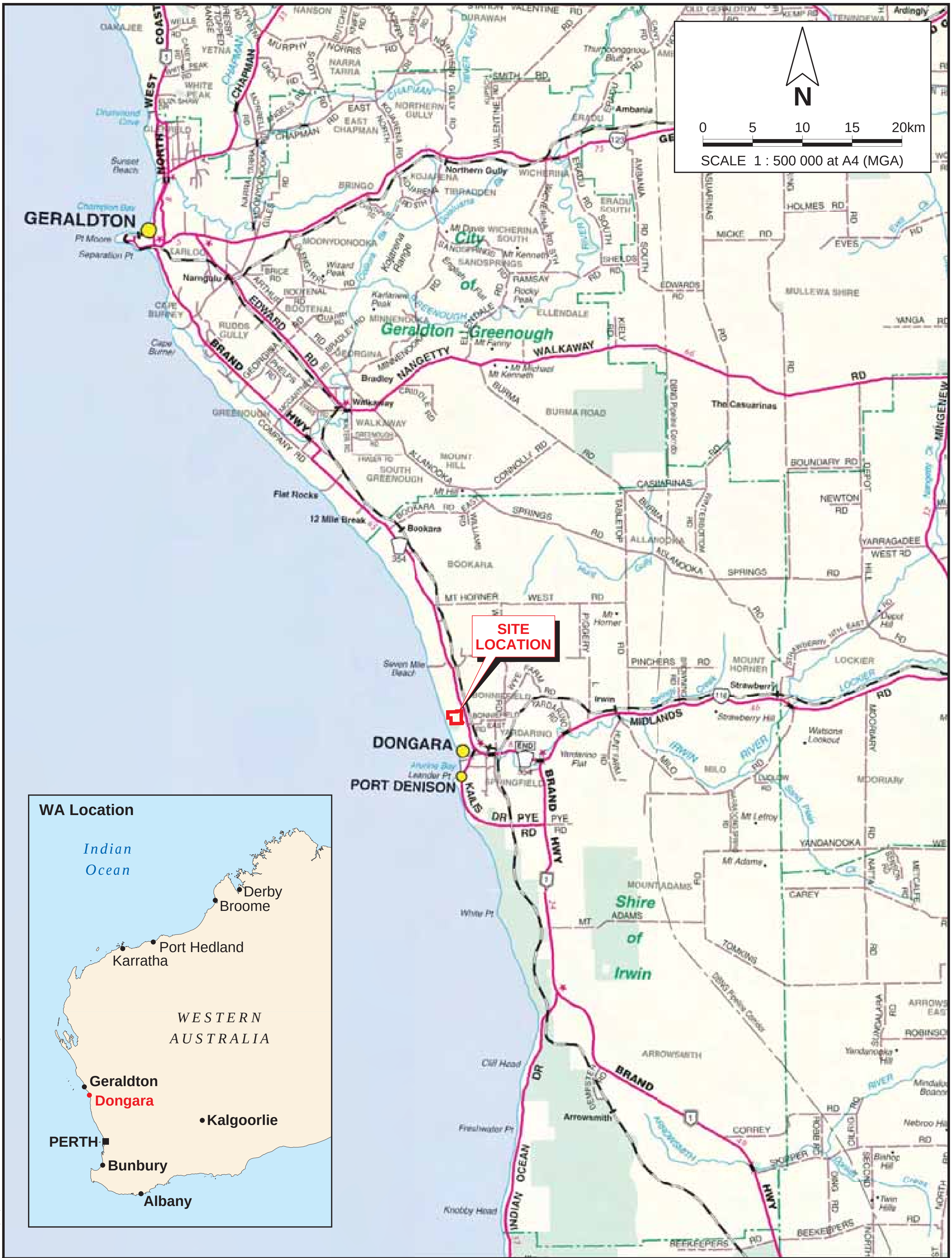
Ecoscape Pty Ltd (2010). *Dongara to Cape Burney Coastal Vegetation Survey.* Prepared for the Northern Agricultural Catchment Council.

Environmental Protection Authority (2008). *Environmental Guidance for Planning and Development*. Guidance Statement No. 33.

Landform Research (2005). *LandCapability and Geotechnical Assessment Lots 10, 15, 16 and 17 Francisco Road, Dongara.*

Western Australian Planning Commission (2010). *Geraldton Regional Flora and Vegetation Survey*. Prepared by the Department of Planning and supported by Ecoscape (Australia) Pty Ltd.

# FIGURES





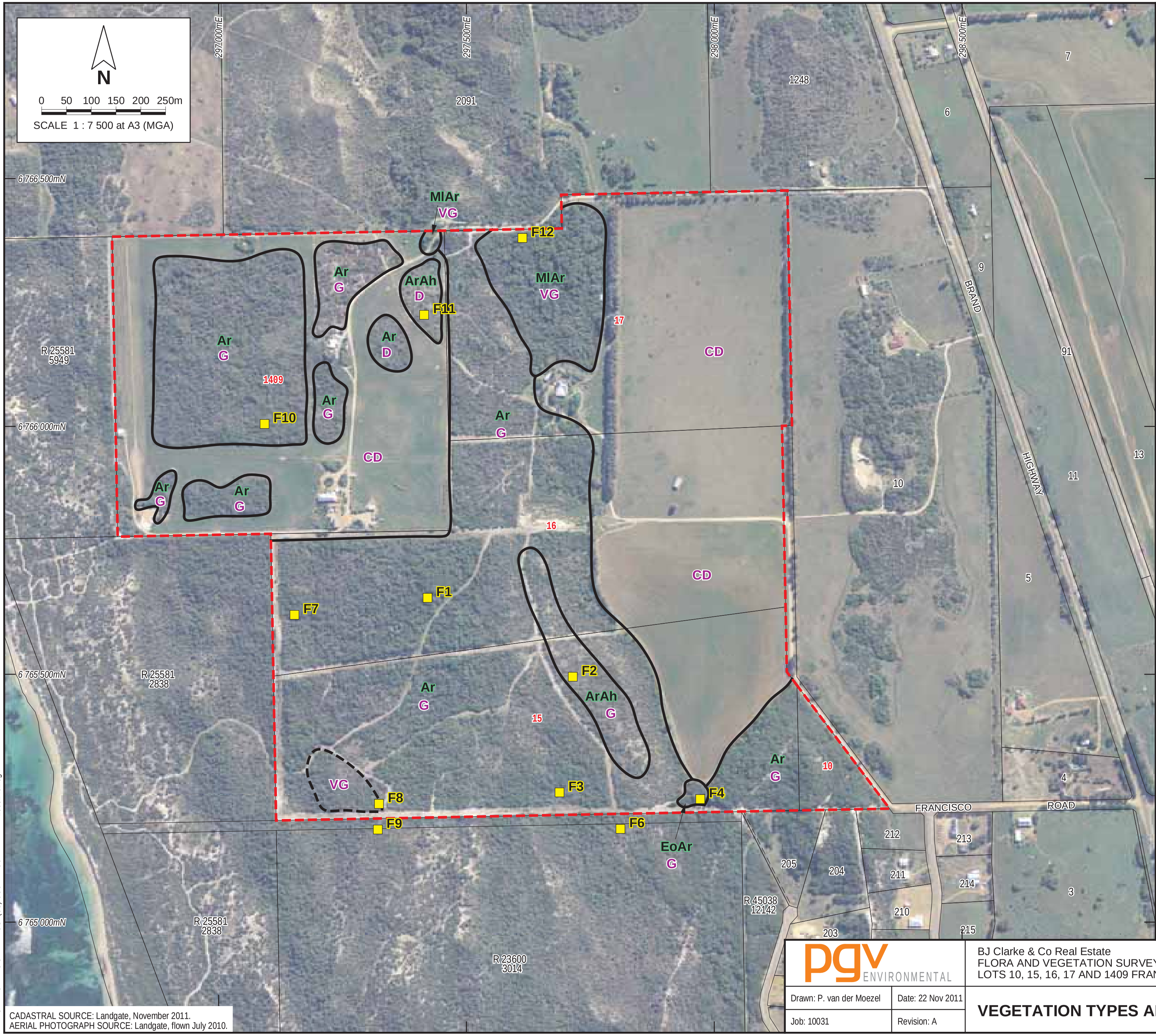

pgv ENVIRONMENTAL

BJ Clarke & Co Real Estate
FLORA AND VEGETATION SURVEY
LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

| | |
|---|---|
| Drawn: P. van der Moezel | Date: 22 Nov 2011 |
| Job: 10031 | Revision: A |

## SITE LOCATION

Figure 1




**Legend**

- Site Boundary
- Cadastral Boundary
- Quadrat Location
- Vegetation Type Boundary
- Vegetation Condition Boundary
- Ar — Vegetation Type
- G — Vegetation Condition

**Vegetation Legend**

**Ar** *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub

**ArAh** *Acacia rostellifera/Alyogyne huegelii* Open Heath

**MlAr** *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland

**EoAr** *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub

**Vegetation Condition Legend**
(Source: BUSH FOREVER Govt. of W.A., 2000)

**P - Pristine**
Pristine or nearly so, no obvious signs of disturbance.

**Ex - Excellent**
Vegetation structure intact, disturbance affecting individual species and weeds are non aggressive species.

**VG - 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.

**G - Good**
Vegetation structure significantly altered by very obvious signs of multiple disturbance. 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.

**D - 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.

**CD - Completely Degraded**
The structure of the vegetation is no longer intact and the areas is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora composing weed or crop species with isolated native trees or shrubs.

**Cl - Cleared**
No native vegetation remaining.

pgv ENVIRONMENTAL

BJ Clarke & Co Real Estate
FLORA AND VEGETATION SURVEY
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|---|---|
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**VEGETATION TYPES AND CONDITION**

**Figure 2**

# APPENDIX 1

## DEC Database Searches

**DECLARED RARE AND PRIORITY FLORA LIST**
**16 September 2010**

| SPECIES / TAXON | CONS CODE | DEC REGION | DISTRIBUTION | FLOWER PERIOD |
|---|---|---|---|---|
| Anthocercis intricata | 3 | MW | Dongara, Port Gregory, Denham, Kalbarri | Jun-Sep |
| Comesperma rhadinocarpum | 2 | MW,SW | Mullewa, Kenwick, Cataby, (Greenough River, Irwin River) | Oct-Nov |
| Conostylis micrantha | T | MW | N of Irwin River | Jul-Aug |
| Cryptandra pendula | 1 | MW | Allanooka | Jul,Aug |
| Eucalyptus macrocarpa x pyriformis | 3 | MW,WB | N of Bolgart, Calingiri, Piawaning, Wongan Hills, Watheroo, Irwin View, Moora | - |
| Eucalyptus zopherophloia | 4 | MW | Dongara, Cliff Head, Illawong, Jurien Bay, Peron Peninsula, Zuytdorp, Eurardy | Nov-Jan |
| Haloragis foliosa | 3 | MW | Winchester, Arrowsmith, Leeman, Beekeepers Reserve, Cliff Head, Dongara | Oct |
| Stylidium carnosum subsp. narrow leaves (JA Wege 490) | 1 | MW | Dongara, Lake Indoon | Sep,Oct |
| Stylidium pseudocaespitosum | 2 | MW | Bookara, Walkaway, Burma Road NR | Sep |

WAHERB SPECIMEN DATABASE
GENERAL ENQUIRY

Acacia telmica
A.R.Chapman & Maslin (Fabaceae)
CONSERVATION STATUS:3
Coll.: A.M. Ashby 5037 Date: 06 08 1974 ( PERTH 00806110 )
LOCALITY Ca 65 km S of Geraldton, found 50 yards from Milo road near Dongara WA
LAT 29 Deg 15 Min Sec S LONG 114 Deg 59 Min Sec E
Previous det.: Acacia telmica A.R.Chapman & Maslin

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: R. Davis 3244 Date: 28 05 1997 ( PERTH 04869451 )
LOCALITY Brand Highway, 5.8 km S of Dongara turnoff, WA
LAT 29 Deg 18 Min 39.500 Sec S LONG 115 Deg 0 Min 32.200 Sec E
Erect, climbing shrub 2 m high x 2 m wide. Sprawling over other shrubs. Flowers white, faint smell. Hard, smooth bark.
Plain, dry, littered, brown sandy clay over limestone. Scrub, Acacia rostellifera.
Abundance: occasional.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: J.S. Beard B 2532 Date: 02 06 1963 ( PERTH 06007309 )
LOCALITY Port Denison Golf Course, WA
LAT 29 Deg 16 Min Sec S LONG 114 Deg 55 Min Sec E
Spreading, partly scandent shrub; 6 ft high; flowers white. On sand and limestone. In mallee.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: R. Davis 9841 Date: 18 07 2001 ( PERTH 05872863 )
LOCALITY 9.6 km SSE along Kalis Street from Port Denison, Dongara, alternative route, WA
LAT 29 Deg 18 Min 59.200 Sec S LONG 114 Deg 59 Min 16.500 Sec E
Erect, compact, perennial shrub. 2 m high x 2 m wide. White flowers. Immature fruits present. Growth phase active.
Hill. Brown/grey sand/loam over limestone. Scrubland. 80+% of population flowering.
Frequency:occasional.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: G. Woodman, C. Godden, A. Harris & F. ARC 47.1 Date: 03 08 2004 ( PERTH 07130880 )
LOCALITY Immediately E of Port Denison, Shire of Irwin WA
LAT 29 Deg 16 Min 17.500 Sec S LONG 114 Deg 55 Min 44.300 Sec E
Sand dune crest. Pale brown sand. Low Forest over mixed shrubland over grasses and herbs.
Associated species:
Alyogyne huegelii, Rhagodia preissii subsp. obovata, Acanthocarpus preissii, Acacia rostellifera, Myoporum tetrandrum.
Healthy population.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: W.E. Blackall 2643 Date: 16 09 1932 ( PERTH 01243802 )
LOCALITY Dongara, S of Geraldton, within 200 yards of sea WA
LAT 29 Deg 14 Min 35.000 Sec S LONG 114 Deg 55 Min 54.000 Sec E

Loose straggling shrub, 3-4 ft. Flowers white. Checked in W.E. Blackall's collecting book. M.A. Lewington 13/8/2009
Previous det.: Anthocercis intricata F. Muell.

Anthocercis intricata
F.Muell. (Solanaceae)
CONSERVATION STATUS:3
Coll.: W.E. Blackall 2643 Date: 16 09 1932 ( PERTH 01243810 )
LOCALITY Dongara, S of Geraldton, within 200 yards of sea WA
LAT 29 Deg 14 Min 35.000 Sec S LONG 114 Deg 55 Min 54.000 Sec E
Loose straggling shrub, 3-6 ft. Flowers white. Checked in W.E. Blackall's collecting book. From identical comment
and location, this is an unrecognised duplicate of 2643. M.A. Lewington 13/8/2009.
Previous det.: Anthocercis intricata F. Muell.

Banksia elegans
Meisn. (Proteaceae)
CONSERVATION STATUS:4
Coll.: J.S. Beard 7225 Date: 31 10 1974 ( PERTH 1149717 )
LOCALITY 7 miles W [E?] of Geraldton Highway at a point 9 miles N of Dongara. [Ca 8 km W of Mount Horner]. WA
LAT 29 Deg 7 Min Sec S LONG 115 Deg 0 Min Sec E
Shrub 5 ft, flower greenish-yellow. Scrub heath. New locality?

Calytrix eneabbensis
Craven (Myrtaceae)
CONSERVATION STATUS:4
Coll.: F.W. Humphreys 48 Date: 21 10 1966 ( PERTH 1022520 )
LOCALITY S of turnoff to Eneabba on road from Dongara. WA
LAT 29 Deg 15 Min Sec S LONG 114 Deg 56 Min Sec E
Previous det.: Calytrix aff. gracilis

Dampiera tephrea
Rajput & Carolin (Goodeniaceae)
CONSERVATION STATUS:2
Coll.: G. Woodman, C. Godden, A. Harris & F. ARC 126.2 Date: 12 08 2004 ( PERTH 07130929 )
LOCALITY S of Dongara and immediately E of Brand Highway WA
LAT 29 Deg 18 Min 15.000 Sec S LONG 115 Deg 0 Min 37.700 Sec E
Upper crest. Yellow-brown sand over limestone. Degraded Heath dominated by Melaleuca. Melaleuca ? leuropoma, Hakea prostrata,
Guichenotia ledifolia, Petrophile brevifolia, Scholtzia umbellifera, Acanthocarpus preissii, Muelenbeckia adpressa. Healthy population.

Dampiera tephrea
Rajput & Carolin (Goodeniaceae)
CONSERVATION STATUS:2
Coll.: G. Woodman, C. Godden, A. Harris & F. ARC 88.3 Date: 09 08 2004 ( PERTH 07130937 )
LOCALITY N of Dongara WA
LAT 29 Deg 10 Min 24.800 Sec S LONG 114 Deg 57 Min 17.900 Sec E
Mid-upper slope. Brown sand over limestone. Heath. Melaleuca ? systena, Jacksonia hakeoides, Acacia rostellifera,
Scholtzia umbellifera, Desmocladus asper, Acacia pulchella var pulchella, Conostylis candicans subsp. calcicola.

Eucalyptus ebbanoensis
subsp. photina Brooker & Hopper (Myrtaceae)
CONSERVATION STATUS:4
Coll.: A.S. George 7854 Date: 04 09 1966 ( PERTH 1370952 )
LOCALITY 27 miles SE of Walkaway, WA
LAT 29 Deg 16 Min Sec S LONG 115 Deg 0 Min 0.000 Sec E

Smooth-barked mallee to 3 m.
Previous det.: Eucalyptus ebbanoensis subsp. photina Brooker & Hopper
Grevillea erinacea
Meisn. (Proteaceae)
CONSERVATION STATUS:3
Coll.: R. Davis 9859 Date: 19 07 2001 ( PERTH 05874319 )
LOCALITY 11.7 km E along Mount Horner West Road from junction of Brand Highway, ca 18 km NNE of Dongara, WA
LAT 29 Deg 6 Min 58.300 Sec S LONG 115 Deg 0 Min 53.100 Sec E
Erect, open, perennial shrub. 1.7 m high x 1.5 m wide. Deep tap roots, tight bark texture. Mature fruits present. Growth phase active. Brown loam.
Banksia woodland. 80% of population flowering.
Frequency:occasional.

Grevillea tenuiloba
C.A.Gardner (Proteaceae)
CONSERVATION STATUS:3
Coll.: R. Wilkins s.n. Date: 01 09 1982 ( PERTH 1021338 )
LOCALITY Grid square 1504, Irwin River WA
LAT 29 Deg 15 Min Sec S LONG 115 Deg 0 Min Sec E
Semi prostrate shrub. Flowers orange.
Liparophyllum congestiflorum
(F.Muell.) Tippery & Les (Menyanthaceae)
CONSERVATION STATUS:4
Coll.: A.S. George 9224 Date: 18 10 1967 ( PERTH 1099108 )
LOCALITY Near 257 mile peg, Geraldton Highway. [ca 46 km N of Mingenew on the Geraldton Highway) WA
LAT 29 Deg 15 Min 0.000 Sec S LONG 115 Deg 0 Min 0.000 Sec E
Damp, sandy creek bed. Acacia cyanophylla.
Previous det.: Villarsia congestiflora F.Muell.

A search was undertaken on the Department's Threatened Ecological Communities database. Please note that there are no known occurrences of threatened ecological communities recorded within this boundary.

Please note not all priority ecological communities are currently recorded on our database. You may like to view the current list in related documents at http://www.dec.wa.gov.au/content/view/849/2017/ .

Attached are the conditions under which this information has been supplied. The information supplied should be regarded as an indication only of the threatened and priority ecological communities that may be present.

It would be appreciated if any occurrences of threatened and priority ecological communities encountered by you in the area could be reported to this Department to ensure their ongoing management. An occurrence report form and associated manual can be found at http://www.dec.wa.gov.au/content/view/5388/2237/.

Search area response information is only accurate at the time of provision. Over time, new occurrences or modifications to existing occurrences may occur as information becomes available. It is recommended that searches be re-submitted every six months where projects occur over a long period of time.

# APPENDIX 2

# Quadrat Data

## QUADRAT F1

**29°13.301'S 114°54.955'E**

**Vegetation**: *Acacia rostellifera* Closed Tall Scrub
**Condition**: Good
**Soil Type**: Brown-grey sand
**Landform**: Lower slope of dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 3 | 80 |
| **Euphorbia terracina* | 0.8 | 2 |
| **Urospermum picroides* | 0.6 | 70 |
| **Sonchus oleraceus* | 0.5 | 10 |
| **Avena fatua* | 0.5 | 1 |
| **Bromus diandrus* | 0.5 | 1 |
| *Rhagodia baccata* | 0.5 | <1 |
| **Poa annua* | 0.3 | 2 |

* introduced species

**QUADRAT F2**

**29°13.390'S 114°55.134'E**

**Vegetation**: *Acacia rostellifera/ Alyogne sp* Open Heath
**Condition**: Good
**Soil Type**: Yellow-grey sand
**Landform**: Upper slope of moderate dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 1.5-2 | 40 |
| *Alyogyne huegelii* | 2 | 5 |
| *Austrostipa elegantissima* | 1.2 | 2 |
| **Avena fatua* | 1 | 10 |
| *Diplolaena grandiflora* | 1 | 1 |
| *Rhagodia baccata* | 1 | 1 |
| **Vulpia myuros* | 0.8 | 15 |
| **Brassica tournefortii* | 0.8 | 2 |
| *Ptilotus divaricatus* | 0.8 | 1 |
| **Urospermum picroides* | 0.5 | 2 |
| *Threlkeldia diffusa* | 0.5 | <1 |
| **Sonchus oleraceus* | 0.4 | 1 |
| **Euphorbia terracina* | 0.3 | 1 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

## QUADRAT F3

**29°13.516'S   114°55.115'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Good
**Soil Type**: Brown-grey sand
**Landform**: Bottom of valley

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 3 | 70 |
| **Avena fatua* | 1 | 5 |
| *Rhagodia baccata* | 1 | 1 |
| **Brassica tournefortii* | 0.5 | <1 |
| **Urospermum picroides* | 0.4 | 50 |
| **Sonchus oleraceus* | 0.4 | 10 |
| **Euphorbia peplus* | 0.4 | 2 |
| **Vulpia myuros* | 0.3 | 1 |
| *Threlkeldia diffusa* | 0.3 | <1 |
| **Ehrharta calycina* | 0.3 | <1 |
| **Arctotheca calendula* | 0.2 | <1 |
| **Solanum nigrum* | 0.1 | <1 |
| **Trifolium dubium* | 0.1 | <1 |
| *Clematis linearifolia* | creeper | 2 |

* introduced species

**QUADRAT F4**

**29°13.526'S 114°55.290'E**

**Vegetation**: *Eucalyptus obrusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub
**Condition**: Degraded - Good
**Soil Type**: Brown loamy sand
**Landform**: Bottom of valley

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Eucalyptus obtusiflora* | 6-7 | 30 |
| **Lycium ferocissimum* | 2 | 40 |
| *Acacia rostellifera* | 2 | 10 |
| **Poa annua* | 0.3 | 20 |
| **Sonchus oleraceus* | 0.3 | 10 |
| **Cerastium glomeratum* | 0.3 | 10 |
| **Euphorbia peplus* | 0.3 | 5 |

* introduced species

**QUADRAT F6**

**29°13.557'S 114°55.190'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Good
**Soil Type**: Yellowish-grey sand
**Landform**: Upper slope of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 2-4 | 40 |
| *Alyogyne huegelii* | 1.5 | 5 |
| *Austrostipa elegantissima* | 1.2 | 10 |
| **Avena fatua* | 1 | 5 |
| *Rhagodia baccata* | 1 | 1 |
| **Urospermum picroides* | 0.3 | 2 |
| **Sonchus oleraceus* | 0.5 | 5 |
| **Bromus diandrus* | 0.5 | 5 |
| *Ptilotus divaricatus* | 0.4 | 1 |
| **Euphorbia peplus* | 0.3 | 2 |
| **Ehrharta calycina* | 0.3 | 2 |
| *Zygophyllum fruticulosum* | creeper | 20 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

**QUADRAT F7**

**29°13.317’S 114°54.789’E**

**Vegetation**: *Acacia rostellifera* Closed Tall Scrub
**Condition**: Good
**Soil Type**: Brownish sand
**Landform**: Upper slope of dune

**QUADRAT (10 x 10m) Pegs:** Non-permanent quadrat

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 5 | 80 |
| *Acanthocarpus preissii* | 1 | 1 |
| *Rhagodia baccata* | 0.6 | <1 |
| **Urospermum picroides* | 0.3 | 25 |
| **Sonchus oleraceus* | 0.3 | 2 |
| **Bromus diandrus* | 0.3 | 30 |
| **Euphorbia peplus* | 0.2 | 15 |
| **Lysimachia arvensis* | 0.3 | 2 |
| **Euphorbia terracina* | 0.3 | 1 |
| **Poa annua* | 0.4 | <1 |
| *Clematis linearifolia* | creeper | 25 |
| *Zygophyllum fruticulosum* | creeper | 1 |

* introduced species

**QUADRAT F8**

**29$^{o}$13.525'S 114$^{o}$54.890'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Very Good
**Soil Type**: Whitish grey sand
**Landform**: Top of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 2 | 60 |
| *Leptomeria empetriformis* | 1.2 | <1 |
| *Diplolaena grandiflora* | 1 | 10 |
| *Austrostipa flavescens* | 1 | <1 |
| **Avena fatua* | 1 | <1 |
| *Rhagodia baccata* | 1 | 1 |
| **Bromus diandrus* | 0.3 | <1 |
| *Enchylaena tomentosa* | 0.4 | 2 |
| *Scaevola crassifolia* | 0.4 | 1 |
| *Acanthocarpus preissii* | 0.3 | 1 |
| **Wahlenbergia capensis* | 0.2 | 1 |
| *Parietaria debilis* | 0.2 | 1 |
| *Trachymene pilosa* | 0.1 | 10 |
| *Calandrinia liniflora* | 0.1 | <1 |
| *Zygophyllum fruticulosum* | creeper | 20 |
| *Cassytha racemosa* | creeper | 1 |

* introduced species

## QUADRAT F9

**29°13.553'S   114°54.888'E**

**Vegetation**: *Acacia rostellifera* Tall Open Scrub
**Condition**: Very Good
**Soil Type**: Brownish-grey sand
**Landform**: Top of low dune

**QUADRAT (10 x 10m)**   **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 1.5-3 | 40 |
| *Austrostipa flavescens* | 1 | 2 |
| **Avena fatua* | 1 | <1 |
| **Bromus diandrus* | 0.4 | 2 |
| *Parietaria debilis* | 0.4 | <1 |
| *Acanthocarpus preissii* | 0.4 | <1 |
| *Threlkeldia diffusa* | 0.3 | 5 |
| *Senecio pinnatifolius var. maritimus* | 0.3 | 1 |
| **Ehrharta calycina* | 0.3 | 1 |
| *Calandrinia liniflora* | 0.2 | <1 |
| *Trachymene pilosa* | 0.1 | <1 |
| **Lysimachia arvensis* | 0.1 | <1 |
| **Crassula glomerata* | 0.1 | <1 |
| *Zygophyllum fruticulosum* | creeper | 40 |
| *Cassytha racemosa* | creeper | 1 |
| *Thysanotus patersonii* | creeper | <1 |

* introduced species

## QUADRAT F10

**29°13.108'S 114°54.756'E**

**Vegetation**: *Acacia rostellifera* Closed Tall Scrub
**Condition**: Good
**Soil Type**: Grey sand
**Landform**: Lower valley slope

**QUADRAT (10 x 10m)** **Peg:** Non-permanent quadrat

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 3-5 | 80 |
| *Rhagodia baccata* | 1.5 | 1 |
| **Lycium ferocissimum* | 1.2 | 2 |
| **Euphorbia terracina* | 0.8 | 30 |
| **Bromus diandrus* | 0.4 | 1 |
| **Urospermum picroides* | 0.4 | 5 |
| **Sonchus oleraceus* | 0.4 | 5 |
| **Euphorbia peplus* | 0.3 | 20 |
| **Ehrharta calycina* | 0.8 | 1 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

**QUADRAT F11**

**29°12.992'S 114°54.957'E**

**Vegetation**: *Acacia rostellifera* Shrubland
**Condition**: Degraded
**Soil Type**: Grey sand
**Landform**: Top of low dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Acacia rostellifera* | 1.5 | 10 |
| *Rhagodia baccata* | 1 | 1 |
| **Lycium ferocissimum* | 1 | 20 |
| **Avena fatua* | 1 | 10 |
| *Anthobolus foveolatus* | 1 | 2 |
| *Acanthocarpus preissii* | 0.5 | 5 |
| **Brassica tournefortii* | 0.5 | 1 |
| **Bromus diandrus* | 0.4 | 70 |
| **Urospermum picroides* | 0.4 | 2 |
| **Salsola tragus* | 0.4 | <1 |
| **Sonchus oleraceus* | 0.3 | 1 |
| **Ehrharta calycina* | 0.3 | 1 |
| **Euphorbia peplus* | 0.2 | 10 |

* introduced species

**QUADRAT F12**

**29°12.910'S 114°55.081'E**

**Vegetation**: *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland
**Condition**: Very Good
**Soil Type**: Dark grey sand
**Landform**: Lower to mid-slope of dune

**QUADRAT (10 x 10m)** **Peg:** South-east corner

| SPECIES | HEIGHT (m) | COVER (%) |
|---|---|---|
| *Melaleuca lanceolata* | 8 | 50 |
| *Acacia rostellifera* | 4 | 20 |
| *Spyridium globulosum* | 1.2 | 1 |
| *Rhagodia sp* | 1 | 75 |
| *Rhagodia baccata* | 1 | 10 |
| *Diplolaena grandiflora* | 1 | 1 |
| *Acanthocarpus preissii* | 0.5 | 2 |
| *Enchylaena tomentosa* | 0.5 | 5 |
| **Parietaria debilis* | 0.3 | 20 |
| **Poa annua* | 0.3 | 10 |
| **Sonchus oleraceus* | 0.3 | <1 |
| *Zygophyllum fruticulosum* | creeper | 2 |
| *Clematis linearifolia* | creeper | 1 |

* introduced species

# APPENDIX 3

## Flora List

## SPECIES LIST – Lots 10, 15,16,17 and 1409 Francisco Road

### MONOCOTYLEDONS

ASPARAGACEAE
*Acanthocarpus preissii*
*Thysanotus patersonii*

POACEAE
*Austrostipa elegantissima*
*Austrostipa flavescens*
**Avena fatua*
**Briza maxima*
**Bromus diandrus*
**Ehrharta calycina*
**Poa annua*
**Vulpia myuros*

### DICOTYLEDONS

AMARANTHACEAE
*Ptilotus divaricatus*

APIACEAE
*Trachymene pilosa*

ASTERACEAE
**Arctotheca calendula*
*Senecio pinnatifolius* var. *maritimus*
**Urospermum picroides*
**Sonchus oleraceus*

BORAGINACEAE
**Echium plantagineum*

BRASSICACEAE
**Brassica tournefortii*

CAMPANULACEAE
**Wahlenbergia capensis*

CARYOPHYLLACEAE
**Cerastium glomeratum*

CHENOPODIACEAE
*Enchylaena tomentosa*
*Rhagodia preissii* subsp. *latifolia*
*Rhagodia sp.*
**Salsola tragus*
*Threlkeldia diffusa*

DILLENIACEAE
*Hibbertia subvaginata*

EUPHORBIACEAE
**Euphorbia peplus*
**Euphorbia terracina*

FABACEAE
*Acacia rostellifera*
**Trifolium dubium*
**Trifolium sp.*

GOODENIACEAE
*Scaevola crassifolia*

LAURACEAE
*Cassytha racemosa*

LORANTHACEAE
*Anthobolus foveolatus*
*Amyema preissii*

MALVACEAE
*Alyogyne huegelii*
*Rulingia borealis*

MYRTACEAE
*Eucalyptus obtusiflora subsp. dongarraensis*
*Melaleuca cardiophylla*
*Melaleuca lanceolata*

PORTULACCACEAE
*Calandrinia liniflora*

PRIMULACEAE
**Lysimachia arvensis*

RANUNCULACEAE
*Clematis linearifolia*

RHAMNACEAE
*Stenanthemum notiale*

RUTACEAE
*Diplolaena grandiflora*

SANTALACEAE
*Anthobolus foveolatus*
*Santalum acuminatum*

SOLANACEAE

*Anthocercis littorea*
**Lycium ferocissimum*
**Solanum nigrum*
*Solanaceae sp.*

STERCULIACEAE
*Rulingia borealis*

URTICACEAE
*Parietaria debilis*

ZYGOPHYLLACEAE
*Zygophyllum fruticulosum*

# APPENDIX 4

## Level 1 Fauna Assessment 2012 (PGV Environmental)

# LOTS 15, 16, 17, 1409 AND PT LOT 10 FRANCISCO ROAD, DONGARA

## LEVEL 1 FAUNA ASSESSMENT

| | |
|---|---|
| Prepared for: | Ben Clarke |
| Report Date: | 18 June 2012 |
| Version: | 2 |
| Report No. | 2012-51 |

PGV ENVIRONMENTAL

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**Appendices**


Appendix 1: DEC Database Search Results

Appendix 2: NatureMaps Database Reports

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# 1 INTRODUCTION

## 1.1 Background

Lots 10, 15, 16, 17 and 1409 Francisco Road, Dongara (the site) are located close to the coast to the west of Brand Highway approximately 3km north of the Dongara town centre. The site is currently being considered by the Department of Planning for its potential urban development to accommodate the future expansion of Dongara.

The owners of the lots are assisting the Department of Planning by undertaking planning and environmental work to investigate the opportunities and constraints to future urban development. This Level 1 Fauna Assessment has been commissioned by the landowners as part of those investigations.

## 1.2 Level 1 Fauna Assessment

The Level 1 Fauna Assessment was undertaken in accordance with EPA *Guidance for Assessment of Environmental Factors: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, No. 56* (EPA, 2004). This assessment involves a 'desktop' study of the site and a site investigation.

The scope of works for the Level 1 Fauna Assessment included desktop searches of databases such as:

- A review of the Department of Environment and Conservation's (DEC) NatureMaps database to identify fauna that has been previously recorded in the project vicinity. This database includes records from the Western Australian Museum, the DEC Fauna Returns database, the Swan Coastal Plain survey and other opportunistic records lodged with the DEC;
- A review of the DEC's Threatened and Priority Species database to identify potential scheduled and threatened species within the region; and
- A review of the Commonwealth Government's database of fauna of national environmental significance to identify species potentially occurring within the area that are protected under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* or international migratory bird agreements (JAMBA/CAMBA).

A level 2 Flora and Vegetation Survey was undertaken on the site in 2011 by PGV Environmental (PGV, 2011) and the results of this study and observations from the survey have been included to identify available fauna habitat types and condition. A landowner that has lived on part of the site for over twenty years was also interviewed.

This Level 1 Fauna Assessment also includes:

- A review of the significance of the site for conservation significant species in a local and regional context;
- Advice on project requirements to satisfy the Commonwealth EPBC Act 1999 or State Legislation; and
- Recommendations on:

- any additional species-specific searches that may be required for conservation significant species within the site; and
- appropriate methodologies for any follow-up comprehensive fauna surveys necessary to identify species of conservation significance or fauna assemblages that are important and likely to be impacted with the construction work.

# 2 EXISTING ENVIRONMENT

## 2.1 Land Use

Part Lot 10 west of Francisco Road currently consists of undeveloped native vegetation. The eastern portions of Lots 15, 16 and 17 have been cleared for agriculture while the western portions contain native vegetation. The native vegetation on these lots has been grazed in the past. A residential dwelling exists on Lot 17. Lot 1409 contains two residential dwellings, some cleared land for horse paddocks, and a central area of native vegetation.

The lots are zoned General Farming in the Shire of Irwin Town Planning Scheme No. 5.

Several tracks and firebreaks occur in the vegetated part of Lots 15, 16 and 17. The beach is located approximately 450m west of Lot 15 and 270m west of Lot 1409. The lots are separated from the coast by two Local Reserves (25581 5949 and 25581 2838) as well as a strip of Unallocated Crown Land.

Conservation Reserve 23600 abuts Lot 15 to the south and consists of native vegetation similar to that on Lot 15 and 16.

Private lots 204, 205 and 212 are located south of Part Lot 10 and a part of Lot 15 and contain native vegetation.

The balance of Part Lot 10 east of Francisco Rd abuts the eastern side of the site and has been predominantly cleared for agriculture.

Private Lots 2092, 2091 and 1248 occur to the north of the site and have been partially cleared for agriculture but retain native vegetation on the majority of the land.

## 2.2 Topography and Landform

The site is located close to the coast and includes undulating coastal Quindalup dunes on the western side and the flatter Tamala limestone landform on the eastern side. Generally the clearing for agriculture has occurred on the eastern Tamala limestone landform although some of the coastal soils on Lot 1409 have been cleared for horse paddocks.

The eastern cleared area is relatively flat from west to east but slopes generally from the north down to the south. Elevation on the eastern portion ranges from 32mAHD down to 9m AHD.

The western dunal area is undulating and ranges in elevation from 20m - 38m AHD on Lots 15-27 and 12m – 33m AHD on Lot 1409.

## 2.3 Geology and Soils

Soils on the site have been described by Landform Research (2005). The eastern Tamala limestone soils are brown sands grading to earthy sands overlying limestone at variable depth. The western Quindalup Dune soils are relatively old Quindalup dunes and therefore contain a brown to cream brown sand with minor clay and calcareous materials. The coarser nature of the older Quindalup

dunes makes them less susceptible to erosion than younger phase Quindalup dunes (Landform Research, 2005).

## 2.4 Hydrology

There are no surface water features such as creeklines, drainage lines or wetlands on the site.

Groundwater occurs under the site at an average level of around 2m AHD (Landform Research, 2005) indicating a minimum depth to groundwater of around 10m.

## 2.5 Vegetation and Flora

### 2.5.1 Vegetation Types

Four separate Vegetation Associations were described and mapped on the site (Figure 2) during a Spring Flora Survey conducted by PGV Environmental (PGV, 2011). The four vegetation types have limited diversity and are described below.

**Ar** *Acacia rostellifera* **Tall Open Scrub to Closed Tall Scrub**

This is the main vegetation on the site. The density of *Acacia rostellifera* is high, ranging from 60-80%. As a result of the high canopy density, the understorey is sparsely vegetated. Most of the species are weeds with the main native species being *Rhagodia preissii* ssp *obovata* and the creeper *Clematis linearifolia.* Common weed species include *Sonchus asper, Sonchus oleraceus, Bromus diandrus* and *Euphorbia peplus* (PGV, 2011).

**ArAh** *Acacia rostellifera/Alyogyne huegelii* **Open Heath**

A narrow band of this vegetation type occurred on the top of the eastern ridge in the Quindalup dunes on Lots 15 and 16 as well as a degraded part on the eastern side of Lot 1409. *Acacia rostellifera* was the dominant species but less dense (40%) than in the Ar vegetation above. *Alyogyne huegelii* was consistently dominant (PGV, 2011).

**MlAr** *Melaleuca lanceolata* **Low Open Forest over** *Acacia rostellifera* **Tall Shrubland**

This vegetation type occurs in two stands, one large stand approximately 5ha in size at the northern end of Lot 17 and one smaller stand in the north-east corner of Lot 1409. The *Melaleuca lanceolata* (Rottnest Island Tea Tree) trees were relatively dense with around a 50% canopy cover. The mid-storey of *Acacia rostellifera* was open (4m high and 20% cover) while the understorey was densely vegetated in ground covers. Native creepers *Zygophyllum fruticulosum* and *Clematis linearifolia* were common (PGV, 2011).

**EoAr** *Eucalyptus obtusiflora* **Tree Mallee over** *Acacia rostellifera* **Tall Open Scrub**

A very small natural stand of *Eucalyptus obtusiflora* (Dongara Mallee) occurred on the south-eastern end of Lot 15. Several *Eucalyptus obtusiflora* trees were present up to 6-7m high with an open mid-storey of *Acacia rostellifera* 2m high and a weedy understorey. The soil type was brown loamy sand (PGV, 2011).

### 2.5.2 Vegetation Condition

The vegetation condition of the site is mostly rated as Good (Figure 2). The rating of Good indicates that the upper *Acacia rostellifera* canopy was considered to be in its natural structure whereas the understorey was significantly altered. The dominance of weeds in the understorey may be due to past clearing of the whole site with subsequent re-growth of the *Acacia rostellifera* trees, or to grazing the understorey, or as a result of high frequency of fires (PGV, 2011).

The vegetation structure in some of the *Acacia rostellifera* vegetation on Lot 1409 has been reduced to an extent that the areas were rated as Degraded. The larger stand of Rottnest Island Tea Tree was assessed as being in Very Good condition. One area of *Acacia rostellifera* vegetation near the south-west corner of Lot 15 had a lower dominance of weed species and was rated as Very Good (PGV, 2011).

# 3 METHODOLOGY

## 3.1 Site Observations

The description of fauna habitats in this report was made based on the results of the 2011 Flora and Vegetation Assessment conducted by PGV Environmental.

## 3.2 Database Search

A desktop search of the DEC's NatureMap online database, DEC Threatened Fauna Database and the EPBC Protected Matters online database was used to develop a list of significant species that potentially could be present on the site. This list was then reviewed in the context of habitats present on the site and anecdotal evidence to determine the likelihood for these species to utilise the site.

## 3.3 Limitations

The conditions that the assessment was undertaken in are presented in Table 2 in order to assess the adequacy of the assessment. In summary, there were no constraints to the assessment.

**Table 1: Fauna Assessment Limitations and Constraints**

| Possible limitations | Constraint (yes/no); significant, moderate or negligible | Comment |
|---|---|---|
| Competency and experience of the consultant carrying out the assessment | No | The Environmental Consultants that undertook this assessment have appropriate training and experience in conducting Level one vertebrate fauna assessments throughout Western Australia. |
| Scope | No | All components required for a Level 1 Fauna assessment have been completed. |
| Proportion of fauna identified, recorded and/or collected | Yes Negligible | An on-site terrestrial fauna assessment has not been undertaken within the site; however, a large proportion of the site is degraded habitat. While the terrestrial fauna in the study area has not been directly assessed, there is sufficient data to assess the impact of development on the likely faunal assemblage. |
| Sources of information | No | Vertebrate fauna information was available from appropriate database searches and both published and unpublished reports. |
| Proportion of the task achieved | No | The assessment fulfils all of the objectives. |
| Timing/weather/season / cycle | No | The site observations were undertaken in spring weather conditions which were appropriate for this type of assessment. |

| Possible limitations | Constraint (yes/no); significant, moderate or negligible | Comment |
|---|---|---|
| Disturbances which affected results of the assessment | No | A large portion of the site is predominantly disturbed or has cleared vegetation as an understorey. This impact has been taken into account in this assessment. |
| Intensity of assessment effort | No | The intensity of the assessment is sufficient for a Level 1 Fauna Assessment. |
| Completeness | No | All major habitat types were visited. |
| Resources | No | Adequate resources were available. |
| Remoteness and/or access problems | No | There were no access problems. |
| Availability of contextual information for the region | No | DEC Threatened and Priority species lists, EPBC Act Protected Matters Search, NatureMap database search and results of previous assessments in both the surrounding area and the bioregion were available to provide comparison at both a local and regional level. |

Negligible – less than 20%; Moderate – 20-60%; Significant – greater than 60%

# 4 RESULTS

## 4.1 Fauna Habitats

Fauna habitats on the site consist of Scrub/Shrubland (Plate 1), Open Heath (Plate 2) and Low Open Forest (Plate 3) with areas of cleared land used for rural purposes (Background Plate 2). There are no areas considered to be habitat that are woodland or forest as very small area of EoAr (*Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub) consists of only two trees.

**Plate 1: Scrub/Shrubland Habitat**

**Plate 2: Open Heath /Cleared Land Habitat**

**Plate 3: Low Open Forest Habitat**

Fauna habitat can be assessed according to the following categories:

> *High quality fauna habitat – These areas closely approximate the vegetation mix and quality that would have been in the area prior to any disturbance. The habitat has connectivity with other habitats and is likely to contain the most natural vertebrate fauna assemblage.*
>
> *Very good fauna habitat - These areas show minimal signs of disturbance (e.g. grazing, clearing, fragmentation, weeds) and generally retain many of the characteristics of the habitat if it had not been disturbed. The habitat has connectivity with other habitats and fauna assemblages in these areas are likely to be minimally effected by disturbance.*

*Good fauna habitat – These areas showed signs of disturbance (e.g. grazing, clearing, fragmentation, weeds) but generally retain many of the characteristics of the habitat if it had not been disturbed. The habitat has connectivity with other habitats and fauna assemblages in these areas are likely to be affected by disturbance.*

*Disturbed fauna habitat – These areas showed signs of significant disturbance. Many of the trees, shrubs and undergrowth are cleared. These areas may be in the early succession and regeneration stages. Areas may show signs of significant grazing, contain weeds or have been damaged by vehicle or machinery. Habitats are fragmented or have limited connectivity with other fauna habitats. Fauna assemblages in these areas are likely to differ significantly from what might be expected in the area had the disturbance not occurred.*

*Highly degraded fauna habitat – These areas often have a significant loss of vegetation, an abundance of weeds, and a large number of vehicle tracks or are completely cleared. Limited or no fauna habitat connectivity. Faunal assemblages in these areas are likely to be significantly different to what might have been in the area pre-disturbance .* (Coffey Environments, 2009)

The vegetated areas in Lots 10, 15, 16 and 17 are linked to other areas of vegetation to the north, south and west. The vegetation is in Good to Very Good Condition however there are many tracks crossing the vegetated portion of the site (Figure 2). Therefore the fauna habitat in the vegetated parts of these lots would be considered to be Good Fauna Habitat.

Lot 1409 has vegetation in Degraded to Good condition and is not connected to surrounding vegetation (Figure 2). Therefore this habitat is considered to be Disturbed Fauna Habitat.

Parts of the site have been cleared in parts for agriculture and fully grazed for a number of years (Figure 2). These are classified as Highly Degraded Fauna Habitat.

## 4.2 DEC Database Search Results

A search of the DEC Threatened Fauna Database (Appendix 1) indicates that 5 species that are listed as rare or priority have been located in the vicinity of the sites. Four of these species were also identified in the Naturemaps database searches and no additional species were identified (Appendix 2; DEC, 2012a). Table 2 lists the species identified in each of these database searches.

**Table 2: List of Fauna Species Identified from DEC Database Searches.**

| Scientific Name | Common Name | Status under Wildlife Cons. Act | Status under EPBC Act |
|---|---|---|---|
| *Anous tenuirostris* subsp. *melanops* | Australian Lesser Noddy | Threatened | Vulnerable |
| *Calyptorhynchus latirostris* | Carnaby's Cockatoo | Schedule 1 | Endangered |
| *Falco peregrinus* subsp. *macropus* | Peregrine Falcon | Schedule 4 | NA |
| *Morelia spilota* subsp. *imbricata* | Carpet Python | Schedule 4 | NA |
| *Neelaps calonotos* | Black-striped Snake | Priority 3 | NA |

The DEC classifies fauna under five different Priority codes and rare and endangered fauna are classified under the Wildlife Conservation (Specially Protected Fauna) Notice 2008 into four schedules of taxa (DEC, 2011). These are outlined in Appendix 3.

## 4.3 Protected Matters Search Tool

A search of the Commonwealth Department of Sustainability, Environment, Water, Population and Communities Protected Matters Search Tool (SEWPaC, 2012a) was undertaken (Appendix 4). This database generates a report that with indicative information on matters of national environmental significance or other matters protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) within an area of interest. The results of the database search are in Appendix 4 and summarised in Table 3.

**Table 3: Results from the Protected Matters Search Tool**

| Life-form | Scientific Name | Common Name | Status under EPBC Act |
|---|---|---|---|
| Birds | *Calyptorhynchus latirostris* | Carnaby's Black Cockatoo | Endangered |
| | *Leipoa ocellata* | Malleefowl | Vulnerable |
| Migratory Marine Birds | *Apus pacificus* | Fork-tailed Swift | Marine/ Migratory |
| | *Ardea alba* | Great Egret, White Egret | Marine/ Migratory |
| | *Ardea ibis* | Cattle Egret | Marine/ Migratory |
| Migratory Terrestrial Species | *Haliaeetus leucogaster* | White-bellied Sea-Eagle | Marine/ Migratory |
| | *Merops ornatus* | Rainbow Bee-eater | Marine/ Migratory |

The definitions of conservation codes under the EPBC Act are in Appendix 3.

## 4.4 Conservation Significant Species

Outlined below is a short description of each of the species that were identified in the DEC database searches and Protected Matters Search Tool search and their preferred habitat in Table 3. The preferred habitat has been compared to the habitats on the site and the likelihood of each species to be present on the site determined.

**Australian Lesser Noddy (***Anous tenuirostris* **subsp.** *Melanops***)**

The Australian Lesser Noddy is a social bird that flies in large flocks. The Australian Lesser Noddy usually occupies coral-limestone islands that are densely fringed with White Mangrove Avicennia marina. It occasionally occurs on shingle or sandy beaches and feeds on small fish (SEWPaC, 2012b).

There are no mangroves or beaches on the site and therefore this species is highly unlikely to occur.

**Carnaby's Black Cockatoo (***Calyptorhynchus latirostris***)**

Carnaby's Cockatoo is found in the south-west of Australia from Kalbarri through to Ravensthorpe. It has a preference for feeding on the seeds of *Banksia, Dryandra, Hakea, Eucalyptus, Grevillea, Pinus* and *Allocasuarina* spp. It is nomadic often moving toward the coast after breeding. It breeds in tree hollows that are 2.5 – 12m above the ground and have an entrance 23-30cm with a depth of 1-2.5m.

Nesting mostly occurs in smooth-barked trees (e.g. Salmon Gum, Wandoo, Red Morrell). Eggs are laid from July to October, with incubation lasting 29 days (SEWPaC, 2012b).

There were no plant species identified in the Flora and Vegetation Survey (PGV, 2011) that are recognised foraging habitat. There is no breeding, potential breeding or roosting habitat on the site. Therefore this species is highly unlikely to occur on the site.

**Peregrine Falcon (*Falco peregrinus*, *Falco peregrinus* subsp. *macropus*)**

The Peregrine falcon is found in a variety of habitats from woodlands to open grasslands and coastal cliffs. It feeds almost entirely on other birds and sometimes rabbits and other moderate sized mammals, bats and reptiles (DEC, 2012b).

The Peregrine Falcon may occasionally fly over the site but the absence of coastal cliffs and scarcity of woodlands means this species is unlikely to frequent the site.

**Carpet Python (*Morelia spilota imbricata*)**

The Carpet Python is a large snake found across the south-west of Western Australia, from Northampton, south to Albany and eastwards to Kalgoorlie including undisturbed remnant bushland near Perth and the Darling Ranges. This subspecies has been recorded from semi-arid coastal and inland habitats, Banksia woodland, Eucalypt woodlands and grasslands (AROD, 2012).

This species is known from a number of locations in Dongara including in rural buildings. Individuals have been seen on the site in sheds and other buildings.

**Black-striped Snake (*Neelaps calonotos*)**

The Black-striped snake has a limited distribution, inhabiting areas with sandy soils that support heathlands and Banksia/Eucalypt Woodlands (Nevill, 2005) on the Swan Coastal Plain generally in the lower west coast from Lancelin to Mandurah (Storr et al, 1999).

The vegetation and soil on the site is not the preferred habitat of this species and Dongara is outside of its usual range. Therefore the Black -striped Snake is Unlikely to be present on the site.

**Malleefowl (*Leipoa ocellata*)**

Malleefowl have been found in mallee regions of southern Australia from approximately the 26th parallel of latitude southwards. Malleefowl are now only found throughout these regions in fragmented patches due to clearing of land for agriculture, increased fire frequency, competition with exotic herbivores (sheep, rabbits, goats and cattle) and kangaroos, predation by foxes and cats, inbreeding as a result of fragmentation and possibly hunting for food (SEWPaC, 2012b).

Malleefowl are unlikely to be found on the site due the lack of appropriate mallee habitat.

**Fork-tailed Swift (*Apus pacificus*)**

The Fork-tailed Swift is almost exclusively aerial and is not known to breed in Australia. They are seen in inland plains but sometimes above foothills or in coastal areas. They often occur over cliffs and beaches and also over islands and sometimes well out to sea. They also occur over settled areas, including towns, urban areas and cities (SEWPaC, 2012b).

This species may fly over the site on occasion.

**Great Egret, White Egret (*Ardea alba* (*modesta*))**

The Eastern Great Egret has been reported in a wide range of wetland habitats and usually frequents shallow waters (SEWPaC, 2012b). This species feeds on fish, insects, crustaceans, molluscs, frogs, lizards, snakes and small birds and mammals (SEWPaC, 2012b).

This species is highly unlikely to be found on the site as there are no wetlands or permanent water bodies on the site.

**Cattle Egret (*Ardea ibis*)**

The Cattle Egret occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands with breeding in Western Australia recorded in the far north in Wyndham in colonies in wooded swamps such as mangrove forests (SEWPaC, 2012b). This species forages away from water on low lying grasslands, improved pastures and croplands generally in areas that have livestock, eating insects, frog, lizards and small mammals (SEWPaC, 2012b).

This species has not been recorded in the area previously however it may occasionally visit the site.

**White-bellied Sea-Eagle (*Haliaeetus leucogaster*)**

The White-bellied Sea-Eagle is found in coastal habitats with large areas of open water, especially those close to the sea-shore. This species feeds opportunistically on a variety of fish, birds, reptiles, mammals and crustaceans, and on carrion and offal (SEWPaC, 2012b).

The site does not contain open water and therefore appropriate habitat for this species. The landowner is aware of Sea-eagles in the Dongara area but has never recorded any Sea-eagles on his property. Therefore the White-bellied Sea-eagle is unlikely to be found on the site.

**Rainbow Bee-eater (*Merops ornatus*)**

The Rainbow Bee-eater is a migratory bird that arrives in the south-west of WA in late September – early October and nests in a burrow dug in the ground. It is found across the better-watered parts of WA including islands preferring lightly wooded, sandy country near open water (SEWPaC, 2012b).

The site contains sandy soil habitat that may be suitable for this species and the Rainbow Bee-eater could potentially occur on the site.

# 5 SUMMARY AND CONCLUSIONS

## 5.1 Summary

The Level 1 Fauna Assessment of Lots 10, 15, 16, 17 and 1409 Francisco Road Dongara resulted in the following findings.

*Fauna Habitat*

- There are four habitats on the site that consist of Scrub/Shrubland, Open Heath, Low Open Forest and Cleared Pasture.
- The vegetated areas in Lots 10, 15, 16 and 17 was considered to be Good Fauna Habitat.
- Vegetated areas in Lot 1409 were considered to be Disturbed Fauna Habitat.
- The areas of Cleared Land were classified as Highly Degraded Fauna Habitat.

*Conservation Significant Species*

- Five conservation significant species were identified in the DEC Database as being recorded in the Dongara region. Of these four were also identified in Naturemaps search;
- The Protected Matters Search Tool identified a further six conservation significant species that could occur in the Dongara area;
- The Carpet Python (*Morelia spilota imbricata*) is known to occur on the site;
- The Peregrine Falcon (*Falco peregrinus, Falco peregrinus* subsp. *macropus*), Fork-tailed Swift (*Apus pacificus*), Cattle Egret (*Ardea ibis*) and Rainbow Bee-eater (*Merops ornatus*) were identified as potentially visiting the site.
- The remainder of the species were considered to be unlikely or highly unlikely to be found on the site due to the absence of appropriate habitat type;

*Further Studies*

Due to the low level of diversity of fauna habitat and the fact that it Good to Highly Degraded Fauna Habitat PGV Environmental believes that it is not necessary to undertake further fauna studies on the site.

*Environmental Approval Requirements*

The Rainbow Bee-eater and the Carpet Python were the only Conservation Significant species deemed to be likely to utilise the habitat on the site (rather than temporarily visit). It is not expected that this site contains significant habitat for these species. Therefore development is unlikely to a significant impact on any species protected under the *Wildlife Conservation Act 1950* or the EPBC Act.

## 5.2 Conclusion

Development of the site for urban purposes will result in most of the Scrub/Shrubland and Open Heath fauna habitat being cleared and retention of the Low Open Forest habitat. PGV Environmental considers that development of the site is highly unlikely to cause a significant impact on any fauna species of conservation significance due to the low usage potential of the site by a few species and the presence of similar habitat in adjoining reserves and the wider Dongara area.

# 6 REFERENCES


Australian Reptile Online Database (AROD) (2012) Australian Reptile Online Database http://www.arod.com.au/arod/reptilia/Squamata/Boidae/Morelia/spilota Accessed June, 2012

Coffey Environments (2009) *Rockingham Industry Zone Fauna Risk Assessment* Report No. 2005/55 for Landcorp.

Department of Environment and Conservation (DEC) (2012a) Naturemaps Database Accessed June 2012 http://naturemap.dec.wa.gov.au/ Government of Western Australia, Perth.

Department of Environment and Conservation (DEC) (2012b) Fauna Species Profiles Accessed June 2012 http://www.dec.wa.gov.au/content/view/3432/1999/1/1/ Government of Western Australia, Perth.

Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) (2012a). *Protected Matters Search Tool* Commonwealth of Australia Accessed June 2012 http://www.environment.gov.au/apps/boobook/mapservlet?app=ert

Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) (2012b). Species Profile and Threats (SPRAT) Database. Accessed June 2012 http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl Commonwealth of Australia

Environmental Protection Authority (EPA) (2004). *Guidance for Assessment of Environmental Factors: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, No. 56.* Government of Western Australia, Perth.

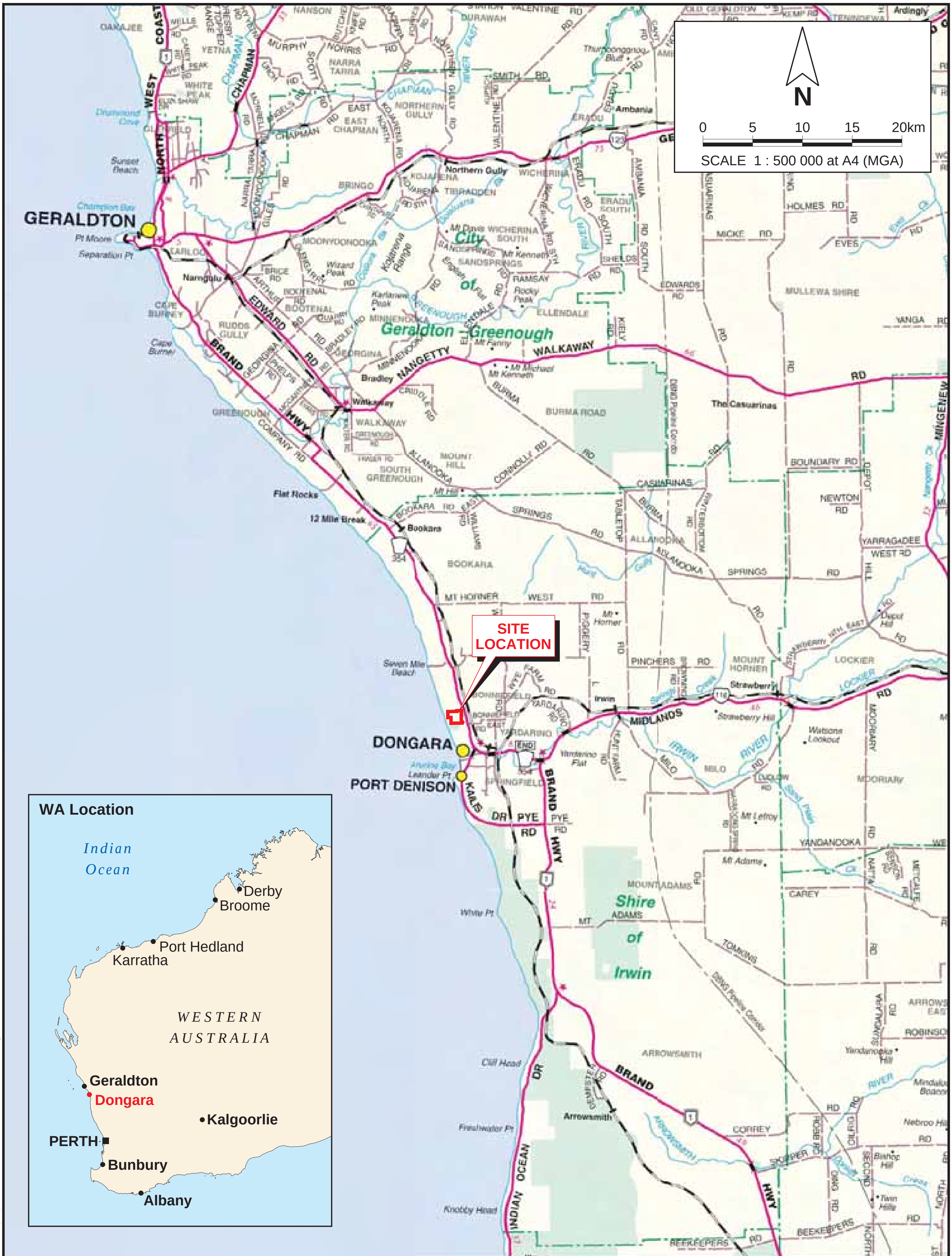
Landform Research (2005). *LandCapability and Geotechnical Assessment Lots 10, 15, 16 and 17 Francisco Road, Dongara.*

Nevill, S (ed) (2005) *Guide to the Wildlife of the Perth Region*. Simon Nevill Publications, Perth, Western Australia

PGV Environmental (2011) *Lots 10, 15, 16, 17 And 1409 Francisco Road, Dongara Flora and Vegetation Survey* Report Number 2011-27 Western Australia

Storr, G.M., Smith, L.A. and Johnstone R.E. (1999) *Lizards of Western Australia* I: Skinks. Revised Edition, WA Museum, Perth, Western Australia.

# FIGURES




pgv ENVIRONMENTAL

BJ Clarke & Co Real Estate
LEVEL ONE FAUNA ASSESSMENT
LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

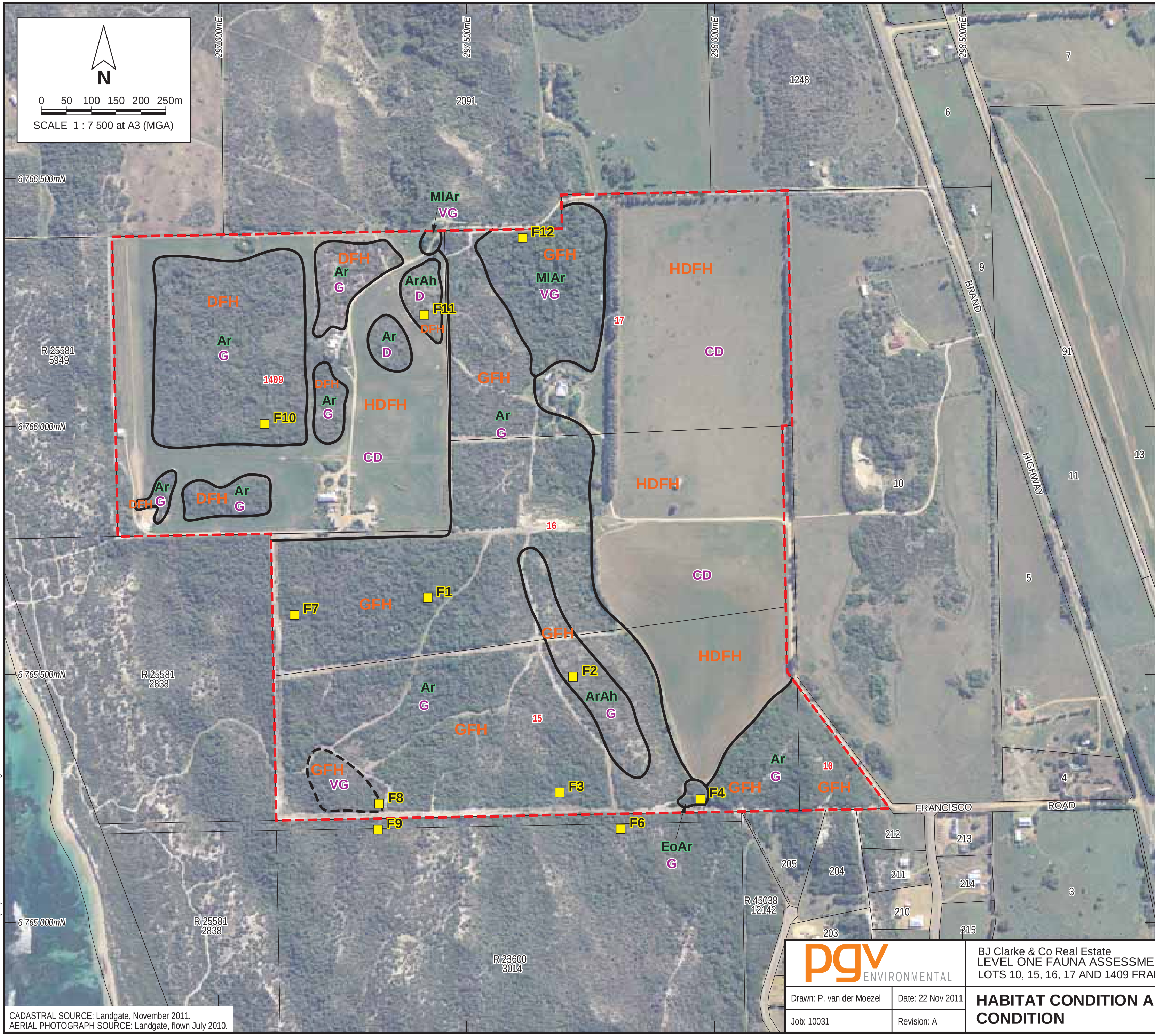
| | |
|---|---|
| Drawn: P. van der Moezel | Date: 22 Nov 2011 |
| Job: 10031 | Revision: A |

## SITE LOCATION

Figure 1

PINPOINT CARTOGRAPHICS (08) 9562 7136

10031-f01.dgn




**Legend**

- Site Boundary
- Cadastral Boundary
- Quadrat Location
- Vegetation Type Boundary
- Vegetation Condition Boundary
- **Ar** Vegetation Type
- **G** Vegetation Condition
- **GFH** Habitat Condition

**Vegetation Legend**
(Source: PGV, 2011)

**Ar** *Acacia rostellifera* Tall Open Scrub to Closed Tall Scrub

**ArAh** *Acacia rostellifera/Alyogyne huegelii* Open Heath

**MlAr** *Melaleuca lanceolata* Low Open Forest over *Acacia rostellifera* Tall Shrubland

**EoAr** *Eucalyptus obtusiflora* Tree Mallee over *Acacia rostellifera* Tall Open Scrub

**Vegetation Condition Legend**
(Source: BUSH FOREVER Govt. of W.A., 2000)

P – Pristine

Ex – Excellent

VG - Very Good

G – Good

D – Degraded

CD - Completely Degraded

Cl – Cleared

**Habitat Condition Legend**
(Source: Coffey Environments, 2009)

HQFH - High Quality Fauna Habitat

VGFH - Very Good Fauna Habitat

GFH - Good Fauna Habitat

DFH - Disturbed Fauna Habitat

HDFH - Highly Degraded Fauna Habitat

pgv ENVIRONMENTAL

BJ Clarke & Co Real Estate
LEVEL ONE FAUNA ASSESSMENT
LOTS 10, 15, 16, 17 AND 1409 FRANCISCO ROAD, DONGARA

| | |
|---|---|
| Drawn: P. van der Moezel | Date: 22 Nov 2011 |
| Job: 10031 | Revision: A |

**HABITAT CONDITION AND VEGETATION TYPES AND CONDITION**

**Figure 2**

PINPOINT CARTOGRAPHICS (08) 9562 7136 10031-f02.dgn

# APPENDIX 1

## DEC Database Search Results

| NAME | SOURCE_CODE | SOURCE_ID | NAME_ID | FAMILY | GENUS |
|---|---|---|---|---|---|
| Anous tenuirostris subsp. melanops | WAMSPECIMENS | A2692\|24506\|01/07/1924 | 24506 | Laridae | Anous |
| Anous tenuirostris subsp. melanops | WAMSPECIMENS | A2691\|24506\|01/07/1924 | 24506 | Laridae | Anous |
| Calyptorhynchus latirostris | BIRDATLAS2 | 99791\|794 | 24734 | Psittacidae | Calyptorhynchus |
| Calyptorhynchus latirostris | BIRDATLAS2 | 434328\|794 | 24734 | Psittacidae | Calyptorhynchus |
| Falco peregrinus | BIRDATLAS2 | 8735\|237 | 25624 | Falconidae | Falco |
| Falco peregrinus subsp. macropus | WAMSPECIMENS | A28544\|24475\|31/01/1900 | 24475 | Falconidae | Falco |
| Morelia spilota subsp. imbricata | WAMSPECIMENS | R12029\|25240\|// | 25240 | Boidae | Morelia |
| Neelaps calonotos | TFAUNA | 15146 | 25249 | Elapidae | Neelaps |
| Neelaps calonotos | WAMSPECIMENS | R141838\|25249\|30/07/2000 | 25249 | Elapidae | Neelaps |

| SPECIES | INFRARANK | INFRANAME | AUTHOR | VERNACULAR | KINGDOM |
|---|---|---|---|---|---|
| tenuirostris | subsp. | melanops | Gould | | Animalia |
| tenuirostris | subsp. | melanops | Gould | | Animalia |
| latirostris | | | Carnaby | Carnaby's Cockatoo | Animalia |
| latirostris | | | Carnaby | Carnaby's Cockatoo | Animalia |
| peregrinus | | | Tunstall | Peregrine Falcon | Animalia |
| peregrinus | subsp. | macropus | Swainson | | Animalia |
| spilota | subsp. | imbricata | (Smith) | Carpet Python | Animalia |
| calonotos | | | (A.M.C. DumΘril, Bibron & A. DumΘril) | Black-striped Snake | Animalia |
| calonotos | | | (A.M.C. DumΘril, Bibron & A. DumΘril) | Black-striped Snake | Animalia |

| CONSV_CODE | CLASS | SITE_NAME | DAY | MONTH | YEAR | LOCALITY_NAME |
|---|---|---|---|---|---|---|
| T | BIRD | | 01 | 07 | 1924 | DONGARA |
| T | BIRD | | 01 | 07 | 1924 | DONGARA |
| T | BIRD | Dongara Oval | 12 | 08 | 2000 | DONGARA |
| T | BIRD | Dongarra | 10 | 10 | 2004 | DONGARA |
| S | BIRD | 100 acre home block, Port Denison | 31 | 01 | 1999 | SPRINGFIELD |
| S | BIRD | | 31 | 01 | 1900 | DONGARA |
| S | REPTILE | DONGARA | | | | DONGARA |
| 3 | REPTILE | ~5km SSE of Port Denison, near Dongara | 30 | 07 | 2000 | PORT DENISON |
| 3 | REPTILE | 5KM SSE PORT DENISON | 30 | 07 | 2000 | PORT DENISON |

# APPENDIX 2

## NatureMaps Database Reports

# NatureMap Species Report

*Created By Guest user on 13/06/2012*

| | |
|---|---|
| **Kingdom** | Animalia |
| **Conservation Status** | Conservation Taxon (T, X, IA, S, P1-P5) |
| **Current Names Only** | Yes |
| **Core Datasets Only** | Yes |
| **Method** | 'By Circle' |
| **Centre** | 114°54' 59'' E,29°13' 19'' S |
| **Buffer** | 5km |

| | | |
|---|---|---|
| **Area (ha)** | | 7853.98 |
| **Taxa:** | Naturalised | 0 |
| | Native | 4 |
| **Endemics:** | | 0 |
| **Families:** | | 4 |
| **Genera:** | | 4 |
| **Conservation Status:** | S | 2 |
| | T | 2 |
| **MS Status:** | - | 4 |
| **Rank:** | subsp. | 3 |
| | - | 1 |

## Top Ten Families

| | Species | Records |
|---|---|---|
| 1. Laridae | 1 | 2 |
| 2. Psittacidae | 1 | 2 |
| 3. Boidae | 1 | 1 |
| 4. Falconidae | 1 | 1 |

## Top Ten Genera

| | Species | Records |
|---|---|---|
| 1. *Anous* | 1 | 2 |
| 2. *Calyptorhynchus* | 1 | 2 |
| 3. *Falco* | 1 | 1 |
| 4. *Morelia* | 1 | 1 |

## [1]Endemic To Query Area

| Name ID | Species | Conservation Status |
|---|---|---|

**Conservation Codes**
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

# APPENDIX 3

## Conservation Codes

**Western Australian and Commonwealth of Australia Conservation Codes**

In Western Australia, all native fauna species are protected under the *Wildlife Conservation Act 1950-1979*. Fauna species that are considered rare, threatened with extinction or have a high conservation value are specially protected under the Act. In addition, some species of fauna are covered under the 1991 ANZECC convention, while certain birds are listed under the Japan and Australian Migratory Bird Agreement (JAMBA) and the China and Australian Migratory Bird Agreement (CAMBA). In addition to the above classification, DEC also classify fauna under five different Priority codes and rare and endangered fauna are classified under the Wildlife Conservation (Specially Protected Fauna) Notice 2006 into four schedules of taxa.

Schedule 1

*Fauna which are rare or likely to become extinct and are declared to be fauna in need of special protection.*

Schedule 2

*Fauna which are presumed to be extinct and are declared to be fauna in need of special protection.*

Schedule 3

*Birds which are subject to an agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction which are declared to be fauna in need of special protection.*

Schedule 4

*Fauna that are in need of special protection, otherwise than for the reasons mentioned in Schedule 1, 2 or 3.*

In addition to the above classification, the DEC also classifies fauna under five different priority codes:

Priority One: Taxa with few, poorly known populations on threatened lands

*Taxa which are known from few specimens or sight records from one or a few localities on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, active mineral leases. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.*

Priority Two: Taxa with few, poorly known populations on conservation lands

*Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation, e.g. national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.*

Priority Three: Taxa with several, poorly known populations, some on conservation lands

*Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.*

Priority Four: Taxa in need of monitoring

*Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.*

Priority Five: Taxa in need of monitoring (conservation dependent)

*Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.*

The Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* has the following nine conservation codes for Flora and Fauna.

Extinct

*Taxa not definitely located in the wild during the past 50 years*

Extinct in the Wild

*Taxa known to survive only in captivity*

Critically Endangered

*Taxa facing an extremely high risk of extinction in the wild in the immediate future*

Endangered

*Taxa facing a very high risk of extinction in the wild in the near future*

Vulnerable

*Taxa facing a high risk of extinction in the wild in the medium-term*

Near Threatened

*Taxa that risk becoming Vulnerable in the wild*

Conservation Dependent

*Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.*

Data Deficient (Insufficiently Known)

*Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.*

Least Concern

*Taxa that are not considered Threatened*

# APPENDIX 4

## Protected Matters Search Tool Report

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

# EPBC Act Protected Matters Report

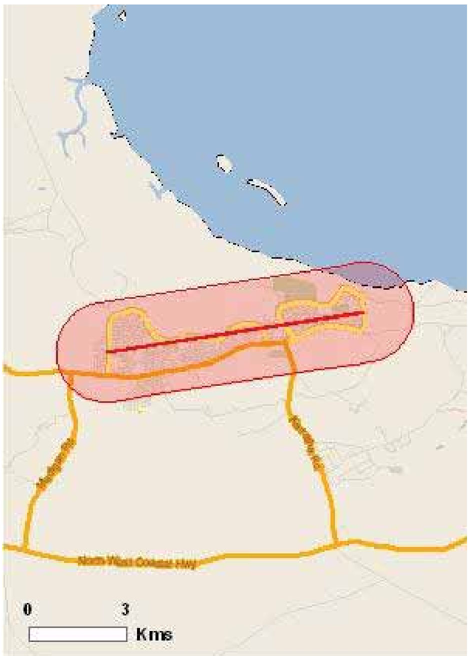
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information about the EPBC Act including significance guidelines, forms and application process details can be found at http://www.environment.gov.au/epbc/assessmentsapprovals/index.html

Report created: 08/06/12 17:16:32

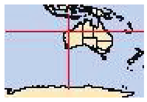

- Summary
- Details
  - Matters of NES
  - Other Matters Protected by the EPBC Act
  - Extra Information
- Caveat
- Acknowledgements


This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2010

Coordinates

Buffer: 1.5Km



## Summary

### Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance - see http://www.environment.gov.au/epbc/assessmentsapprovals/guidelines/index.html

| | |
|---|---|
| World Heritage Properties: | None |
| National Heritage Places: | None |
| Wetlands of International | None |
| Great Barrier Reef Marine Park: | None |
| Commonwealth Marine Areas: | None |
| Threatened Ecological Communities: | None |
| Threatened Species: | 14 |
| Migratory Species: | 23 |

## Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place and the heritage values of a place on the Register of the National Estate. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage/index.html

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species. Information on EPBC Act permit requirements and application forms can be found at http://www.environment.gov.

| | |
|---|---|
| Commonwealth Lands: | 1 |
| Commonwealth Heritage Places: | None |
| Listed Marine Species: | 58 |
| Whales and Other Cetaceans: | 11 |
| Critical Habitats: | None |
| Commonwealth Reserves: | None |

## Extra Information

This part of the report provides information that may also be relevant to the area you have

| | |
|---|---|
| Place on the RNE: | 2 |
| State and Territory Reserves: | None |
| Regional Forest Agreements: | None |
| Invasive Species: | 6 |
| Nationally Important Wetlands: | None |

# Details

## Matters of National Environmental Significance

### Threatened Species [ Resource Information ]

| Name | Status | Type of Presence |
|---|---|---|
| BIRDS | | |
| Macronectes giganteus<br>Southern Giant-Petrel [1060] | Endangered | Species or species habitat may occur within area |

| Name | Status | Type of Presence |
|---|---|---|
| MAMMALS | | |
| Dasyurus hallucatus | | |
| Northern Quoll [331] | Endangered | Species or species habitat likely to occur within area |
| Macrotis lagotis | | |
| Greater Bilby [282] | Vulnerable | Species or species habitat likely to occur within area |
| Megaptera novaeangliae | | |
| Humpback Whale [38] | Vulnerable | Species or species habitat known to occur within area |
| Rhinonicteris aurantia (Pilbara form) | | |
| Pilbara Leaf-nosed Bat [82790] | Vulnerable | Species or species habitat likely to occur within area |
| REPTILES | | |
| Aipysurus apraefrontalis | | |
| Short-nosed Seasnake [1115] | Critically Endangered | Species or species habitat likely to occur within area |
| Caretta caretta | | |
| Loggerhead Turtle [1763] | Endangered | Species or species habitat likely to occur within area |
| Chelonia mydas | | |
| Green Turtle [1765] | Vulnerable | Species or species habitat likely to occur within area |
| Dermochelys coriacea | | |
| Leatherback Turtle, Leathery Turtle, Luth [1768] | Endangered | Species or species habitat likely to occur within area |
| Eretmochelys imbricata | | |
| Hawksbill Turtle [1766] | Vulnerable | Species or species habitat likely to occur within area |
| Liasis olivaceus barroni | | |
| Olive Python (Pilbara subspecies) [66699] | Vulnerable | Species or species habitat may occur within area |
| Natator depressus | | |
| Flatback Turtle [59257] | Vulnerable | Species or species habitat likely to occur within area |
| SHARKS | | |
| Pristis clavata | | |
| Dwarf Sawfish, Queensland Sawfish [68447] | Vulnerable | Species or species habitat likely to occur within area |
| Rhincodon typus | | |
| Whale Shark [66680] | Vulnerable | Species or species habitat may occur within area |

## Migratory Species

[ Resource Information ]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

| Name | Threatened | Type of Presence |
|---|---|---|
| Migratory Marine Birds | | |
| Apus pacificus | | |
| Fork-tailed Swift [678] | | Species or species habitat may occur within area |
| Ardea alba | | |
| Great Egret, White Egret [59541] | | Species or species habitat may occur within area |
| Ardea ibis | | |
| Cattle Egret [59542] | | Species or species habitat may occur within area |

| Name | Threatened | Type of Presence |
|---|---|---|
| Macronectes giganteus<br>Southern Giant-Petrel [1060] | Endangered | Species or species habitat may occur within area |
| **Migratory Marine Species** | | |
| Balaenoptera edeni<br>Bryde's Whale [35] | | Species or species habitat may occur within area |
| Caretta caretta<br>Loggerhead Turtle [1763] | Endangered | Species or species habitat likely to occur within area |
| Chelonia mydas<br>Green Turtle [1765] | Vulnerable | Species or species habitat likely to occur within area |
| Dermochelys coriacea<br>Leatherback Turtle, Leathery Turtle, Luth [1768] | Endangered | Species or species habitat likely to occur within area |
| Dugong dugon<br>Dugong [28] | | Species or species habitat known to occur within area |
| Eretmochelys imbricata<br>Hawksbill Turtle [1766] | Vulnerable | Species or species habitat likely to occur within area |
| Megaptera novaeangliae<br>Humpback Whale [38] | Vulnerable | Species or species habitat known to occur within area |
| Natator depressus<br>Flatback Turtle [59257] | Vulnerable | Species or species habitat likely to occur within area |
| Orcinus orca<br>Killer Whale, Orca [46] | | Species or species habitat may occur within area |
| Rhincodon typus<br>Whale Shark [66680] | Vulnerable | Species or species habitat may occur within area |
| Sousa chinensis<br>Indo-Pacific Humpback Dolphin [50] | | Species or species habitat may occur within area |
| Tursiops aduncus (Arafura/Timor Sea populations)<br>Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900] | | Species or species habitat likely to occur within area |
| **Migratory Terrestrial Species** | | |
| Haliaeetus leucogaster<br>White-bellied Sea-Eagle [943] | | Species or species habitat likely to occur within area |
| Hirundo rustica<br>Barn Swallow [662] | | Species or species habitat may occur within area |
| Merops ornatus<br>Rainbow Bee-eater [670] | | Species or species habitat may occur within area |
| **Migratory Wetlands Species** | | |
| Ardea alba<br>Great Egret, White Egret [59541] | | Species or species habitat may occur within area |
| Ardea ibis<br>Cattle Egret [59542] | | Species or species |

| Name | Threatened | Type of Presence |
| --- | --- | --- |
| | | habitat may occur within area |
| Charadrius veredus<br>Oriental Plover, Oriental Dotterel [882] | | Species or species habitat may occur within area |
| Glareola maldivarum<br>Oriental Pratincole [840] | | Species or species habitat may occur within area |

## Other Matters Protected by the EPBC Act

### Commonwealth Lands [ Resource Information ]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

| Name |
| --- |
| Commonwealth Land - |

### Listed Marine Species [ Resource Information ]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

| Name | Threatened | Type of Presence |
| --- | --- | --- |
| **Birds** | | |
| Apus pacificus<br>Fork-tailed Swift [678] | | Species or species habitat may occur within area |
| Ardea alba<br>Great Egret, White Egret [59541] | | Species or species habitat may occur within area |
| Ardea ibis<br>Cattle Egret [59542] | | Species or species habitat may occur within area |
| Charadrius veredus<br>Oriental Plover, Oriental Dotterel [882] | | Species or species habitat may occur within area |
| Glareola maldivarum<br>Oriental Pratincole [840] | | Species or species habitat may occur within area |
| Haliaeetus leucogaster<br>White-bellied Sea-Eagle [943] | | Species or species habitat likely to occur within area |
| Hirundo rustica<br>Barn Swallow [662] | | Species or species habitat may occur within area |
| Macronectes giganteus<br>Southern Giant-Petrel [1060] | Endangered | Species or species habitat may occur within area |
| Merops ornatus<br>Rainbow Bee-eater [670] | | Species or species habitat may occur within area |
| **Fish** | | |
| Bulbonaricus brauni<br>Braun's Pughead Pipefish, Pug-headed Pipefish [66189] | | Species or species habitat may occur within area |
| Campichthys tricarinatus<br>Three-keel Pipefish [66192] | | Species or species habitat may occur within |

| Name | Threatened | Type of Presence |
|---|---|---|
| | | area |
| Choeroichthys brachysoma<br>Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194] | | Species or species habitat may occur within area |
| Choeroichthys suillus<br>Pig-snouted Pipefish [66198] | | Species or species habitat may occur within area |
| Doryrhamphus janssi<br>Cleaner Pipefish, Janss' Pipefish [66212] | | Species or species habitat may occur within area |
| Doryrhamphus negrosensis<br>Flagtail Pipefish, Masthead Island Pipefish [66213] | | Species or species habitat may occur within area |
| Festucalex scalaris<br>Ladder Pipefish [66216] | | Species or species habitat may occur within area |
| Filicampus tigris<br>Tiger Pipefish [66217] | | Species or species habitat may occur within area |
| Halicampus brocki<br>Brock's Pipefish [66219] | | Species or species habitat may occur within area |
| Halicampus grayi<br>Mud Pipefish, Gray's Pipefish [66221] | | Species or species habitat may occur within area |
| Halicampus nitidus<br>Glittering Pipefish [66224] | | Species or species habitat may occur within area |
| Halicampus spinirostris<br>Spiny-snout Pipefish [66225] | | Species or species habitat may occur within area |
| Haliichthys taeniophorus<br>Ribboned Pipehorse, Ribboned Seadragon [66226] | | Species or species habitat may occur within area |
| Hippichthys penicillus<br>Beady Pipefish, Steep-nosed Pipefish [66231] | | Species or species habitat may occur within area |
| Hippocampus angustus<br>Western Spiny Seahorse, Narrow-bellied Seahorse [66234] | | Species or species habitat may occur within area |
| Hippocampus histrix<br>Spiny Seahorse, Thorny Seahorse [66236] | | Species or species habitat may occur within area |
| Hippocampus kuda<br>Spotted Seahorse, Yellow Seahorse [66237] | | Species or species habitat may occur within area |
| Hippocampus planifrons<br>Flat-face Seahorse [66238] | | Species or species habitat may occur within area |
| Micrognathus micronotopterus<br>Tidepool Pipefish [66255] | | Species or species habitat may occur within area |
| Solegnathus hardwickii<br>Pallid Pipehorse, Hardwick's Pipehorse [66272] | | Species or species habitat may occur within area |

| Name | Threatened | Type of Presence |
|---|---|---|
| Solegnathus lettiensis<br>Gunther's Pipehorse, Indonesian Pipefish [66273] | | Species or species habitat may occur within area |
| Solenostomus cyanopterus<br>Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183] | | Species or species habitat may occur within area |
| Solenostomus paegnius<br>Rough-snout Ghost Pipefish [68425] | | Species or species habitat may occur within area |
| Syngnathoides biaculeatus<br>Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279] | | Species or species habitat may occur within area |
| Trachyrhamphus bicoarctatus<br>Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280] | | Species or species habitat may occur within area |
| Trachyrhamphus longirostris<br>Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281] | | Species or species habitat may occur within area |
| Mammals | | |
| Dugong dugon<br>Dugong [28] | | Species or species habitat known to occur within area |
| Reptiles | | |
| Acalyptophis peronii<br>Horned Seasnake [1114] | | Species or species habitat may occur within area |
| Aipysurus apraefrontalis<br>Short-nosed Seasnake [1115] | Critically Endangered | Species or species habitat likely to occur within area |
| Aipysurus duboisii<br>Dubois' Seasnake [1116] | | Species or species habitat may occur within area |
| Aipysurus eydouxii<br>Spine-tailed Seasnake [1117] | | Species or species habitat may occur within area |
| Aipysurus laevis<br>Olive Seasnake [1120] | | Species or species habitat may occur within area |
| Aipysurus tenuis<br>Brown-lined Seasnake [1121] | | Species or species habitat may occur within area |
| Astrotia stokesii<br>Stokes' Seasnake [1122] | | Species or species habitat may occur within area |
| Caretta caretta<br>Loggerhead Turtle [1763] | Endangered | Species or species habitat likely to occur within area |
| Chelonia mydas<br>Green Turtle [1765] | Vulnerable | Species or species habitat likely to occur within area |
| Dermochelys coriacea<br>Leatherback Turtle, Leathery Turtle, Luth [1768] | Endangered | Species or species habitat likely to occur within area |
| Disteira kingii<br>Spectacled Seasnake [1123] | | Species or species habitat may occur within |

| Name | Threatened | Type of Presence |
|---|---|---|
| | | area |
| Disteira major<br>Olive-headed Seasnake [1124] | | Species or species habitat may occur within area |
| Emydocephalus annulatus<br>Turtle-headed Seasnake [1125] | | Species or species habitat may occur within area |
| Ephalophis greyi<br>North-western Mangrove Seasnake [1127] | | Species or species habitat may occur within area |
| Eretmochelys imbricata<br>Hawksbill Turtle [1766] | Vulnerable | Species or species habitat likely to occur within area |
| Hydrelaps darwiniensis<br>Black-ringed Seasnake [1100] | | Species or species habitat may occur within area |
| Hydrophis czeblukovi<br>Fine-spined Seasnake [59233] | | Species or species habitat may occur within area |
| Hydrophis elegans<br>Elegant Seasnake [1104] | | Species or species habitat may occur within area |
| Hydrophis mcdowelli<br>null [25926] | | Species or species habitat may occur within area |
| Hydrophis ornatus<br>a seasnake [1111] | | Species or species habitat may occur within area |
| Natator depressus<br>Flatback Turtle [59257] | Vulnerable | Species or species habitat likely to occur within area |
| Pelamis platurus<br>Yellow-bellied Seasnake [1091] | | Species or species habitat may occur within area |

## Whales and other Cetaceans [ Resource Information ]

| Name | Status | Type of Presence |
|---|---|---|
| Mammals | | |
| Balaenoptera acutorostrata<br>Minke Whale [33] | | Species or species habitat may occur within area |
| Balaenoptera edeni<br>Bryde's Whale [35] | | Species or species habitat may occur within area |
| Delphinus delphis<br>Common Dophin, Short-beaked Common Dolphin [60] | | Species or species habitat may occur within area |
| Grampus griseus<br>Risso's Dolphin, Grampus [64] | | Species or species habitat may occur within area |
| Megaptera novaeangliae<br>Humpback Whale [38] | Vulnerable | Species or species habitat known to occur within area |
| Orcinus orca<br>Killer Whale, Orca [46] | | Species or species habitat may occur within area |

| Name | Status | Type of Presence |
|---|---|---|
| Sousa chinensis | | |
| Indo-Pacific Humpback Dolphin [50] | | Species or species habitat may occur within area |
| Stenella attenuata | | |
| Spotted Dolphin, Pantropical Spotted Dolphin [51] | | Species or species habitat may occur within area |
| Tursiops aduncus | | |
| Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418] | | Species or species habitat likely to occur within area |
| Tursiops aduncus (Arafura/Timor Sea populations) | | |
| Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900] | | Species or species habitat likely to occur within area |
| Tursiops truncatus s. str. | | |
| Bottlenose Dolphin [68417] | | Species or species habitat may occur within area |

## Extra Information

### Places on the RNE [ Resource Information ]

Note that not all Indigenous sites may be listed.

| Name | State | Status |
|---|---|---|
| Natural | | |
| Coastal Margin Cape Preston to Cape Keraudren | WA | Indicative Place |
| Dampier Archipelago Marine Areas | WA | Indicative Place |

### Invasive Species [ Resource Information ]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit,

| Name | Status | Type of Presence |
|---|---|---|
| Mammals | | |
| Felis catus | | |
| Cat, House Cat, Domestic Cat [19] | | Species or species habitat likely to occur within area |
| Oryctolagus cuniculus | | |
| Rabbit, European Rabbit [128] | | Species or species habitat likely to occur within area |
| Vulpes vulpes | | |
| Red Fox, Fox [18] | | Species or species habitat likely to occur within area |
| Plants | | |
| Cenchrus ciliaris | | |
| Buffel-grass, Black Buffel-grass [20213] | | Species or species habitat likely to occur within area |
| Parkinsonia aculeata | | |
| Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301] | | Species or species habitat likely to occur within area |
| Prosopis spp. | | |
| Mesquite, Algaroba [68407] | | Species or species habitat likely to occur within area |

# Coordinates

-20.74076 116.79874,-20.72979 116.87001,-20.74061 116.79889,-20.7301 116.86818,
-20.72964 116.86955

# Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World Heritage and Register of National Estate properties, Wetlands of International Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

# Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Department of Environment, Climate Change and Water, New South Wales
-Department of Sustainability and Environment, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment and Natural Resources, South Australia
-Parks and Wildlife Service NT, NT Dept of Natural Resources, Environment and the Arts
-Environmental and Resource Management, Queensland
-Department of Environment and Conservation, Western Australia
-Department of the Environment, Climate Change, Energy and Water
-Birds Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-SA Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium

-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
-State Forests of NSW
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

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Please feel free to provide feedback via the Contact Us page.


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# APPENDIX 5

## Land Capability and Geotechnical Assessment 2005 (Landform Research)

# LAND CAPABILITY and GEOTECHNICAL ASSESSMENT

# LOTS 10, 15, 16 and 17 FRANCISCO ROAD, DONGARA

JUNE 2005

Landform Research

# LAND CAPABILITY and GEOTECHNICAL ASSESSMENT

# LOTS 10, 15, 16 and 17, FRANCISCO ROAD, DONGARA

**June 2005**

Landform Research
Land Systems - Quarries - Environment
ABN 29 841 445 694

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## 1.0 INTRODUCTION

Dongara is a popular fishing, beach and holiday location, that is growing in popularity. The land north of Dongara is one of the areas that have been identified as suitable for a node of development.

The site (Lots 10, 15, 16 and 17) lies just inland from the coast, some 2 km north of Dongara.

### Methodology

Lindsay Stephens of Landform Research visited the area on 13 April 2005 during which traverses were made across the site, the geology and soils were investigated and the vegetation communities noted. During that study the soils were mapped to confirm soil type or gain information on the soils, the geology, and hydrology.

The site was also investigated by ARC Energy as part of their assessment for a 3D Seismic Survey conducted in early 2005. The ARC Assessment was subjected to Public Environmental Review through the Environmental Protection Authority and covered, in particular, the environmental issues associated with that survey, particularly disruptions to soils an vegetation.

Soils have also previously been assessed as part of the Geraldton Region, Land Resources Survey, (Rogers, 1996).

### Site Description

The site straddles a zone of coastal dunes extending from the coastal Quindalup Dunes to the older Tamala Dunes in the east.

The eastern part (Tamala) dunes are cleared and used for rural activities with the more hilly western dunes generally remaining covered by coastal vegetation.

## 2.0 EXISTING ENVIRONMENT

### 2.1 Geology and Geomorphology

The coast at this location consists of a series of old sand ridges ranging from those developed at various time in the Pleistocene and Recent. The oldest are the limestone ridges to the east of the Greenough Flats, well to the east of the study site.

The site straddles a portion of Pleistocene Tamala Limestone and soil system in the east which is an interdunal swale of degraded older dunes, and portion of the younger coastal Quindalup Dunes in the west, which rise some 20 to 30 metres above the eastern portion of the site. The eastern portion of the site is gently sloping dropping slightly from a low ridge along the eastern edge of the site towards the centre and to the eastern boundary.

The Older eastern Tamala dunes are part of an older coastal dune sequence of calcareous sands that has been lithified and weathered to form limestone with associated brown sands.

The dunes are formed from quartz or calcium carbonate in the form of shell fragments or foraminifer skeletons and marine organism skeletal remnants such as sponge spicules.

Superimposed on this older system of dunes is a younger set of dunes. The younger dunes parallel the pre existing dunes as a series of stabilised dunes formed at a time when the beach was accreting (having sand added to it).

Over time the calcium carbonate is dissolved leading to hardening of the underlying dunal materials and thus the older the dunes the more cemented and rock like the underlying sediments are. The "Tamala" Dunes along the eastern edge have limestone (calc-arenite) bases which can be seen protruding up through the soil on the low eastern ridge.

The dunes in the west are younger but are the oldest of the Quindalup system. They consist of brown coloured sands with variable amounts of silica and calcium carbonate. With exposure to the atmosphere, rainwater percolates down through the sands dissolving the calcium carbonate through the action of weak acids derived from organic matter and depositing the calcium carbonate lower in the profile. The deposition of the calcium carbonate forms cemented deposits in the base of these dunes.

**Dune Stability**

The lithified Tamala dunes and brown sands are underlain by limestone and are stable.

The Quindalup dunes are younger and less lithified and are therefore less stable than the Tamala dunes. The dune on the western side of the site is the oldest of the Quindalup Dune System and has therefore been stabilised by soil formation processes to be stable particularly in the swales. They are much more stable than new coastal sands being deposited at the rear of the current beaches, with the only areas of likely instability being the two high ridges in the south.

## 2.2 Soils

General information on the soil and land units can be found in Rogers, 1996.

Soils developed on the western Quindalup Dunes are sandy but have grey quartz rich surface horizons stained by organic matter. The age of the soils has an impact on the colour of the soils. The older the soils the more grey and brown they become, with the grey being due to accumulation of organic matter in the upper soil horizons and the brown due to goethite (a form of iron oxide) coating sand grains in older soils and originating from a break down of heavy minerals in the sands. A small amount of clay may also be present in the subsoils of older dunes due to a break down of feldspar grains.

As the Quindalup Dunes on site are the oldest of the system the sand is brown to cream brown sand containing minor clay and calcareous material, makes the soil stable. Existing tracks have cut down due to the impact of vehicles but have not eroded significantly.

The older Tamala system soils are brown sands grading to earthy sands and overlying limestone at variable depth. There has been little bleaching of the sand in the A horizon and minor accumulation of humus. In general the porous nature of the sand allows the humus to be broken down and clay to be washed down to lower levels in the soil profile.

**Phosphate Retention**

The goethite coatings of the sand grains in the older dunes has capability for absorbing phosphate, as does the calcium carbonate content of the soils.

Phosphate Retention Index (PRI) tests can frequently be misleading because all materials greater than 2 mm are sieved from the sample prior to testing. This means that a coarse sand for example will have the larger phosphate retaining particles removed from the sample prior to testing.

On the other hand the calcareous sand may have a better PRI, but in the field water movement may be so fast that the grains have little opportunity to adsorb nutrients.

Phosphate retention therefore cannot be considered in isolation, because the type of land use, type and placement of nutrients, flow paths and distances all contribute to variations in the behaviour of nutrients.

The phosphate retention (PRI) of the brown eastern Tamala System sands in the eastern half of the site is similar to Spearwood Sands which are rated at 5 - 20 during research by the Chemistry Centre. The soils on the eastern portion of the site would have similar PRI and the whole soil profile will be highly phosphate adsorption when the whole soil profile is taken into account and the flow paths of water are considered.

The soils western half consist of brown sands with variable composition of quartz or calcium carbonate in the form of shell fragments or foraminifer skeletons and marine organism skeletal remnants such as sponge spicules. The phosphate retention of soils such as this can normally vary from 2 - 5 (PRI) but can go higher when more lime is present. Sorption by calcareous soils is dominated by precipitation and sorption reactions with calcium carbonate and the formation and precipitation of minerals such as di-calcium phosphate, $CaHP0_4.2H_20$.

Permeability and porosity of the soils is moderate to high, reduced slightly by non wetting and the small clay content, but microbial purification is high because of the depth of sand above the water table.

The generalised soil properties are summarised below.

| **Soil Characteristics** | **Brown Sand over Limestone (Tamala)** | **Grey Coastal Sands over Limestone (Quindalup)** |
|---|---|---|
| Location | Eastern portion of site | Western portion of site |
| Topsoil Texture | Brown sand | Grey calcareous sand |
| Subsoil Texture | Brown medium grained silica sand that becomes earthy and loamy on the lower elevation | Light brown to cream medium grained silica and calcareous sand with up to 80% calcareous sand grains. |
| Stone | Low apart from some patches of weathered weakly lithified limestone that occurs on the ridge in the east | Nil |
| Depth to Bedrock | Limestone (calc-arenite) from 1 to perhaps 5 metres | Weakly lithified limestone is possibly present to depths greater than 10 metres |
| Hardpan | No evidence in the soils apart from underlying limestone and some compaction effects in the more loamy soils | No evidence in the soils |
| pH | Neutral to alkaline | Alkaline |
| Salinity | Low | Low |

| | | |
|---|---|---|
| Soil Permeability | High | High |
| Soil Shrinkage | Very low | Minor compaction possible |

| **Land Qualities** | **Brown Sand over Limestone (Tamala)** | **Grey Coastal Sands over Limestone (Quindalup)** |
|---|---|---|
| Slope | Gentle to moderate on localised dune slopes | Gentle to steep localised dune slopes |
| Slope Stability | High | Moderate. There are two ridge areas that have potentially unstable soils but the remainder have brown sands that are relatively stable |
| Rock/Gravel | Present on ridge in the east | Not obvious but may be present as weakly lithified limestone generally below 500 mm |
| Wind Erosion Risk | Moderate to high if the vegetation is removed and the soils are exposed to wind | Moderate to high if the vegetation is removed and the soils are exposed to wind. There are two potentially unstable areas on steeper ridges. |
| Water Erosion Risk | Low, but as the sands can be non wetting summer storm events can cause minor water erosion rills on sloping dune sands that have no vegetation cover. The extent of this is minimal. | Low, but as the sands can be non wetting summer storm events can cause water erosion rills on steeply sloping dune sands that have no vegetation cover. The extent of this is minimal. |
| Drainage | Rapid to water table | Rapid to water table |
| Moisture Availability | Moderate to low | Low |
| Water Logging | Nil | Nil |
| Wetability | Moderate to high. Non wetting behaviour depending on the season | Moderate to low. Non wetting behaviour depending on the season |
| Flood Risk | Nil | Nil |
| Surface Water - Availability/Quality | Nil | Nil |
| Ground Water - Availability/Quality | Groundwater is present at about 3.0 metres below the lowest elevation. Quality varies from 1925 mg/L to 3 575 mg/L | Groundwater is present at about 3.0 metres below the lowest elevation. Quality varies from 1925 mg/L to 3 575 mg/L |
| Salinity Risk | Nil | Nil |
| Microbial Purification | High based on the depths of sand and depth to the water table. Higher elevations have longer travel distances and therefore better purification ability. | High based on the depths of calcareous sand and depth to the water table. Higher elevations have longer travel distances and therefore better purification ability. |
| Water Pollution Risk | Moderate. Design and management can reduce the potential for water pollution risk | Moderate. Design and management can reduce the potential for water pollution risk |
| Soil Profile; Phosphate absorption | High based on the proportion of calcium carbonate, minor clay, sesquioxides, porosity and permeability and distance of water travel. | Moderate based on the proportion of the calcium carbonate depth of soils, travel distances, porosity and permeability<br>Can be improved by use of an alternative waste water treatment system. |
| Soil Profile; Nitrogen Removal | High based on the travel distances | Moderate based on the travel distances. Can be improved by use of an alternative waste water treatment system. |
| Degradation | Low, but cleared | Low, uncleared apart from strategic fire breaks. |

## 2.3 Climate

Weather data is recorded at the Geraldton Airport which is slightly inland. Onsite temperatures can therefore be expected to have slightly lower summer maxima and slightly higher winter minima than Geraldton.

Geraldton averages show maxima of 32 degrees C. in summer, down to an average of 19 degrees C. in winter. Minima range from 18 degrees C. to 9 degrees C.

Rainfall averages 472 min per annum at Geraldton and 462 at Dongara.

9.00 am wind data shows a predominantly east to south east direction in summer and lighter north easterly directions in winter. At 3.00 pm there is a predominance of south westerly sea breezes which exceed 30 km/h for over 30% of the time. Strong northerly winds can occur ahead of cold fronts in autumn to spring and can be significant but short term events.

Swell directions are predominantly from the south west with storms from the north west in winter and occasional cyclonic storms from the decaying remnants of cyclones in late summer.

## 2.4 Vegetation

The vegetation was assessed briefly on 13 April 2005.

The eastern half of the site is cleared apart from *Acacia rostelfifera* regrowth that is now coming back on the limestone ridge.

The western portion has been previously cleared in the swales for grazing but is regrowing strongly as *Acacia rostellifera* Thicket. The tops of the ridges and the steeper slopes have largely been uncleared although grazed in the past. They are also regrowing.

The vegetation is dominated by *Acacia rostellifera* Ticket.
The species are typical of the older Quindalup Dunes, grading to more coastal species towards the west.

Common Species are;

*Acacia rostellifera* predominates, particularly in regrowth over previously cleared areas.

Additional species generally as understorey include *Acacia cyclops, Acanthocarpus praise, Alyxia buxifolia, Anthoceris littorea, Atriplex cinerea, Atriplex isatidea, Beyeria viscosa, Nitraria billardierei, Olearia axillaris, Rhagodia baccata, Desmocladus flexuosa, Leucopogon parviflorus, Cassytha racemosa, Alyogyne* spp, *Exocarpus sparteus, Tetragonia decumbens, Dianella divaricata, Westringia dampieri,* some *Melaleuca systena and Templetonia retusa.* Some *Melaleuca huegelii* is added to the communities of the ridge tops.

*Eucalyptus decipiens* occurs on site in scattered locations, and one plant *of Eucalyptus obtusifolia* was observed in the north.

A stable swale area in the north has a stand of *Melaleuca lanceolata* that is worthy of preservation.

Towards the coast the vegetation remains predominantly *Acacia rostellifera* Thicket but more coastal species are added to the communities with a higher component of *Spinifex longifolius, Myoporum insulare, Scaevola crassifolia , Acanthocarpus preissi Olearia axillaris, Carpobrotus virescens, Alyxia buxifolia, Anthoceris littorea, Salsola kali, Atriplex cinerea, Atriplex isatidea, Beyeria viscosa, Cassytha racemosa Exocarpus sparteus, Leucopogon parviflorus, Ozothamnus cordatus, Ficina nodosa, Dianella divaricata Scaevola anchusifolia, Nitraria billardierei, Rhagodia baccata* and *Tetragonia decumbens*.

**Rare and Priority Species**

It was the wrong time of year to search for Rare or Priority species, and a definitive search was therefore not possible. However the chances of recording any Priority or Declared species in these coastal vegetation communities is low because the species are widespread and common.

ARC Energy investigated the Declared Rare and Priority Species and made a list of the species likely to occur within their seismic area which covered the subject land, but also included large areas of land to the south of Dongara and different inland soil types. The Declared Rare and Priority species are listed in Table 4.14 of their report. None of the species is likely to occur in coastal dunes.

Therefore there is regarded to be a very low chance of there being any Declared Rare and Priority Species occurring on the subject land.

**Dieback**

CALM generally recognises that Dieback is less likely to impact on vegetation on limestone and Spearwood/Cottesloe Land Systems, Podger F D and K R Vear, 1998, *Management of Phytophthora and disease caused by it*, IN *Phytophthora cinnamomi* and the disease caused by it - protocol for identifying protectable areas and their priority for management, EPA 2000.

There are, however, other plant diseases caused by fungus such as *Armillaria* that can cause dieback symptoms.

No evidence of significant plant diseases was observed during the brief traverses.

**Vegetation Condition**

The vegetation of the majority of the western portion of the site appears to have been cleared in the swales and or significantly grazed. It is however regrowing as *Acacia rostellifera* Regrowth Thicket. Its condition ranges from small areas of Completely Degraded to Degraded - Good.

The vegetation condition is improving as stock remain excluded from the vegetation

The small high ridges in the south east are covered by vegetation in better condition, probably because of the steeper slopes. This vegetation appears to range from locally Degraded to Very Good with the majority above Good. The condition scale is taken from Bush Forever 2000.

### 2.5 Surface and Groundwater

There is no surface drainage on the site with all infiltration moving vertically downwards to the water table.

Two bores are located on site with water available at 14 metres depth in the north and 6.5 metres in the south, making the water table at about 2 metres AHD.

These bores are associated with the cleared land. The water quality is 2475 mg/L in the north and 1705 mg/L in the south. The water is suitable for stock and some more hardy plants but is not generally suited to horticulture.

The quality was apparently better in the past and may have decreased due to reduced rainfall in recent years or mixing with a more saline water body, perhaps by general overpumping in the Dongara area.

The quality is, however, well suited to stock on small rural holdings.

## 3.0 HYDROLOGICAL ASSESSMENT - WATER AVAILABILITY

Bore water on site is suitable for stock but is not potable.

Potable water can therefore be provided by scheme water, tanks or desalination and/or bore water combined with a UV steriliser.

## 4.0 ALTERNATIVE LANDUSES

The site is adjacent to special rural lots and the eastern portion of the site is well suited to that purpose. The western area of higher dunes is suited to rural residential whilst retaining the significant amounts of vegetation to maintain soil cover and managing the fire risk

Alternatively the site is suited to urban development on smaller lots and is no different to many areas that have been developed in coastal towns. The same vegetation community is retained on the coastal reserve.

The Local Planning Strategy has identified Lot 10 as suitable for rural residential with the balance being urban.

Some management of the less stable soils and steeper slopes is recommended.

## 5.0 GEOTECHNICAL FACTORS

### 5.1 Foundation Stability

The eastern area is deep silica sand over limestone. These soils provide good foundation stability. According to AS 2870, Site Class A to S would probably apply to the silica sands. Site Class P will apply when slopes require > 800 mm sand fill, particularly on filled sites where differential levels of fill are required or a section of dwelling is located on limestone.

There are however situations on the limestone ridge where some care needs to be taken. See points 5 and 6 below.

The western portion of he site is underlain by calcareous coastal dunes which include some steeper slopes. This can raise some foundation issues that can be addressed at the time of dwelling construction. Constructions on these sands will vary from AS 2870 Site Class S to P. Site Class P will apply when slopes require > 800 mm sand fill, particularly on filled sites where differential levels of fill are required or a section of dwelling is located on limestone after cut.

The main issues with foundation stability on the calcareous sands are;

1. Calcium carbonate sands can crush or settle under load. For example where one corner of a dwelling is located on limestone at shallow depth and another corner is located on calcareous sand fill.

2. Calcium carbonate can dissolve in acidic garden conditions or acidic waste water conditions.

3. Underlying limestone may be less competent.

4. Earthworks should be sympathetic to any potential to destabilise sand. For example roads and paths should be located in areas where wind erosion is less likely and or the verges, revegetated or covered to minimise the risks.

5. There is potential for a dwelling on a concrete slab to be located with one portion of the slab located on limestone, with less potential for settlement, and other portions of the slab on calcareous sands which can settle. This might lead to differential settlement of the slab and the potential for cracking.

6. Calcareous sands can be non wetting and need to be treated appropriately to ensure adequate compaction.

7. When levelling a dune ridge for construction the original part of the dune is potentially more competent and compacted than the fill area, which should be filled and compacted and tested to ensure adequate compaction and a lack of potential for differential settling.

8. Undermining of footings during strong wind events or storms. There is also the risk of local undermining of isolated piers such as a carport through excessive stormwater from roof drainage. This should be managed by sympathetic disposal of stormwater away from the footings and maintaining good groundcover at all times.

**Management Actions** that may be used to improve foundation stability could include management of the points above and following.

Other techniques that can be of assistance are

- Provide retaining walls and structures for fill.
- Retain shrubs and deeper rooted vegetation on slopes.
- Consider the use of flexible or split level structures

- Design for lateral creep pressures on slopes.
- Ensure adequate compaction of all areas and to depth.
- Use rows of piers or strip footings orientated up slope on sloping ground.
- Minimise the potential for acidic water loading of footings.
- Prevent undermining and removal of sand from around or from under constructions, particularly on exposed steeper slopes in the western portion.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.1.1 | Foundation stability | • See the above Management Actions for some methods of reducing potential foundation limitations on calcareous soils and dune ridges.<br>• Each dwelling site will need to be individually assessed at the time of design and construction to determine any potentially deleterious conditions and to incorporate methods to mitigate them.<br>• AS 2870 Site Class S - P depending on the location of the potential dwelling from a low sand swale to a steep calcareous sand ridge.<br>• The adequate ground cover is recommended to minimise the risk of undermining structures. |

- Site Class P may apply. For example constructions requiring more than 400 mm natural fill and/or 800 mm sand should be classified as Site Class P to ensure adequate compaction to prevent differential settling.
- Individual site assessment may be required for any dwelling or development because of lateral and vertical soil changes that may be present and because of previous soil disturbance that cannot be detected by visual assessment.

## 5.2 Drainage and Flood Risk

Almost the whole site is well drained with no risk of inundation or flooding. The exception is a small area in the central south where heavy rainfall can cause pools of water on the surface for a short time.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.2.1 | Inundation | • Some consideration of surface water may need to be made in the area marked on the aerial photograph. This can be through drainage or fill. |
| 5.2.2 | Flood risk | • No issues. |

## 5.3 Capability for On Site Effluent Disposal

The critical issues in the design and placement of effluent disposal systems is to ensure adequate microbial purification and adequate protection from bores. The soils are very permeable.

Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974, require 1.2 metres of free draining soil under a waste water disposal system and a location not closer than 30 metres to a bore. Normal practice is to allow 5 metres of sand travel for adequate microbial purification.

The separation distances between the water table, at about 2.0 metres AHD, is 4 - 5 metres at the small low point on the site in the central south. The separation then increases to 8 metres in the east and to over 35 metres in the west. This would comply for lot sizes down to 2 000 $m^2$. Smaller lot sizes in the future would require connection to sewerage.

There are only two bores, and waste water systems can be located over 30 metres from any bore. This would particularly apply to any bore used for a domestic supply. Water from such a bore that is closer than 30 metres could be sterilised using an in line UV steriliser.

Under land systems such as this the main nutrient loss is nitrate, with phosphorous being taken up by the iron oxides and calcium carbonate in the calcareous sands and basal limestone. This is discussed in 2.2 Soils.

The soils comply with the Government Country Sewerage Policy, the Health Act Regulations (1974) and Health Department Guidelines for the installation of both conventional septic systems and, alternative waste water systems and the Greywater Disposal Guidelines.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.3.1 | Site Capability for Effluent Disposal | • Conventional septic systems or alternative waste water systems are acceptable and comply with the Health Regulations 1974 and the Country Sewerage Policy.<br>• Alternative effluent system disposal areas are to be sized at $10L/m^2$ .<br>• Appropriate setbacks are recommended from domestic bores of at least 30 metres. |

## 5.4 Landslip Risk

Whilst the steeper slopes are sandy they are more susceptible to having structures undermined by wind if unprotected rather than slippage. Undermining could lead to unacceptable movements if allowed to occur. The only risk to structures is from foundation stability.

| | GEOTECHNICAL ISSUE | MANAGEMENT |
|---|---|---|
| 5.4.1 | Landslip Risk | • Covered by the considerations in 5.1 Foundation stability. |

## 6.0 ENVIRONMENTAL MANAGEMENT

The following items are identified as the most likely to impact on the environment. These items can be managed by the implementation of the management recommendations. Other items are unlikely to impact or the impact is regarded as small.

### 6.1 Aesthetics

The aesthetics depend on the level of visibility that can be obtained of dwellings and other developments, particularly from the beach, Brand Highway and other dwellings. The use of Lot 10 for rural residential will provide a buffer to Brand Highway.

The site has setbacks and reserve land separating it from the beach. It is unlikely that few dwellings will be able to be seen from ground level from the beach because of coastal dunes and vegetation, even though the dwellings may well have ocean views. Some may be able to be seen from the ocean.

The low ridge in the east protects a significant portion of the site from Brand Highway. In addition trees are normally planted on smaller rural lots and lifestyle lots. Retention of vegetation in the west can be addressed as part of the subdivision approval process.

The colour, height and style of dwellings and other structures should be visually compatible with the area and to this end developments should be coloured, painted or colour bond sheeting used where applicable. The use of grey galvanised or zinc/alum sheeting should be avoided unless as an integral part of a development such as a roof on a "country style" home or shielded from key sight lines.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.1.1 | Remnant vegetation | • The identification of areas of vegetation to be retained can be established as part of the subdivision approval process.<br>• The eastern portion of the site is cleared and all the swale areas on the western half were previously cleared and are now occupied by regrowing *Acacia rostellifera* Thicket.<br>• Dongara townsite is growing and the subject land is a logical extension of urban and rural living lots to the south. |
| 6.1.2 | Dwellings, fences and other developments are to be aesthetically compatible with the area. | • The Shire of Irwin can place restrictions on the use of visually non compatible materials at the time of Development Approval.<br>• Appropriate conditions can be placed during the Subdivision approval process. |

### 6.2 Preservation of Agricultural Land

The western half is substandard agricultural land only suited to grazing in the swales. The cleared land in the east is cropping and grazing land, but is dissected by the limestone ridge. A portion was used for horticulture in the past but the bore water has become brackish to the point where it is not suitable for sensitive crops.

The amount of agricultural land that will be lost is small and offset by an extension to the Dongara townsite.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.2.1 | Protection of agricultural land | • A small area of agricultural land will be impacted on. |

## 6.3 Land Use Buffers

As the use of the site is proposed to be rural living, and possibly for future urban development, no particular buffers are required, The land adjoins reserve land and is bordered on the east by the Brand Highway.

The buffer to the coast is a minimum of 450 metres at its closest point. Management actions are suggested to minimise impacts on the coastal reserves in 6.8 Stormwater, Erosion Potential and Soil Management. It is suggested that the western boundaries of lots be fenced and that there only be one permitted and defined track to the beach from the subject land. Uncontrolled access could lead to destabilisation of some coastal reserve land.

The other potential issue is the dumping of garden waste over the back fences. This can lead to significant weed issues, but is little different to other areas. The best means of managing this is to have a hard paved surface separating the lots from the coastal reserves. This tends to discourage the dumping of weeds and provides a better opportunity for management, including access.

A hard surface track along the western boundary will also provide fire access.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.3.1 | Rural land | • No particular buffers are required. |
| 6.3.2 | Buffers to Agriculture | • Buffered by reserve land and Brand Highway. |
| 6.3.3 | Buffers to Coast | • Buffered by reserve land, fences and defined pathways.<br>• See recommendations in 6.8 Stormwater, Erosion Potential and Soil Management. |

## 6.4 Flora and Fauna

### Flora

The vegetation was assessed briefly on 13 April 2005.

The eastern half of the site is cleared apart from *Acacia rostelfifera* regrowth that is now coming back on the limestone ridge. This has minimal to generally no understorey species.

The western portion has been previously cleared in the swales for grazing but is regrowing strongly as *Acacia rostellifera* Thicket. The tops of the ridges and the steeper slopes have largely been uncleared although grazed in the past. They are also regrowing.

The vegetation of the western portion is dominated by *Acacia rostellifera* Thicket as discussed in 2.4 Vegetation. The same vegetation communities occur along much of the Western Australian coastal dunes and is generally well reserved.

The species are typical of the older Quindalup Dunes, grading to more coastal species towards the west.

ARC Energy investigated the Declared Rare and Priority Species and made a list of the species likely to occur within their seismic area which covered the subject land, but also included large areas of land to the south of Dongara and different inland soil types. The Declared Rare and Priority species are listed in Table 4.14 of their report. None of the species is likely to occur in coastal dunes and therefore none are expected to occur on site.

**Fauna**

The fauna was not assessed and is related to habitat. The more remnant vegetation remaining the greater the amount and chances of fauna. The adjoining land to the west and south are reserves, Reserve 25581, 23600 and 45038.

The best means of minimising impact on fauna is to retain habitat and minimise disruptions to fauna usage by fences and tracks. However the site is a logical extension of the Dongara townsite and this has to be balanced against the need for urban and rural living properties and town expansion.

The amount of habitat to be retained will be determined as part of the subdivision approval process.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.4.1 | Flora | • Some remnant vegetation to link the existing reserves to the north and west and the remnant vegetation along the eastern boundary is desirable.<br>• Fire breaks and fuel reduction zones will apply to the western edge of the site and could be formed on existing cleared/slashed areas and existing tracks. This can be determined as part of a Fire Management Plan to be prepared.<br>• Onsite firebreaks could be located in already cleared or disturbed areas and existing tracks.<br>• The better vegetation on the steeper south eastern corner could be considered when allocating public open space.<br>• The same vegetation community is retained in the coastal reserve. |
| 6.4.2 | Fauna | • Fauna depends on the retention of habitat and providing habitat linkages and corridors. See 6.5.1 above. |

## 6.5 Nutrient Management

The main issues with nutrient impacts is from waste water disposal and the potential for increased nutrients on the cleared land of the eastern half.

Phosphorous is the main nutrient implicated in algal blooms in waterways. Nitrates are normally taken up by vegetation, denitrified by bacteria under anoxic soil conditions or lost through volatilisation of ammonia. Microbial material is normally deactivated by soil micro-organisms.

Phosphorous will be taken up by the iron oxides and calcium carbonate in the calcareous sands and basal limestone. The soils of the site are coloured sands over limestone which together have sufficient phosphate retention capability to minimise phosphorous export. Sorption by calcareous soils is dominated by precipitation and sorption reactions with calcium carbonate and the formation and precipitation of minerals such as di-calcium phosphate, $CaHP0_4.2H_20$.

Nitrogen and microbial material are dealt with during travel through the subsoils.

The depth to groundwater is a minimum of 4 - 5 metres in a small area in the central south with the majority of the site having a separation of 5 to 15 metres in the eastern half and 15 plus metres in the western half.

Phosphate Retention Index (PRI) is a measure of the potential adsorption of phosphorous by soils. At a low PRI of 2 each cubic metre of soils and limestone can adsorb 3.0 kg phosphorous. At a PRI of 5 the potential adsorption is 12 kg. This provides for substantial adsorption capability for the soils, even at the lowest PRI.

A typical septic system loses at least half the nitrogen through denitrification in the two tanks. This brings the concentration down to 10 - 40 mg/L. Conventional septic systems release 5 - 6 kg phosphorous per year. As such all the phosphorous will be adsorbed within 1 metre of a standard dual 9 metre leach drain system for a period of 33 years at a soil PRI of 2.

Further denitrification occurs in moist sands in the presence of organic matter. Therefore it is also unlikely that nitrogen will either reach the coast or reach it in significant concentrations.

Considering the travel distances to the water table and coast it is most unlikely that phosphorous will be exported to the marine environment, or the concentration will be below significant levels. The closest corner of the site to the ocean is 450 metres and the majority of the site is 10 to 15 plus metres to the water table.

On reaching the coast there will be additional very large dilution by the ocean.

### Change of landuse

The eastern portion of the site is currently used for broad acre cropping and grazing.

With a current average stocking rate on the eastern half of 5 DSE, the estimated nutrient loading when fully stocked with sheep or equivalent numbers of stock could be 53 kg/N/ha/year and 7.3 kg/P/ha/year.

The use of nutrients on broad acre crops is not dissimilar to these levels, but will vary depending on the existing nutrient status of the soils and the type of crop grown, for example if a legume or green manure crop had been used in rotation and if stubble is retained. Phosphorous rates could be 10 - 30 kg P/ha (20 kg requires 220 kg superphosphate). Nitrogen requirements can be 100 to 200 kg/ha depending on the quality and protein content of the cereal crop. These fertiliser application rates are discounted for stubble retained (eg 40 kgN), and the existing retained soil levels from past cropping, and thus the actual application rates can be substantially less, particularly in the case of nitrogen.

Lantzke and Summers, 2005, state that the measured nutrient inputs for various land uses near Bunbury for cereal cropping was 30 kg/N/ha/year and 30 kg/P/ha/year.

With rural living the behaviours of nutrients is influenced by denitrification, volatilisation of ammonia, recycling, uptake by vegetation and phosphate absorption by sesqui-oxides.

To gain some idea of nutrient changes a typical conventional septic system releases 5.5 kg P year and 18 kg N/year. However allowing for six chickens, a dog and cat and a 250 $m^2$ area of fertilised gardens, a further loading of 12.3 kg N/year and 5.2 kg P/year can be added for the dwelling area. (Data from Select Committee on Metropolitan Development and Groundwater Supplies, Legislative Assembly 1994 and Nitrate management in the Jandakot UWPCA, Dames and Moore, undated).

One horse is estimated at 60 kg/N/year and 11 Kg/P/year, and one sheep 10.06 kg/N/year and 1.47 Kg/P/year. Data for cattle from Select Committee on Metropolitan Development and Groundwater Supplies shows cattle as 57.4 kg/N/year and 17.6 kg/P/year. The value for phosphorous may be too high for cattle not fed introduced feed.

Data for typical land uses listed below, which might be used at some stage in the future, show that overall nutrient loading is unlikely to rise with changes in land use, and with continued grazing there will also be no change.

For the western areas covered by remnant vegetation the inputs are likely to be less because a substantial portion of the existing vegetation is likely to be retained and stock reduced or excluded. For example a horse can release double the phosphorous of a conventional septic tank and three times the nitrogen when fed introduced feed. This is normally spread across paddocks but can be concentrated at a point source when a horse is stabled.

For smaller or urban lot sizes stock are normally removed, sewerage is provided and therefore the input rates of nutrients reduce.

**Typical nutrient loadings of some land uses**

| Possible lot size and activity | Nitrogen loading per hectare | Phosphorous loading per hectare | Likely nutrient scenario |
|---|---|---|---|
| Estimated average current stocking rate over the whole property 5 DSE per hectare | 53 kg/N/ha/year | 7.3 kg/P/ha/year | Possible nutrient loss through washing of dung down slope during waterlogged conditions and during storms. |
| Cereal cropping | 30 kg/N/ha/year | 30 kg/P/ha/year | |
| 2 hectare rural residential property, conventional septic system, garden, dog and cat as listed above and 1 horse | 45.2 kg/N/ha/year | 10.9 kg/P/ha/year | Unlikely to be nutrient export when correctly established. |
| 0.5 hectare rural residential property, conventional septic system, no stock, but garden and dog and cat as listed above | 60.6 kg/N/ha/year | 21.4 kg/P/ha/year | Unlikely to be nutrient export when correctly established. |

| | | | |
|---|---|---|---|
| 0.1 hectare urban lot with reticulated sewerage, 250 $m^2$ high nutrient garden and 50% of lots having a dog and cat as listed above | 60.0 kg/N/ha/year | 27.0 kg/P/ha/year | Unlikely to be nutrient export when correctly established. |

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.5.1 | Effluent disposal | • Interpretations of the groundwater movement, input of nutrients and soils suggest that it is unlikely that there will be any or minimal export of phosphorous or nitrogen to the coast. Any concentrations arriving there are likely to be insignificant and readily diluted by sea water. |

## 6.6 Salinity

There is no evidence of salinity on site and, with the free draining soils, salinity is not regarded as a significant issue.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.6.1 | Salinity | • Unlikely to be any significant changes to the current regime. |

## 6.7 Stormwater, Erosion Potential and Soil Management

The potential for wind erosion of the site is high in soils such as this.

Potential water erosion is minimal and confined to storm events when the soils are non wetting.

Some site conditions and management activities that will minimise the potential for wind erosion and prevent further dune degradation are;

- Constructing roads, fences and firebreaks in locations which are less likely to lead to soil erosion.
- The swales of the western areas have lower wind erosion risk. The two high sand ridges shown on the attached aerial photograph have higher risk and may require additional management.
- Existing roads in coastal areas such as Mulloway and Red Emperor Drive at Flat Rocks in the Greenough Shire demonstrate that construction of access is possible without leading to soil erosion.
- Unnecessary tracks can be closed with the exception of one track to allow public access to the beach.
- The access track to the coast should be defined by fencing, poles or some other mechanism where it is likely that the track will be breached or additional tracks formed.
- A perimeter fence along the lots, particularly in the west will minimise the incursions into the coastal vegetation.
- Some remnant vegetation on the remainder of the western portion of the site can be incorporated into the subdivision design.

- Firebreaks should be strategic and consist of low fuel zones through slashing rather than removal of vegetation.

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.7.1 | Water erosion | • Runoff from roads is to the sand along the verges and drainage detention basins. |
| 6.7.2 | Wind erosion | • The management actions listed in the dot points above will be implemented. No special recommendations required. |

## 6.9 Fire Control

Fire Control falls under the Bush Fires Control Act (as amended) and the Shire of Irwin.

The remnant vegetation will pose a High risk, and fuel reduction zones between the vegetation and dwellings will be required.

The main issues with fire management are the reduction in fuel by slashing to minimise the potential for soil erosion.

A condition of subdivision could be for a tank holding at least 10 000 litres or a rainwater tank to at all times, or a standpipe facility to be available for fire fighting

| | ENVIRONMENTAL ISSUE | MANAGEMENT |
|---|---|---|
| 6.9.1 | Fire Risk | • Dwellings could have adequate Building Protection Zones and be protected by a strategic fire break and/or fuel reduction zones.<br>• Access and fire management could be discussed with the relevant fire control officer and addressed in a Fire Management Plan.<br>• Guidelines in Planning for Bush Fire Protection, 2001 (FESA and DPI) and Shire of Irwin can be implemented.<br>• Provision of an emergency water supply is possible either through standpipe or similar mechanism or agreed to by the proponent and can be a condition of development or subdivision. |

## 7.0 CONCLUSIONS

The proposed development of Lots 10, 15, 16 and 17 Francisco Road, Dongara to rural residential or conventional residential development is sustainable.

The amount of land removed from agricultural production is small. Some vegetation in the west will require clearing, but this is typical coastal vegetation of which a substantial portion was previously cleared and is now regrowing to *Acacia rostellifera* Thicket.

Previous studies suggest that there are unlikely to be any Declared Rare or Priority species likely to be present. The coastal vegetation is common all along the coast and its taking of portion of an area such as this must be weighed against the planning consideration for the potential future expansion of the Dongara Townsite, this being the next closest land to the existing townsite.

The potential for nutrient export is assessed to be low either from rural living, special rural or urban lots.

The proposed subdivision is set well back from the coast at a minimum of 450 metres and is not likely to have significant impact on the coast, and may provide an opportunity to manage uncontrolled coastal access.

The use of Lot 10 for rural residential will provide a visual buffer between urban land and the Brand Highway.

There are no significant reasons why Lots 10, 15, 16 and 17 Francisco Road, Dongara cannot be rezoned to rural residential or at some point in the future, an expansion of the urban townsite.

**REFERENCES - BIBLIOGRAPHY**

Allen D G and R C Jeffery, 1990, *Methods for Analysis of Phosphorous in Western Australian Soils*, Chemistry Centre, Report on Investigation No 37.

ARC Energy - Origin Energy, 2004, *Denison 3D Seismic Survey*, Public Environemtnal Review.

ARMCANZ, ANZECC, September 1995, *Guidelines for Groundwater Protection in Australia,*

ANZECC, 2000, *Guidelines for Fresh and Marine Water Quality.*

Coles and Moore, 1998, *Runoff and Water Erosion*, in Soil Guide, WA Department of Agriculture, Bulletin 4343.

Dames and Moore, undated, *Nitrate management in the Jandakot UWPCA.*

Data from *Select Committee on Metropolitan Development and Groundwater Supplies*, Legislative Assembly 1994.

Dawes L and A Goonetilleke, 2001, *The importance of site assessment in designing effluent disposal areas*, Proceedings of the 2nd Australia and New Zealand Conference on Environmental Geotechnics - Geoenvironment, University of Newcastle, New South Wales.

Department of Environment WA, 2004A, *Stormwater Management Manual for Western Australia.*

EPA Guidance Number 26, *Management of Surface Runoff from Industrial and Commercial Sites* (draft) 1999.

Environmental Protection Authority Victoria/ Melbourne Water, undated, *Urban Stormwater, Best Practice Environmental Management Guidelines.*

FESA and WAPC, 2001, *Planning for Fire*, Fire and Emergency Services Authority of Western Australia.

Gerritse et al, 1995A, *Nitrogen Losses from a Domestic Septic Tank System on the Darling Plateau in Western Australia*, Wat. Res. Vol 29, No 9.

Gerritse et al, 1995B, *Retention of Nitrate and Phosphate in Soils of the Darling Plateau in Western Australia: Implications for Domestic Septic Tank Systems*, Aust. J. Soil Res. 33, 353-67.).

Gerritse R, 1993, *The influence of landuse and soil type on nutrient losses*, IN Swan River - The Future, Swan River Trust Report No 8.

Gerritse R G and J A Adeney, *Nutrient export from various land uses on the Darling Plateau in Western Australia CSIRO Report 92/41.*

Lantzke, 1997, *Phosphorous and nitrate loss from horticulture on the Swan Coastal Plain*, Agriculture WA

Podger F D and K R Vear, 1998, *Management of Phytophthora and disease caused by it*, IN *Phytophthora cinnamomi* and the disease caused by it - protocol for identifying protectable areas and their priority for management, EPA 2000.

Rogers L G, 1996, *Geraldton Region Land Resources Study*, Department of Agriculture, Land Resources Series Number 13.

*Select Committee on Metropolitan Development and Groundwater Supplies*, Legislative Assembly 1994.

# APPENDIX 6

## Bushfire Management Plan 2013 (Roger Underwood)

# Bushfire Management Plan

# Francisco Road Dongara

**Prepared by York Gum Services**

**November 2013**

# Bushfire Management Plan

## Francisco Road Dongara, Shire of Irwin WA

# 1. Introduction

## 1.1 General

This Bushfire Management Plan sets out the background, principles and commitments for minimising potential bushfire damage for a proposed residential development at Francisco Road Dongara, in the Shire of Irwin WA ("the property"). The plan is prepared on behalf of the proprietors (the "developer") of Lots 4, 5 and 10 at the corner of Brand Highway and Francesco Road (the "site") in the Shire of Irwin's (the "Shire") locality of Dongara by Roger Underwood of York Gum Services (the "consultant").

## 1.2 Purpose of this plan

The purpose of this Bushfire Management Plan is:

- To identify measures at the planning stage that will minimise the risk of bushfire damage to life, property and communal assets at the site;
- To address the requirements set out in the *Planning for Bushfire Protection Guidelines* (Western Australian Planning Commission and Fire and Emergency Services Authority, 2010) and the planning and bushfire requirements of the Shire of Irwin;
- To take into account the need to conserve environmental values including soil, flora and fauna and waterways;
- To identify the location of roads, fire breaks, fuels management, access and egress points;
- To describe proposed arrangements for water and power supply; and
- To identify standards, if necessary, to be adopted in the construction of homes.

In addition the developer recognises that some years could elapse before a subdivision plan is approved and development commences. For this reason, an interim fire management regime is proposed for the site.

The following underlying principles are adopted by the developer to underpin bushfire management at the site:

- Current and future bushfire threats will be identified and, as far as possible, mitigated;
- Planning will be undertaken in the light of an understanding of bushfire threats to human, economic and environmental/conservation values;
- Development will be in compliance with a formal bushfire management plan (this document) that must satisfy, as far as is practical, the bushfire management requirements of the Shire and the Department of Fire and Emergency Services (DFES).
- The developer will set out measures to be adopted to minimise the risk of bushfire damage at the site before development begins.

The developer also recognises a responsibility to the neighbours of the site, and further recognises that it will be important to ensure as far as possible that residents at the property maintain a high standard of bushfire preparedness. The developer undertakes to do this through education at the point in time of the sale of a lot, including providing lot buyers with copies of this management plan, and encouraging lot buyers to support the Shire and the local volunteer bushfire brigades in maintaining high standards of bushfire preparedness.

## 1.3 Description of the proposed development

### 1.3.1 Location

The site is located immediately north of the town of Dongara, west of the Brand Highway and north of Francisco Road, and about 1.5 kilometres from the sea. Immediately to the west is cleared farmland and beyond that an area of coastal scrub. To the east is long-established farmland, to the south the town of Dongara and to the north an area of hobby farms with scattered bush and clearings.

The total area of the three lots on which the development will be located is 57.7 hectares

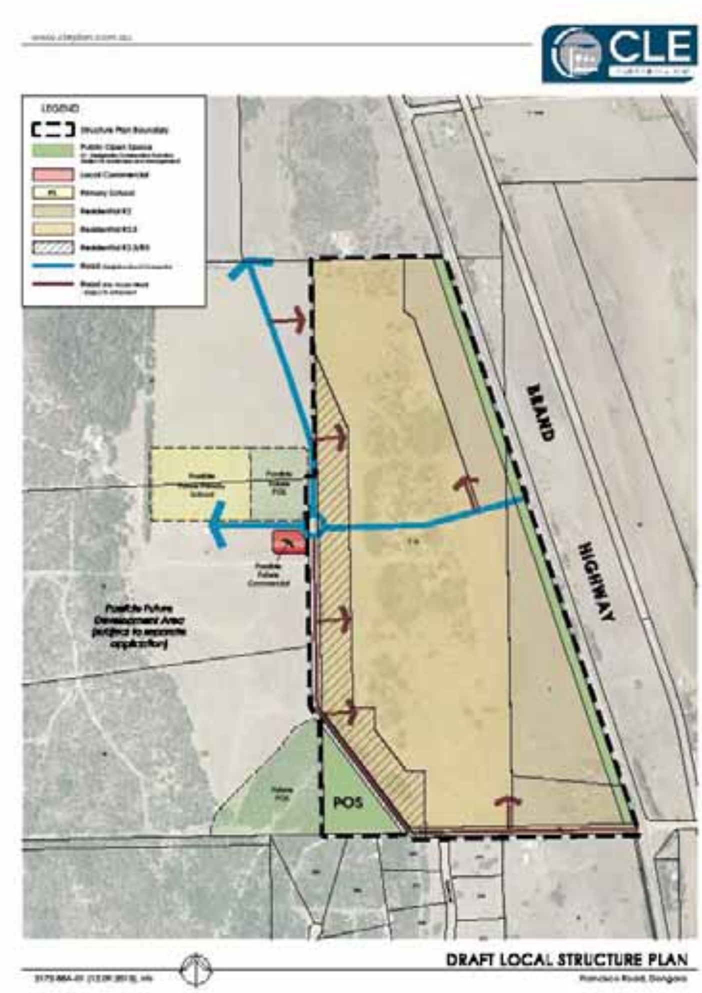


**Figure 1: Location and context**

### 1.3.2 District context

The site is readily accessed from (and new internal roads will be linked to) the Brand Highway and Francisco Road and from the north on planned future road link providing access over Lots 10 and 17 to Lot 1409.

Adjoining the property on its south-west corner is a small area of native bushland that will become public open space (POS), under the management of the Shire of Irwin.. Beyond that to the southwest is Nature Reserve 23600 which comprises coastal scrubland. This reserve is managed by the Department of Parks and Wildlife.The Dongara–Port Denison Volunteer Brigade station is located approximately 4 kilometres away. The property can be reached within 30 minutes by road by other fire brigades in the region.

Beyond the Dongara townsite the principal land-use is broad-acre farming. The farmers are generally well-organised and well-equipped and rapidly attend any bushfire that is threatening community or farm assets.

### 1.3.3 Zoning

The property is zoned 'Development" under the Shire's  Town Planning Scheme No. 5.


**Figure 2: Concept plan showing proposed lots and roads**

#### 1.3.4 Proposed lots

No formal subdivision plan has been prepared as yet, but the developer has foreshadowed that the property will be subdivided into 83 residential lots ranging in size from 4000 sq metres to 1.2 hectares, and has prepared a conceptual subdivision layout which accompanied the proposal to rezone the land from it former rural zone to the current Development Zone..

In this layout, all lots will be serviced by fully constructed and sealed roads.

#### 1.3.6 Relationship of this Bushfire Management Plan to approval requirements

It is a requirement of the Development zone that a Structure Plan be adopted by both the Shire and the WA Planning Commission ("WAPC"). The Shire requires that a proposed structure plan be accompanied by a bushfire management plan that demonstrates how bushfire protection is to be planned and implemented at the site.

This Bushfire Management Plan is prepared to meet this requirement.

The developer undertakes to update this Bushfire Management Plan if, after a Structure Plan has been approved, there are any significant changes to the draft subdivision plan that has been foreshadowed in this Bushfire Management Plan.

#### 1.3.7 Existing Bushfire Management Plans impacting on the property

There is no existing Fire Management Plan covering the site.

# 2. Site Details

## 2.1 Climate

The climate of the region is Mediterranean, with cool wet winters and hot dry summers. Summer thunderstorms with lightning occur nearly every year. This climate is conducive to bushfire occurrence and fire spread, with hot days and low relative humidity for weeks at a time every summer.

The area experiences strong winds most summer days, especially the easterlies in the morning and a south-westerly sea breeze on most summer afternoons.

Under this climate bushland in the area will burn intensely in the height of summer when the vegetation is fully cured.

## 2.2 Topography

The site is gently undulating, rising to a high point in the northwestern corner. There is a north-south ridge running through the centre. There are no grades steeper than 1:10, and no dissected gullies or watercourses.

## 2.3 Rock outcrops and soil types

The bulk of the site comprises brown sand, but the north-south ridge comprises limestone caprock.

The small triangle of proposed POS on the south-west corner comprises a consolidated sand dune.

## 2.4 Vegetation

The site is about 75% cleared of it origainl native veagtation. The remainder, comprising the non-arable land along the capstone ridge, carries dense clumps of wattle scrub, mostly *Acacia rostellifera*. Lines of tuart (*Eucalyptus gomphocephela*) trees have been planted in three areas.

## 2.5 Existing water resources

Existing dwellings on the site are served by rainwater and/or bores.

The site sits over substantial reserves of underground water, located at a depth of about 10 metres.

## 2.6 Existing land use and improvements

The site has been used as farmland for many decades (principally grazing with sheep). The site has a boundary fence with locked gates.

There are three existing dwellings, located on the site. These existing dwellings may be incorporated into the future proposed development of the site.

# 3. Bushfire risk and threat

## 3.1 Bushfire history at the site

No data is available on the precise bushfire history at the site, although it is likely that fires have occurred in the area many times in the past.

## 3.2 Bushfire fuels

Current fuels over the bulk of the area of the site are light and while grazing continues will not carry a sever bushfire. The fuels are grass, Acacia scrub and exotic weeds, all of which have been heavily grazed.

There is a small patch of ungrazed bush on a steep dune in the south-west corner which is proposed to become POS. This portion of the site comprises heavy bushfire fuels.

## 3.3 Factors affecting the risk of a bushfire occurring

Fires are likely to be started by lightning, accident or arson. The likelihood of accidental or deliberate lighting of fires will increase as the population increases, but this can be counteracted by increased education and awareness.

Currently there are overhead powerlines on the site, and these represent a risk of a fire starting, but these will be replaced by underground power at the time of development. The site is adjacent to Brand Highway, which could be a potential source of fire in the form of an accident or careless disposal of a cigarette butt or match.

## 3.4 Assessment of bushfire hazard

Using the methodology set out in *Planning for Bushfire Protection Guidelines*, bushfire hazard on the site is assessed as follows:

- Low Hazard: all areas of open cleared paddock, and grazed grassland
- High Hazard: clumps of dense coastal scrub on the central ridge including weed infestations

## 3.5 Values threatened by bushfire

The following values will be potentially threatened by a bushfire following development of the site:

- Human lives: approximately 250 people are expected to reside at the site or be present at the site on any day, following completion of development;
- Buildings and other personal assets, including sheds, gardens, vehicles, animals;

## 3.6 Assessment of Bushfire Attack Level (BAL)

Bushfire Attack Level (BAL) has been assessed according to the methodology set out in the *Planning for Bushfire Protection Guidelines* as follows:

There will be no bushland retained on the site other than in the POS in the south-west corner..

For that proposed lots that will have no adjoining bushland the BAL is assessed as being Low, and no special housing construction standards are considered necessary.

For lots adjoining the bushland in the POS in the southwest corner:

- The bushland is classed as Low Open Forest (Class 4)
- The bushland will be uphill of any dwellings
- The distance from bushland to dwelling will be at least 19 metres
- This indicates a BAL of 19
- Lots with a BAL of 19 must have dwellings that comply with the construction standards set out in sections 3 and 6 of ASA 3959-2009

### 3.8 Summary of potential bushfire issues

That portion of the site proposed for development is either cleared pasture or low scrub that will be cleared during development. Following development and the construction of roads, houses and gardens the area is, therefore, unlikely to carry a running bushfire.

Dwellings in the south-west corner will need to have special protection from fires that might start in the adjacent Conservation Reserve and burn into the small triangle of POS.

The principal bushfire threat to the site will be from fires starting in the coastal bushland to the west and driven by a strong south-westerly wind, or fires coming in from the north under the influence of a northerly wind. Such fires will be fast moving and will generate flying embers that could reach the dwellings on the site.

A range of precautions must therefore be adopted to minimize the threat of damage from a bushfire or from an ember storm entering the property

## 4. Bushfire Action Plan

### 4.1 Interim bushfire management

The developer acknowledges that some years might elapse between the issue of an approval to subdivide the site and the time when the site becomes fully developed with dwellings. In the interim, the developer undertakes to implement the following measures on the site:

- Continue to maintain a secure fence around the property to discourage illegal access;
- Continue to maintain the perimeter firebreak and existing access routes and to meet all requirements of the Shire of Irwin;
- Continue to maintain low bushfire fuels on the site by grazing or other measures; and
- Continue to support the local volunteer bushfire brigades.

### 4.2 Protection of human lives and property

The following measures are proposed to protect, as far as is possible, the lives of residents and their assets from bushfire damage if this development proceeds:

1. The developer will register, with the co-operation of the Shire, a Section 70A Trasnfer of Land Act 1893 (as amended) Notification on each lot stating as follows:

   *The Shire of Irwin advises that:*
   *a. a Fire Management Plan applies to this lot; and,*
   *b. dwelling construction on the lot is required to comply with sections three and six of Australian Standards ASA 3959-2009 ("Construction of Houses in Bushfire-prone Areas");*

2. Each lot owner will be required to install and maintain a Building Protection Zone (free of flammable material) around any dwelling they constrct on a lot.

3. Building Protection Zones (BPZ) are to be contained fully within the lot as indicated on an approved subdivision plan Each BPZ is to have the following characteristics:

   - width: 20 metres measured from the outermost external walls of the building;

- location: within the boundaries of the lot on which the building is situated, unless this zone overlaps with a BPZ on an adjoining property or within a road reserve;
- fuel load: reduced to and maintained at 2 tonnes per hectare;
- any trees planted within the BPZ to be a minimum of 10 metres apart and trees low pruned at least to a height of 2 metres;
- no native scrub to be located within 2 metres of a building (including windows) and no tree crowns are to overhang the building;
- fences and sheds within the BPZ are to be constructed using non-combustible materials (e.g. colourbond iron, brick, limestone);
- shrubs in the BPZ are to have no dead material within the plant and tall shrubs in the BPZ are not to be planted in clumps close to the building i.e. within 3 metres; and

BPZs are to be installed before houses are constructed.

4. The developer will recommend to the Shire, that the Shire impose as a condition on building permits that all dwellings constructed on any lot created within the site be secured against bushfire embers entering through rooftop facilities. This means that:

   (a) Rotary roof ventilators should be fitted with metal gauze spark screens with a minimum aperture size of 1.8 mm; and,

   (b) Roof-mounted evaporative air conditioners have the openings to the cooling unit fitted with metal gauze spark guards.

5. The developer will provide a copy of the Bushfire Management Plan and appropriate bushfire preparedness literature to each initial lot purchaser.

## 4.3 Bushfire risk mitigation

The developer will ensure (by providing initial lot owners with a copy of this Bushfire Management Plan at te time of sale of a lot) that initial lot owners are aware of the risk of fires starting in bushland to the west and north of this property under severe weather conditions, and will encourage initial lot owners to support the Shire;'s fire risk management protocols and the local bushfire brigades.

## 4.4 Access/egress and fire breaks

The draft subdivision plan for the site provides for high quality access/egress via sealed roads to every lot, permitting two-way movement of vehicles in an emergency and rapid ingress for fire appliances. Alternative egress will be possible from every lot east to the Brand Highway or south to Francisco Road.

At a future date, access/egress will also be available in the north-western section of the property. This will result from an integration of the road system for Lot 10 upon a future development of adjacent Lot 17 (as depicted on Map 2).

The current draft subdivision layout depicts one short battle-axe access to three lots adjoining the proposed new entry point to Brand Highway. This provides for safer access to these lots.

Lot owners will be required to meet the Shire's annual Fire Break Order (FBO) issued pursuant to Section 33(1) of the Bush Fires Act 1954 (the "Act").

Driveways to dwellings will be required to meet the same standards in terms of width and vertical clearance as firebreaks.

All lots will be fenced.

Any signage erected by the developer will meet standards set out by the Shire.

## 4.5 Water supplies

Every lot will be serviced by pressurised reticulated water supply, with the Water Corporation being the asset owner.

In addition, the developer will install a fire hydrant to the specifications of DFES every 200 metres along the internal road system.

Lot buyers will be advised (via this Bushfire Management Plan) that they should also consider the installation of rainwater tanks to provide a back-up water supply in the event of an emergency.

## 4.6 Power supply

The developer will arrange for all lots to be supplied with electric power. All power cables within the site will be installed underground. Existing overhead powerlines will be removed within the site.

## 4.7 Fire safer area

The developer will consult with the Shire in relation to the designation of a bushfire refuge, or "fire safer area", in the event that residents must be evacuated due to a large regional bushfire. All initial buyers of each lot will be notified of the location of the fire safer area, which will be signposted.

The author of this Bushfire Management Plan suggests that an appropriate area to be so designated is the football oval in Dongara, which is located approximately 10 minutes drive from the site.

## 4.8 Fire protection during stages of development

The developer will retain responsibility for bushfire protection measures on unsold lot/s as an ongoing owner, until ownership of such lot/s is transferred.

## 4.9 Public education and community awareness

The developer will provide to all initial lot buyers with a copy of this Bushfire Management Plan, plus a copy of the booklet *A Homeowner's Guide to Bushfire Safety* and bushfire literature from the Shire of Irwin. All initial lot buyers will be advised to familiarise themselves with an FBO (non-compliance with same being the subject of penalties under the Act).

The developer will advise (via this Busfire Management Plan) all initial lot purchasers that they should attend a Bushfire Induction Course to be conducted by the Shire and will recommend that they join or offer support to the local Bushfire Brigades.

### 4.10 Ongoing assessment of fire management risk

It is recomemded that the Shire should, following subdivision of the land, inspect the site at intervals which the Shire considers reasonable and appropriate and, having regard to this Bushfire Management plan and the provisions of the Act, issue any FBO's it considers to be appropriate.

## 5. Summary

### 7.1 Overall fire threat

The site is naturally susceptible to bushfires. This is because of the climate, the flammability of nearby bushland, and potential sources of fire such as lightning.

Following development, the site will contain values and assets that may be threatened by a bush fire, including life, property and community and the environment.

However, over most of the area of the site, the potential threat can be mitigated by sensible planning, and the institution of a number of critical measures, for example by utilising Building Protection Zones, constructing dwellings to ASA 3959-2009, installation of an adequate underground power and reticulated water supply (incorporating fire hydrants), providing good thoroughfare (both in to and out of the site), creating a reasonably well-educated community (being the measures prescribed in this Bushfire Management Plan).

### 7.2 Fire Management Plan

The developer has arranged for the preparation of a Bushfire Management Plan (this document) as a basis for mitigating the fire threat on the site.

This Bushfire Management Plan provides for measures that either must, or should be adopted by the lot purchasers and builders and makes commitments on behalf of the developer (limited to where the developer is lawfully able to make those commitments).

The developer undertakes to update this Bushfire Management Plan if changes are made to the development design during the preparation/approval of a subdivision plan following adoption of the Structure Plan.

### 7.3 Owners responsibilities

It will be the responsibility of lot owners to:

- Read and familiarise themselves with key documents, including this Bushfire Management Plan;

- Comply with an FBO or any other bushfire management requirement issued by the Shire or DFES under the Act;
- Install and maintain BPZ's (for all dwellings);
- Ensure houses are constructed to the appropriate ASA 3959-2009 standard where applicable as set out in this plan;
- Be familiar with evacuation routes and bushfire safer areas so as to be prepared in the event of a major regional bushfire;
- Support fire management operations by the Shire and volunteer bushfire brigades.

### 7.4 Developer's responsibilities

The developer undertakes to meet all of the commitments made by the developer in this Bushfire Management Plan

### 7.5 Shire of Irwin responsibilities

The Shire will, when satisfied, approve an appropriate bushfire management plan for the site (this document), and ensure lot owners meet their responsibilities under the Act and its regulations in future years.

The Shire should also liaise with the Department of Parks and Wildlife to seek appropriate fire preparedness operations be undertaken on the conservation reserve nearby.

## 8. Disclaimer

The Consultant preparing this Bushfire Management Plan takes no responsibility for the impacts of a future bushfire on any values at the Francisco Road Dongara development described in this management plan. He has done his best in this strategy to alert residents to the threat of bushfires, and to suggest measures to minimise these threats and potential bushfire damage, but there may occur an unusual combination of events or human actions or lack of actions which could not reasonably have been expected at the time of preparing the Plan. The Consultant takes no responsibility for the standard of bushfire preparedness or damage mitigation undertaken by lot owners in the future.

## Appendix:

# Compliance checklist for performance criteria and acceptable solutions

### Based on Appendix 4 from *Planning for Bushfire Protection*

## Element 1: Location

Does the proposal comply with the performance criteria by applying acceptable solution A1.1?

Yes The site comprises land whidk is mostly classified as Low bushfire hazard, and, in addition, a Bushfire Management Plan has been adopted that specifies the installation of 20m wide Building Protection Zones and, where required by BAL analysis, the construction of homes to accord with ASA 3959 depending on the assessed BAL. These measures are prescribed in the Bushfire Management Plan and will become enforced upon lot buyers by the Shire.

## Element 2: Vehicular access

Does the proposal comply with the performance criteria by applying acceptable solution A2.1?

Yes Every lot will be serviced by a fully engineered and sealed road. There will be 2 alternative access/egress points to the property, all of which will be options that lot-owners can take in an emergency, or which can be used for entry by firefighters. A further access/egress point is foreshadowed if development of the adjoining Lot 17 proceeds.

Does the proposal comply with the performance criteria by applying acceptable solution A2.2?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A2.3?

Yes There are no cul-de-sacs in the proposal.

Does the proposal comply with the performance criteria by applying acceptable solution A2.4?

Yes There is one very short battleaxe entry, but this will not compromise bushfire operations.

Does the proposal comply with the performance criteria by applying acceptable solution A2.5?

Yes Constructed private driveways will be required to meet the same specifications as perimeter and internal firebreaks.

Does the proposal comply with the performance criteria by applying acceptable solution A2.6?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A2.7?

Not Applicable

Does the proposal comply with the performance criteria by applying acceptable solution A2.8?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A2.9?

Yes All lots must meet the firebreak requirements of the Shire of Irwin

Does the proposal comply with the performance criteria by applying acceptable solution A2.10?

Yes The Bushfire Management Plan specifies that compliance level and signs erected by the developer must meet the specifications laid down by the Shire of Irwin

## Element 3: Water

Does the proposal comply with the performance criteria by applying acceptable solution A3.1?

Yes Reticulated water supply will be provided

If no, please explain in writing how the proposal satisfactorily complies with performance criterion P3 for this area of non-compliance, and attach this explanation to the rear of this checklist.

Does the proposal comply with the performance criteria by applying acceptable solution A3.2?

Not applicable

Does the proposal comply with the performance criteria by applying acceptable solution A3.3?

Not applicable

If no, please explain in writing how the proposal satisfactorily complies with performance criterion P3 for this area of non-compliance, and attach this explanation to the rear of this checklist.

## Element 4: Siting of development

Does the proposal comply with the performance criteria by applying acceptable solution A4.1?

Yes Every dwelling constructed must have a Building Protection Zone. Dwellings on lots with a BAL of 19 are identified and must, as a minimum, meet the prescribed requirements in ASA 3959-2009. In addition the developer has recommended high standards of rooftop protection from ember attack for all dwellings.

Does the proposal comply with the performance criteria by applying acceptable solution A4.2?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A4.3?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A4.4?

Yes

Does the proposal comply with the performance criteria by applying acceptable solution A4.5?

Not applicable. No shielding is proposed.

## Element 5: Design of development

Does the proposal comply with the performance criteria by applying acceptable solution A5.1?

Yes The design of the development in terms of building protection, hazard/fuel reduction, standard of construction, fire breaks, water supply, access/egress and education of lot buyers will ensure that the bushfire threat on the property is minimised, provided all of the provisions in this plan are instituted and maintained.

Does the proposal comply with the performance criteria by applying acceptable solution A5.2?

Not applicable

## Applicant Declaration

I declare that the information provided is true and correct to the best of my knowledge.

Full name: Roger Underwood

Applicant signature:

Date: November 25th 2013

# APPENDIX 7

## Traffic Report 2014 (Jonathan Riley)

# FRANCISCO ROAD, DONGARA

# STRUCTURE PLAN TRAFFIC REPORT

January 2014


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Perth WA 6831

0413 607 779 Mobile


| | | | |
|---|---|---|---|
| Issued on | 13 January 2014 | Amendments | Date |
| Version | V2 | V1 published<br>V2 minor text edits | 18-11-13<br>13-01-14 |
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## 1.0 EXECUTIVE SUMMARY

Riley Consulting has been commissioned through CLE planning consultants to consider the traffic and transport impacts of developing 85 residential lots at land west of the Brand Highway, Dongara. The key findings of the traffic investigations are:

- The site can be expected to generate up to 850 vehicle movements per day once fully developed. A local road network in accordance with *Liveable Neighbourhoods* is proposed.

- Longer term planning may see additional land being developed to the west of the subject land. This traffic report is cognisant of the implications of this potential future development.

- Traffic generated by the subject site is not expected to result in a significant impact to existing adjacent streets.

- Access to the site will be taken from Brand Highway at a location already approved by Main Roads Western Australia. The full development of the subject land will require the provision of a fully channelised access intersection to Brand Highway.

- Analysis of the proposed access indicates that the warrants for the provision of turn lane pocket will not be met until 24 dwellings are occupied (based on the expected Brand Highway volume in 2025). It is considered therefore that an opportunity exists to develop 20 lots as a first stage with no turning pockets provided on the Brand Highway.

## 2.0 THE SITE AND SURROUNDING ROAD NETWORK

The subject land is located approximately 1.5km north of Dongara town adjacent to the Brand Highway. The location of the subject site is shown in Figure 1.

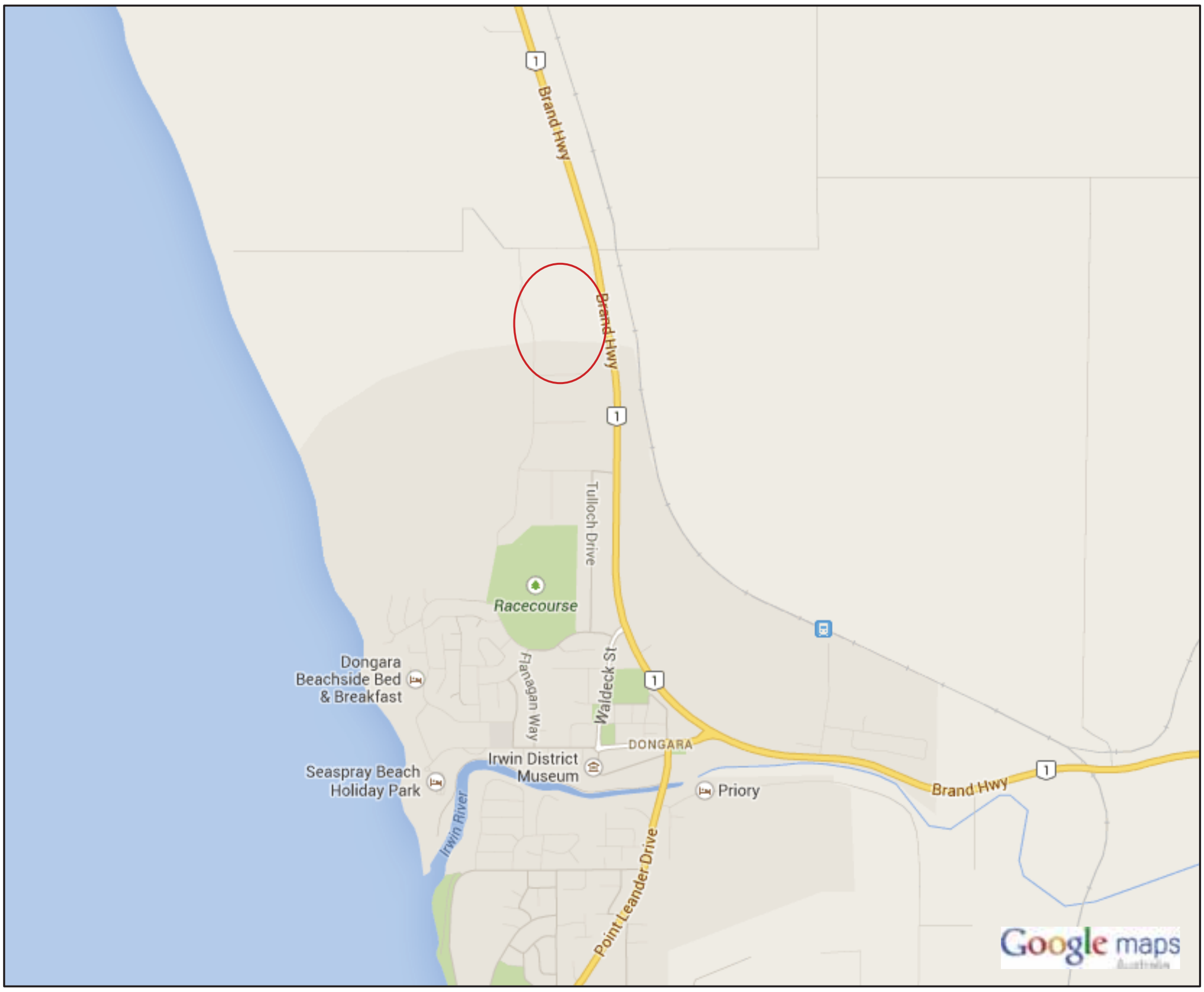



**Figure 1 Site Location**

Roads expected to be affected by the development of the site are considered below.

### 2.1 Brand Highway

The Brand Highway is a primary distributor road falling under the control of Main Roads Western Australia (MRWA). It provides significant regional access between Geraldton and Perth. The Highway is constructed as a two-lane single carriageway road for the majority of its length. Through the urban area of Dongara the speed limit is reduced, but to the north of Francisco Road returns to the national 110kph limit.

Traffic data provided by MRWA indicates a current average weekday volume of 3,140 vehicles per day (vpd) to the south of Matsen Road (about 10km north of the subject site). Traffic data recorded in 2013 to the west of Midlands Road (just south of Dongara) shows an average weekday flow of 2,722vpd with an evening peak period equating to 5.6% of the daily volume.

Historical data from 2007 recorded to the north of Waldeck Street, provides the following peak hour proportions and directional split.

- 8am – 9am 7.3% of daily flow - 38% north / 62% south
- 1pm – 2pm 7.4% of daily flow - 52% north / 48% south
- 4pm – 5pm 7.4% of daily flow - 53% north / 47% south
- 5pm – 6pm 6.9% of daily flow - 70% north / 30% south

It is not expected that a major change to the peak hour proportion or directional split would have occurred. Whilst more recent traffic data is available to the south side of Dongara, the peak hour proportions are lower than indicated by historical data.

### 2.2 Francisco Road

Francisco Road is a local access road currently unmade to the west of the Brand Highway. A four-way intersection is created at Brand Highway with the eastern leg sealed. Traffic data is not available for Francisco Road, but the current unmade status and access to 11 properties would suggest s daily flow of less than 100vpd.

Once sealed a speed limit of 60kph or 50kph may apply to Francisco Road.

### 2.3 Brennand Road

Brennand Road is a local access street and is constructed with a 7 metre wide pavement (approximately). The rural location of the road would suggest a posted speed of 60kph.

No traffic data is available for Brennand Road, but based on the current level of residential construction, it is estimated to carry less than 300 vehicles per day north of Philby Road.

### 2.4 Philby Road

Philby Road is a local access street providing an east-west link between Brennand Road and the Brand Highway. It has a standard 7 metre wide road pavement (approximately). It is rural in nature with no kerbs and has no footpaths.

No traffic data is available for Philby Road, but based on the current level of residential construction, it is estimated to carry about 470vpd east of Brennand Road and about 700vpd west of Brand Highway.

### 2.5 Tulloch Drive

Tulloch Drive is a local access street providing a north-south connection from Philby Road to the town. It is constructed with a standard 7 metre wide pavement (approximately). It is rural in nature with no kerbs and has no footpaths.

No traffic data is available for Tulloch Drive, but based on the current level of residential dwellings in its catchment, it is estimated to carry about 500 vehicles per day.

Figure 2 shows the draft local structure plan.

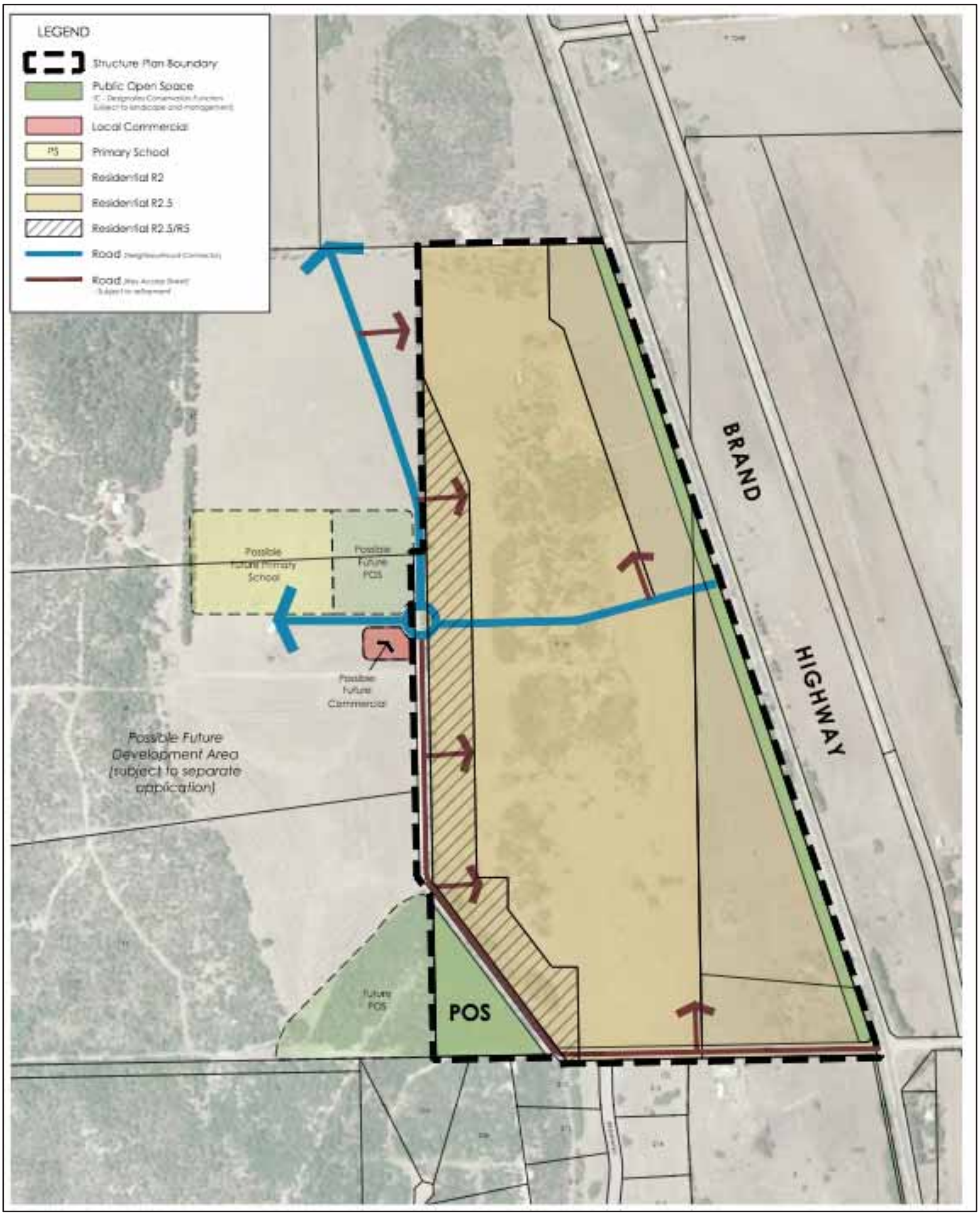



**Figure 2** **Draft Local Structure Plan** (refer CLE for detail)

## 3.0 TRAFFIC GENERATION AND DISTRIBUTION

The development of residential land at Dongara will provide for the growing population forecast for the region.

Reference to trip generation source documents suggests that the trip generation of a typical household can vary from 5 trips to 11 trips per dwelling per day. Traffic analysis of developments to the south of Geraldton identified a residential trip rate of 9 trips per dwelling per day based on local traffic counts. The trip rate is based on typical R20 density which is attractive to families. It can be expected that the subject land would generate a similar level of traffic.

For the purpose of assessing the potential traffic generation of the subject land, a trip rate of 10 trips per dwelling per day is used. The trip rate should result in an over-estimation of the future traffic movements, ensuring the road network is considered in a robust manner.

The subject land is expected to yield 85 residential lots and on the basis of 10 trips per lot, can be expected to generate (85 x 10) 850 vehicle movements per day.

### 3.1 Distribution

Traffic associated with the subject site is distributed to the road network based on trip purpose. Primary school trips are assigned to the local school based on the Education Department's expectations of 0.35 students per dwelling.

Table 1 shows the distribution assumptions by trip purpose used to assign traffic onto the external road network.

**Table 1 Dongara Distribution**

| Purpose[1] | North | South |
|---|---|---|
| Work Trips @ 29% | 70% | 30% |
| Home based Other @ 36% | 30% | 70% |
| Home Based Evening @ 21% | 20% | 80% |
| Non Home Based 14% | 70% | 30% |

[1] Trip purpose is based on the Perth Metropolitan Travel Survey 1986, factored to exclude education trips.

Figure 3 shows the forecast daily volumes associated with the subject land.

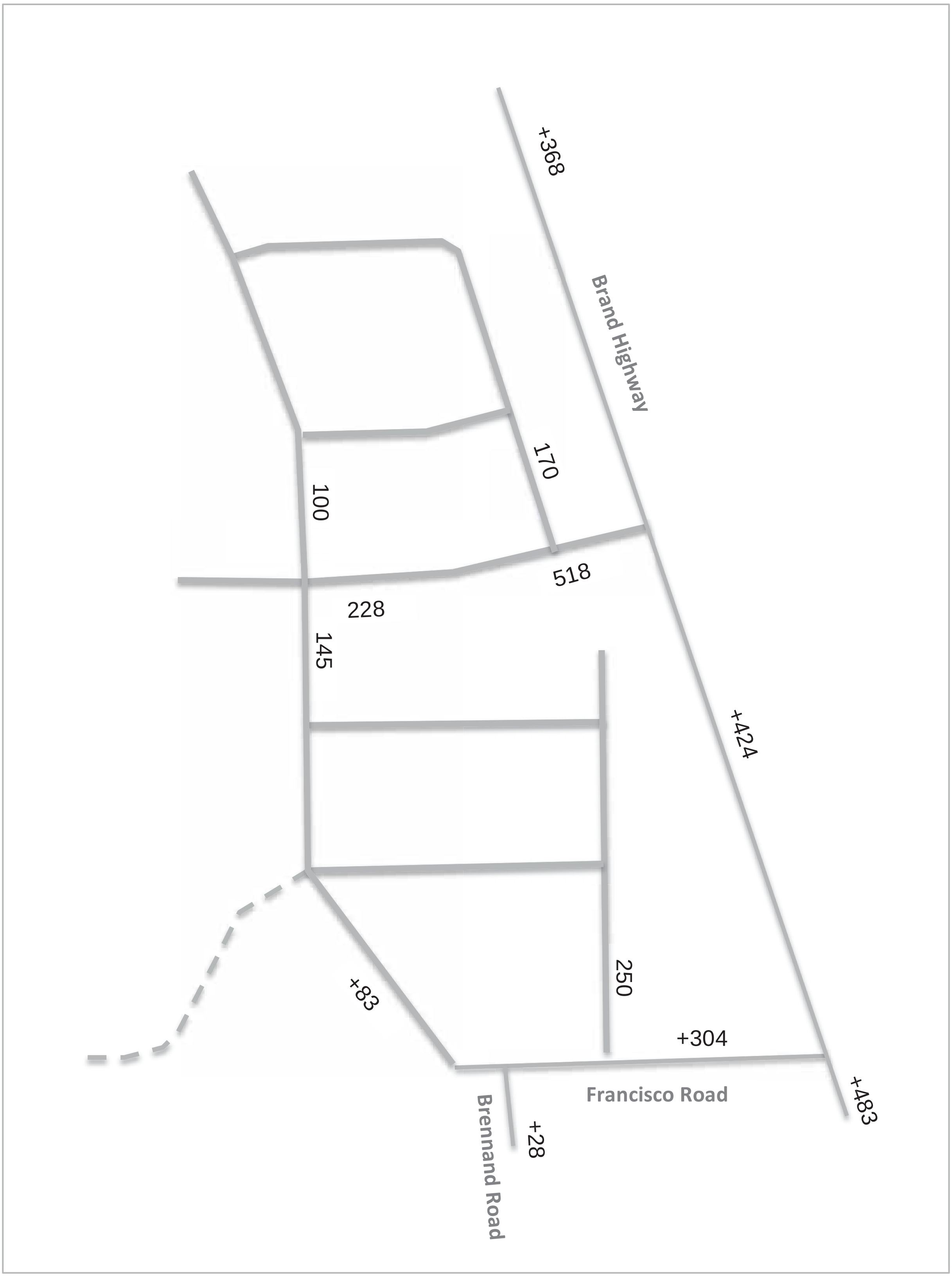



**Figure 3 Forecast Traffic Volumes**

### 3.2 Future Development

Land to the west of the subject site has also been identified for future residential development. An indicative lot yield of 1,500 dwellings has been suggested. Whilst this adjacent land area is not part of the current structure plan, traffic generated by future development will impact the structure plan road network and therefore needs to be considered.

Appendix A shows the draft structure plan for the locality and access to the west land parcels is provided almost solely through the subject site.

Figure 2 indicates a central neighbourhood connector linking land to the west to Brand Highway. It can also be expected that some traffic will filter through the southern access street to reach Brennand Road. Based on the potential of 1,500 lots, the adjacent land could generate (1,500 x 10) 15,000vpd. It could be expected that 80% of the generated traffic (12,000vpd) will leave the locality. Of this externalised traffic, potentially 20%, or 2,400vpd may use local roads to access Dongara.

- Ultimately the central neighbourhood connector could be expected to carry (9,600vpd + 518vpd) 10,118vpd.

- The link to Brennand Road may attract (2,400vpd + 145vpd) 2,252vpd

- Francisco Road may ultimately attract (2,400vpd + 304vpd) 2,704vpd.

The above forecast traffic demands are used to consider the road reservation requirements within the subject land.

## 4.0 DEVELOPMENT TRAFFIC IMPACTS

Based on the forecast traffic increases anticipated from the subject land, Table 2 shows the potential impacts to the road network in terms of Levels of Service (LoS). The Levels of Service by road type are shown as Appendix B.

**Table 2 Daily Traffic Volumes and Development Increase Impacts to LoS**

| Road | Daily Flow | LoS | Development | % | LoS |
|---|---|---|---|---|---|
| Brand Highway north | 3,140 | B | +368 | +12% | B |
| Brand Highway south | 3,140 | D | +483 | +15% | D |
| Francisco Road | <100 | A | +304 | +300% | A |
| Brennand Road | <300 | D | +28 | +9% | D |
| Philby Road | @470 | A | +28 | +6% | A |
| Tulloch Drive | @500 | A | +28 | +6% | A |

The LoS is based on Appendix A

In traffic engineering it is considered that traffic flow changes to the surrounding road network of +/-5% fall within the daily variation of traffic volumes and are considered to have no significant impact. It can be seen from Table 2 that the proposed development can be expected to increase current traffic flows by 6% up to 300% and such increases can be considered as significant.

When traffic flow increases are significant, it is appropriate to consider the operation of the affected roads. Table 2 provides an overview of the Level of Service that can be expected with various daily traffic flows by road type and is based on advice contained in Austroads *Guide to Traffic Engineering Practice*.

Table 2 indicates that the proposed development can be expected to have no impact to current Levels of Service. Whilst the traffic increases may be considered proportionately high, their impact will not result in a detriment to the operation of the surrounding road network. It is concluded therefore that the proposed development will have no detrimental impact.

***The proposed development will create no detrimental impact.***

## 5.0 ACCESS

Access to the subject site will be taken via a new road link to Brand Highway. It is understood that previous discussions with MRWA have identified the location of access shown in Figure 2 as being suitable. It is also understood that the location has been assessed in terms of achieving appropriate visibility to Austroads standards (MRWA).

Analysis of the future operation of the access intersection is undertaken for the proposed subject site. Long term operation may change as a result of future development to the west (if land is rezoned).

**Intersection Control**

The present day traffic demand on Brand Highway is in the order of 3,000vpd and with growth at a rate of 3%pa, by 2025 the Highway could be carrying about 4,000vpd. The subject site is shown to generate 850 trips per day, which can be expected to access Brand Highway in the medium term (access to Francisco Road will occur in later stages). Based on the forecast traffic demands, advice contained in Appendix C indicates that priority control would be appropriate.

Appendix D shows the expected traffic volumes in the year 2025 (10 year planning horizon) with full development of the subject site.

**Turn Lane Requirements**

Austroads provides advice in regard to intersection layouts and the provision of turning lanes. Ultimately Brand Highway may be subjected to a reduced speed, but in regard to the subject site, assessment of access to a 110kph road environment is required. Appendix E shows the turn lane warrants.

Based on the forecast demands in 2025, the following warrants are investigated:

Right turn lane $Q_R$ = 25 vehicles $Q_{T1} + Q_{T2} + Q_L$ = 340 vehicles

***Austroads indicates the warrants for a right turn lane will be met.***

Left turn lane $Q_L$ = 31 vehicles $Q_{TL}$ = 216 vehicles

***Austroads indicates the warrants for a left turn lane will be met.***

The deceleration lengths based on a posted speed of 110kph will be:

| | |
|---|---|
| Right turn lane | 185 metres (including diverge taper) |
| Left turn lane | 175 metres (including diverge taper) |

Analysis of the access intersection has been undertaken using SIDRA for the year 2025. Table 3 shows the summary of the analysis attached as Appendix E.

**Table 3 Brand Highway / Site Access 2025**

| Approach | V/C | Delay | LoS |
|---|---|---|---|
| **AM Peak** | | | |
| Brand Highway south | 0.07 | 0.8s | A |
| Site Access | 0.089 | 10.7s | A |
| Brand Highway north | 0.115 | 0.5s | A |
| **PM Peak** | | | |
| Brand Highway south | 0.123 | 1s | A |
| Site Access | 0.039 | 10.8s | A |
| Brand Highway north | 0.053 | 2s | A |

Where V/C = volume of capacity
Delay is average delay per vehicle
LoS = Level of Service

Table 3 indicates that the proposed access to Brand Highway will operate with excellent Levels of Service. Figure 4 shows the form of access intersection required.

**Figure 4 Form of Access** (subject to MRWA)

Due to the high-speed environment of Brand Highway it is recommended that the intersection be created as a painted treatment. Raised medians may introduce an un-necessary road safety hazard.

## 6.0 THE INTERNAL ROAD NETWORK

The proposed development of 85 residential lots is expected to generate about 850 vehicle movements per day and therefore all roads would be exected to operate as Access Streets. However, at some future time it has been indicated that development may occur to land to the west which has the potential to generate an additional 12,000vpd through the subject land.

The forecast traffic flows provide a basis to develop an internal road hierarchy. Table 4 reproduces the advice on road types recommended by *Liveable Neighbourhoods.*

**Table 4 *Liveable Neighbourhoods* Road Hierarchy**

| **Indicative Daily Traffic Flow*** | **Designation** | **Street Characteristics** |
|---|---|---|
| < 1,000 vpd | Access Street | Narrower access streets (5.5 to 6m) may be appropriate in locations further away from centres and activity where traffic flows are less than 1,000 vpd and a low on-street parking demand exists. |
| 1,000 vpd to 3,000 vpd | Higher Order Access Street | Wider access streets (7 to 7.5m) cater for higher traffic volumes and are located closer to neighbourhood centres. |
| 3,000 vpd to 7,000 vpd | Neighbourhood Connectors | Generally 2-lane undivided. These are 'special' streets and their design needs to have regard to context, function and adjacent land uses. |
| 7,000 vpd to 20,000 vpd | District Distributor Type B | Typically will have 1 clear lane of travel in each direction and a parking / manoeuvring lane. |
| 15,000 vpd to 35,000 vpd | District Distributor Type A | Typically have service roads and development frontage with ample on-street parking to support a mixture of land uses. Direct vehicle access from adjoining property should be limited where no service roads are provided. |

* Function of streets needs to be considered as well as traffic volume.

The road hierarchy considers those streets that have a connective function and assigns an appropriate classification based on volume and continuity of movement.

Figure 5 shows the internal road hierarchy.

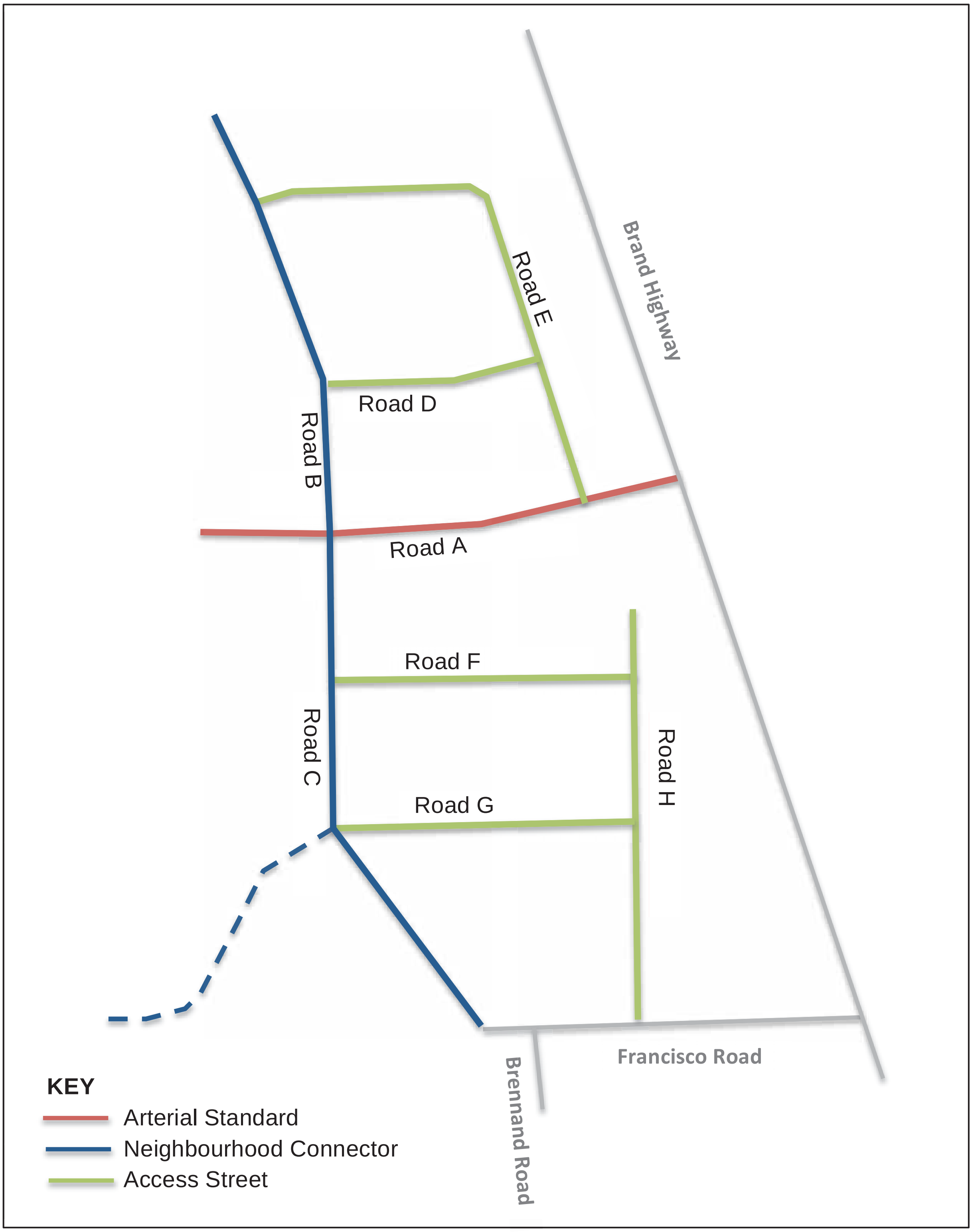



**Figure 5 Local Road Hierarchy**

### 6.1 Road A

Road A forms the main access to the subject land and has a forecast flow of less than 1,000vpd. It would be expected to be classified as an access street. However, it is acknowledged that land to the west, currently not zoned, may be developed to provide up to

1,500 new dwellings. The resulting traffic demands to Road A could potentially increase to about 10,120vpd. The traffic demand falls into the *Liveable Neighbourhoods* classification of Integrator Arterial and a minimum road reservation of 25.2 metres will be required.

Road A is shown to carry very low traffic flows and direct lot access is acceptable. However, in the long term if traffic flows exceed 5,000vpd, then direct lot access would not be acceptable. The road reservation at 25.2m will allow the provision of a 7.2m pavement and two one-way service roads of 4.1m (the Austroads minimum pavement width). The verge can provide a 2m median, a 4.1m one-way lane and a residual 3m verge. The road reservation will therefore be capable of accommodating the arterial status should land to the west be developed in the future. However, contemplation of the road reservation has determined that the first section from Brand Highway will be provided at 25 metres to the first intersection. All adjacent dwellings have an alternative form of access and direct access is not required. Beyond the first intersection a road reservation of 27 metres will be provided to allow the provision of one-way service lanes should future development occur.

***Road A will be provided with a 25m – 27m road reservation.***

### 6.2 Road B and Road C

Roads B and C provide a north-south connection between Francisco Road and possible future development located to the north. The forecast traffic flows on these roads are expected to be less than 500vpd and Access Street status would be expected. However, a classification of Neighbourhood Connector has been used to ensure robustness for future planning. A 20 metre road reservation is recommended for Road B and Road C.

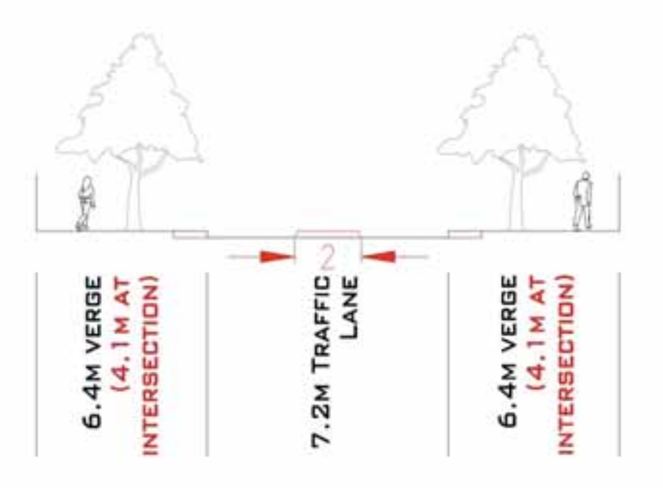



**Figure 6 20m Road Reserve**

Figure 6 shows a typical cross-section for a single carriageway road in a 20 metre road reservation. The reservation shown allows for the provision of 2 metre wide medians at intersections.

***Roads B and C are recommended to have a 20 metre road reservation.***

### 6.3 Roads D, E F, G and H

The remaining roads within the subject site will not provide for a through function and can be classified as Access Streets. It is recommended that the minimum carriageway width be provided to encourage a slower speed environment. Streets with 7.0+ metre carriageways and low-density lots frequently experience traffic speeds well in excess of the posted 50kph limit. A reduced carriageway width will assist in achieving a more appropriate 40kph typical travel speed.

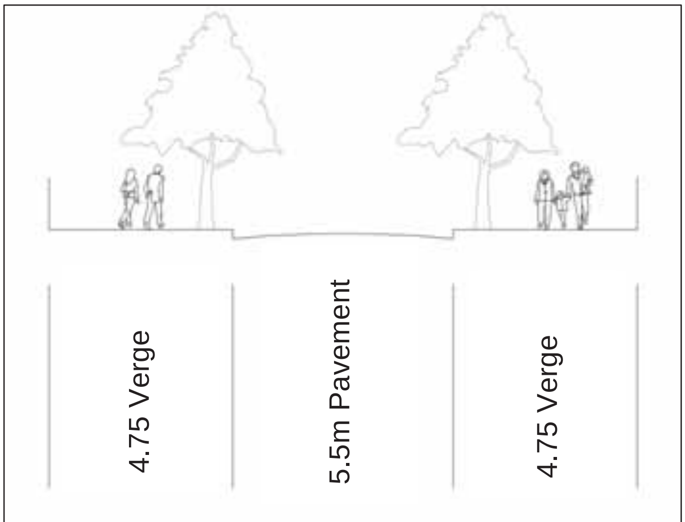



**Figure 7 15m Road Reserve**

All internal Access Streets have forecast traffic flows of less than 300vpd and will fall under the Access Street D classification in *Liveable Neighbourhoods*. A 5.5m – 6.0m road pavement width is considered appropriate for the forecast flows. Further, as larger lots are proposed, there is minimal need to cater for on-street parking. Figure 7 shows a typical cross-section suited to Roads D, E, F, G and H. A 6m pavement can be used and will provide a residual 4.5m verge.

***Access Streets are suited to a 5.5 metre pavement in a 15 metre road reservation.***

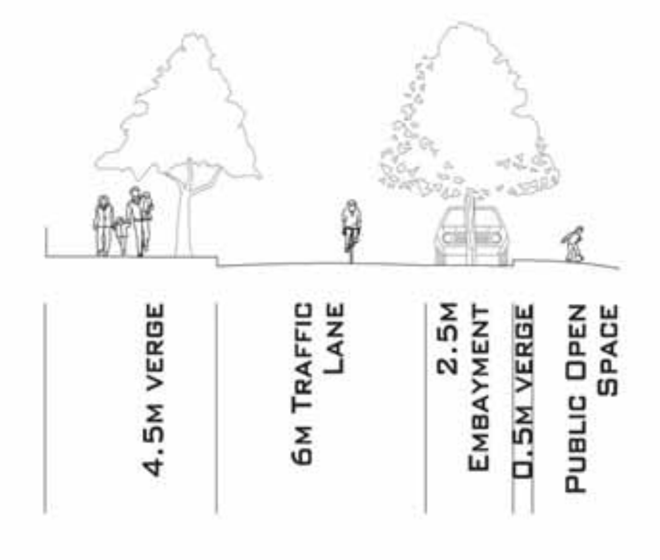



**Figure 8 Roads Adjacent to POS**

### 6.4 Roads Adjacent to Open Space

Where the road reservation abuts POS, bushland, golf courses etc, there is limited need to provide a verge. The verge may be reduced where parking and/or services are not required and should be considered at the time of subdivision. A minimum verge of 0.75 metres is advised by current road planning standards to accommodate street furniture.

Footpaths do not need to be adjacent to the road where POS is provided, but must be provided in a safe and appropriate manner. Figure 8 shows an example of a reduced road reservation adjacent to open space.

### 6.6 Four-way Intersections

Within the structure plan area daily traffic volumes are shown to be low and the use of four-way intersections is appropriate. Figure 9 shows an extract from Liveable Neighbourhoods on the preferred treatment of four-way intersections.

*Liveable Neighbourhoods* suggests that four-way intersections are an appropriate treatment at the meeting of two access streets and where daily flows through the intersection are less than 2,000vpd. Approach legs should be limited to a maximum length of 160 metres with some form of speed reducing feature where the length is greater than 80 metres.

Access streets meeting neighbourhood connectors and some arterial streets are considered acceptable, but will generally require a treatment as indicated in Figure 9. However, introducing four-way priority intersections on arterial streets is not recommended.

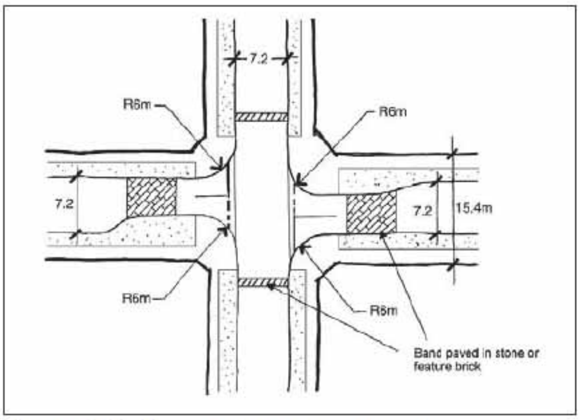



**Figure 29A: Access street to access street with-four way and stagger.**

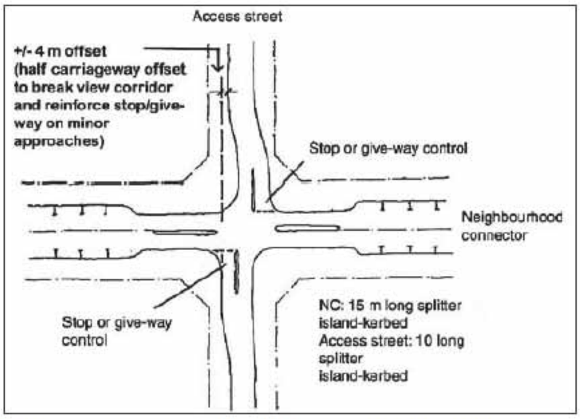



**Figure 31: Left-right minor offset four-way on neighbourhood connector (derived from Austroads Guide to traffic engineering, Part 5 Intersections, Figure 5-8).**

**Figure 9 Liveable Neighbourhoods Four-way Intersections**

In the interim years the use of a four-way at the intersection of Road A and Roads B / C is an acceptable treatment. In the long term, should land to the west be developed, the intersection would require control by a roundabout. This will need to be addressed by any future structure plan for land to the west.

### 6.7 Corner Treatments

To reduce the opportunity for speeding it is recommended that corner radii advised by *Liveable Neighbourhoods* be used within the subdivision. The recommended radii are:

- 6.0 metres - access street / access street intersections
- 9.0 metres - access street / neighbourhood connector

Where larger vehicles are expected, such as buses accessing the school, larger radii may be required and should be considered at subdivision stage.

All streets are of relatively short lengths and high traffic speeds would not be expected. Further, the narrower carriageway widths proposed in low traffic residential streets will assist in reducing the attraction for speeding, making a safer environment for local children.

***No specific traffic management features are considered to be required.***

## 7.0 PEDESTRIANS, CYCLISTS AND PUBLIC TRANSPORT

Current planning guidelines suggest that all streets should be provided with a footpath wherever possible. Where traffic flows exceed 1,000 vehicles per day, a footpath to both sides of the road should be provided. Figure 10 shows those streets where a footpath is required to both sides.

### 7.1 Cycling

Cycling would be safe on the majority of local streets where traffic flows are less than 1,000 vehicles per day. On the neighbourhood connectors shared paths should be provided to provide a safe alternative to on-road cycling. Figure 10 shows the recommended cycle and footpath network. The figure aims to encourage cyclists and pedestrians to use Brennand Road rather than Brand Highway.

Off-street cycle routes are desirable to provide recreational cycling opportunities in the region and should be contemplated with structure planning of land to the west.

### 7.2 Public Transport

The rural locality of Dongara is likely to make the provision of public transport unviable. However, planning for a long term bus service should be considered and Road A is suited to cater for a future bus service.

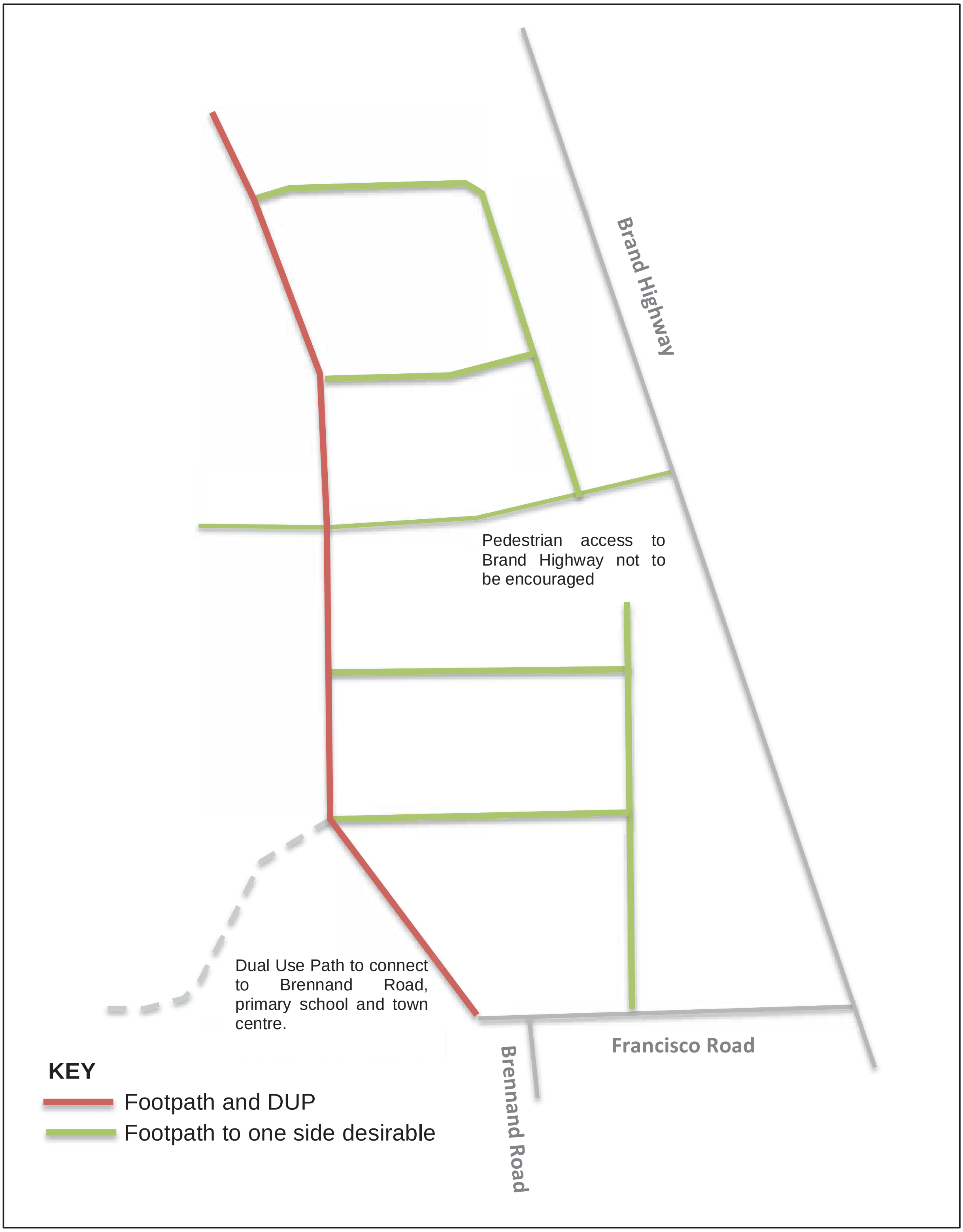



**Figure 10 Local Pedestrian and Cycle Paths**

## 8.0 DEVELOPMENT STAGING

The development of the subject land will occur in stages. It has been shown that ultimately the warrants will be met for a fully channelised intersection at Road A / Brand Highway to cater for the forecast traffic demands. The cost of constructing this intersection is significant and there is a strong desire to stage the implementation of the intersection.

Based on the traffic generation and distribution, it can be derived that peak hour turn movements equate to:

- Right turn (25 / 85) 1 movement per 3.4 dwellings
- Left turn (31 / 85) 1 movement per 2.7 dwellings

Using the forecast trafic volumes shown in Appendix E it is possible to derive at what stage of development the turn lane warrants will be met. The forecast flows on Brand Highway for the year 2025 are used to ensure robustness to the assessment. The level of turning traffic below the threshold of the turn lane provision will be (based on Appendix E) :

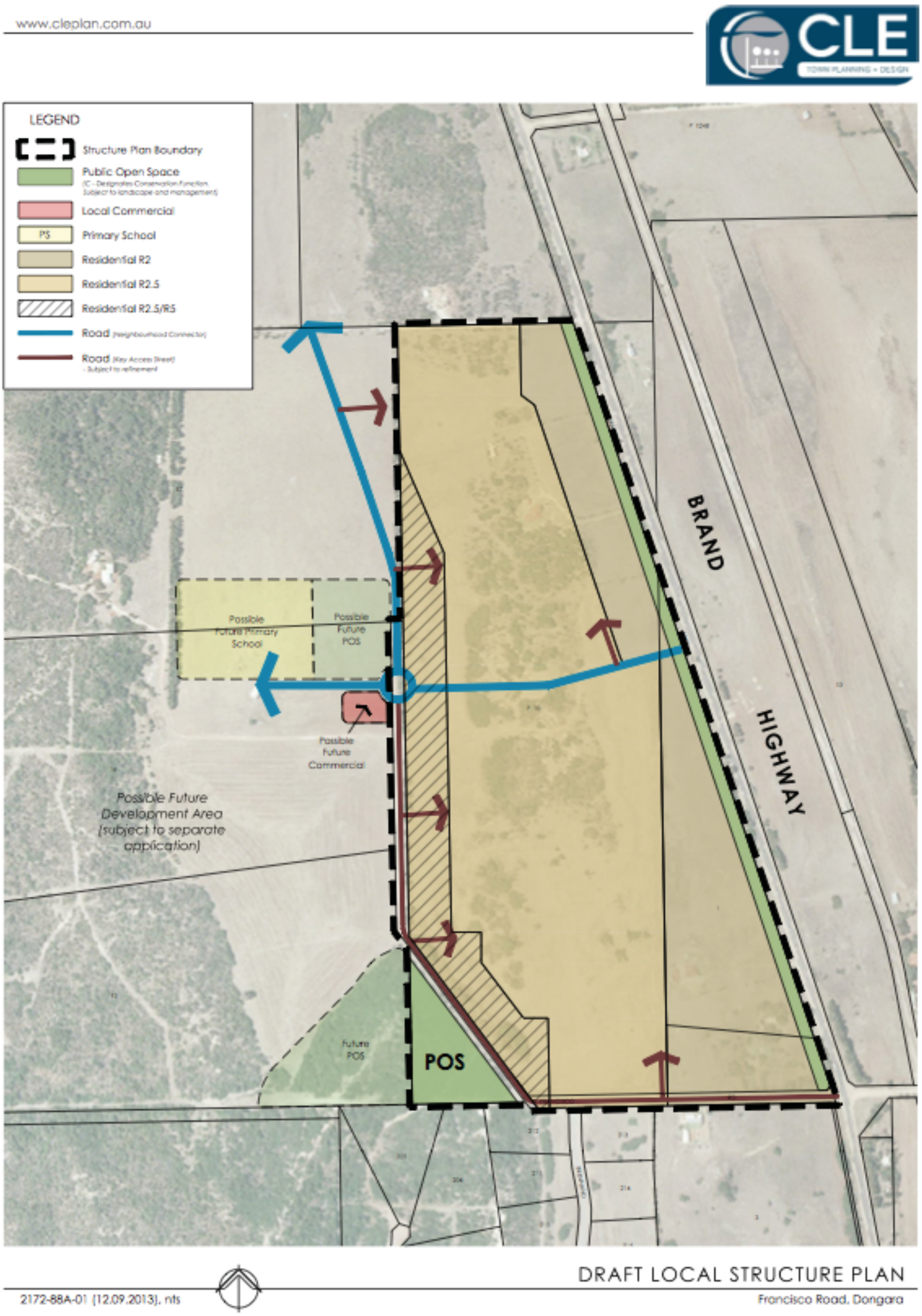
- Right turn lane $Q_{T1} + Q_{T2}$ = 309 vehicles $Q_R$ = 7 vehicles
- Left turn $Q_{TL}$ = 216 vehicles $Q_L$ = 18 vehicles

- Right turn of 7 movements = 23.8 dwellings
- Left turn of 18 movements = 48 dwellings

Thus it can be seen that the warrants to provide a right turn lane (full intersection) would not be met until 24 dwellings are occupied. It is recommended therefore that the first stage of development considers the creation of 20 lots and that development of stage 2 would be expected to provide the access intersection as indicated in Figure 4.

## APPENDIX A

## Draft Structure Pan



## APPENDIX B

**Table 1 Levels of Service by Road Type**

| LOS | Single Carriageway[1] | 2-Lane Boulevard[2] | Dual Carriageway (4-Lanes)[3] | Dual Carriageway (4-lane Clearway)[3] |
|---|---|---|---|---|
| A | 2,400vpd | 2,600vpd | 24,000vpd | 27,000vpd |
| B | 4,800vpd | 5,300vpd | 28,000vpd | 31,500vpd |
| C | 7,900vpd | 8,700vpd | 32,000vpd | 36,000vpd |
| D | 13,500vpd | 15,000vpd | 36,000vpd | 40,500vpd |
| E | 22,900vpd | 25,200vpd[4] | 40,000vpd | 45,000vpd |
| F | >22,900vpd | >25,200vpd[4] | >40,000vpd | >45,000vpd |

[1] Based on Table 3.9 Austroads - Guide to Traffic Engineering Practice Part 2
[2] Based on single carriageway +10% (supported by Table 3.1 Austroads - Guide to Traffic Engineering Practice Part 3) – Boulevard or division by medians.
[3] Based on RRR Table 3.5 - mid-block service flow rates (SF.) for urban arterial roads with interrupted flow. Using 60/40 peak split.
[4] Note James Street Guildford passes 28,000vpd.

## APPENDIX C

## Guide to Intersection Requirements (RTUA – UK)

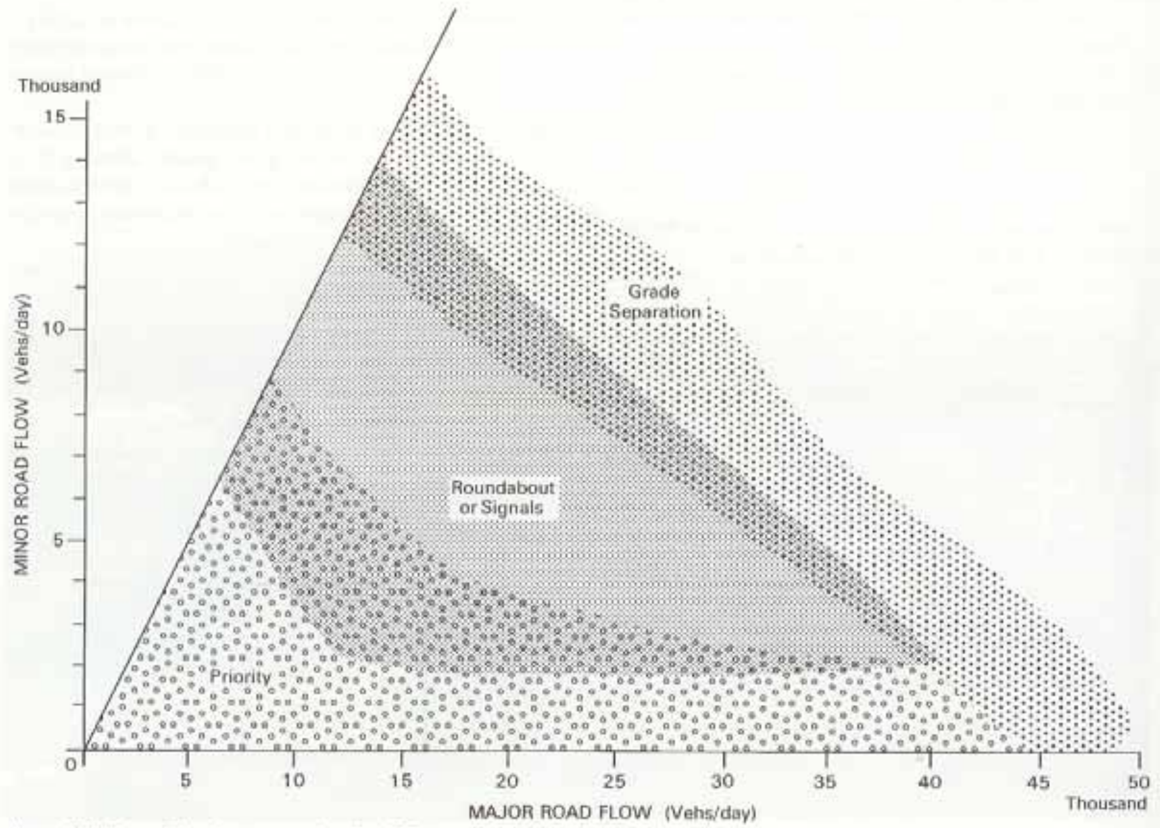
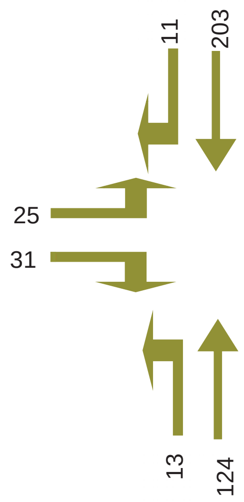


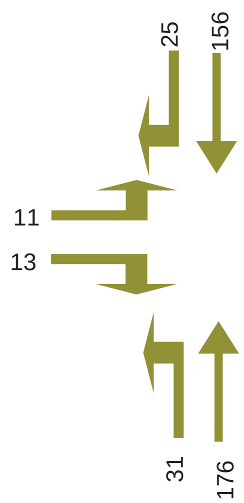

*Figure 38.1* Type of junction appropriate for different traffic flows

**APPENDIX D**

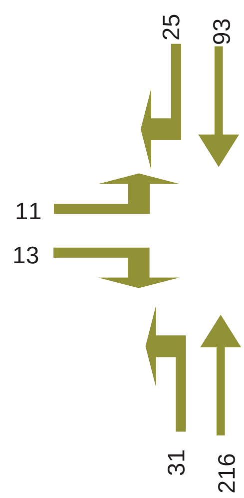
**Access Peak Hour Demand Volumes 2025**




**AM Peak (8am – 9am)**




**PM Peak (4pm-5pm)**



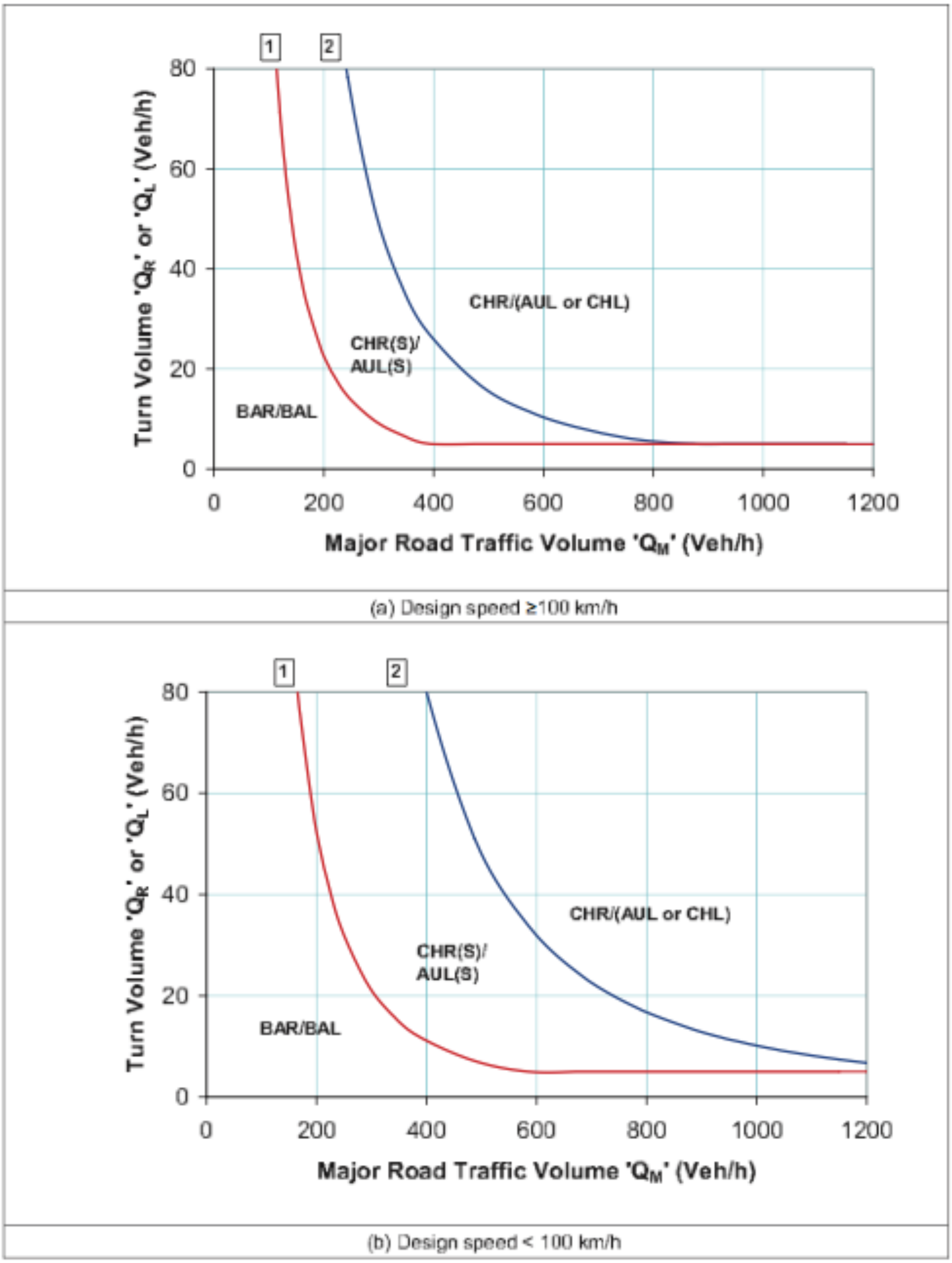

**PM Peak (5pm – 6pm)**

Note: Development flows based on 10% generation during peak periods.

## APPENDIX E

### Austroads Turn Lane Warrants

Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections




(a) Design speed ≥100 km/h

(b) Design speed < 100 km/h

Source: Arndt and Troutbeck (2006).

**Figure 4.9:** **Warrants for turn treatments on the major road at unsignalised intersections**

## APPENDIX F

## BRAND HIGHWAY ACCESS ANALYSIS

Brand Highway / Site Access
Year 2025 Full Development
AM PEAK
Giveway / Yield (Two-Way)

**Movement Performance - Vehicles**

| Mov ID | Turn | Demand Flow veh/h | HV % | Deg. Satn v/c | Average Delay sec | Level of Service | 95% Back of Queue Vehicles veh | 95% Back of Queue Distance m | Prop. Queued | Effective Stop Rate per veh | Average Speed km/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Brand Highway South | | | | | | | | | | | |
| 1 | L | 14 | 0.0 | 0.007 | 8.2 | LOS A | 0.0 | 0.0 | 0.00 | 0.67 | 49.0 |
| 2 | T | 131 | 8.0 | 0.070 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| Approach | | 144 | 7.2 | 0.070 | 0.8 | LOS A | 0.0 | 0.0 | 0.00 | 0.06 | 58.7 |
| North: Brand Highway North | | | | | | | | | | | |
| 8 | T | 214 | 8.0 | 0.115 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| 9 | R | 12 | 0.0 | 0.009 | 8.8 | LOS A | 0.0 | 0.3 | 0.24 | 0.61 | 47.8 |
| Approach | | 225 | 7.6 | 0.115 | 0.5 | LOS A | 0.0 | 0.3 | 0.01 | 0.03 | 59.2 |
| West: Site Access | | | | | | | | | | | |
| 10 | L | 26 | 0.0 | 0.089 | 10.9 | LOS A | 0.4 | 2.9 | 0.37 | 0.63 | 46.2 |
| 12 | R | 33 | 0.0 | 0.089 | 10.6 | LOS A | 0.4 | 2.9 | 0.37 | 0.71 | 46.4 |
| Approach | | 59 | 0.0 | 0.089 | 10.7 | LOS A | 0.4 | 2.9 | 0.37 | 0.68 | 46.3 |
| All Vehicles | | 428 | 6.4 | 0.115 | 2.0 | NA | 0.4 | 2.9 | 0.06 | 0.13 | 56.9 |

Brand Highway / Site Access
Year 2025 Full Development
PM PEAK
Giveway / Yield (Two-Way)

**Movement Performance - Vehicles**

| Mov ID | Turn | Demand Flow veh/h | HV % | Deg. Satn v/c | Average Delay sec | Level of Service | 95% Back of Queue Vehicles veh | 95% Back of Queue Distance m | Prop. Queued | Effective Stop Rate per veh | Average Speed km/h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| South: Brand Highway South | | | | | | | | | | | |
| 1 | L | 33 | 0.0 | 0.018 | 8.2 | LOS A | 0.0 | 0.0 | 0.00 | 0.67 | 49.0 |
| 2 | T | 227 | 8.0 | 0.123 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| Approach | | 260 | 7.0 | 0.123 | 1.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.08 | 58.4 |
| North: Brand Highway North | | | | | | | | | | | |
| 8 | T | 98 | 8.0 | 0.053 | 0.0 | LOS A | 0.0 | 0.0 | 0.00 | 0.00 | 60.0 |
| 9 | R | 26 | 0.0 | 0.024 | 9.3 | LOS A | 0.1 | 0.8 | 0.34 | 0.64 | 47.4 |
| Approach | | 124 | 6.3 | 0.053 | 2.0 | LOS A | 0.1 | 0.8 | 0.07 | 0.14 | 56.8 |
| West: Site Access | | | | | | | | | | | |
| 10 | L | 12 | 0.0 | 0.039 | 11.0 | LOS A | 0.2 | 1.3 | 0.43 | 0.66 | 46.2 |
| 12 | R | 14 | 0.0 | 0.039 | 10.7 | LOS A | 0.2 | 1.3 | 0.43 | 0.70 | 46.3 |
| Approach | | 25 | 0.0 | 0.039 | 10.8 | LOS A | 0.2 | 1.3 | 0.43 | 0.68 | 46.2 |
| All Vehicles | | 409 | 6.4 | 0.123 | 1.9 | NA | 0.2 | 1.3 | 0.05 | 0.14 | 57.0 |

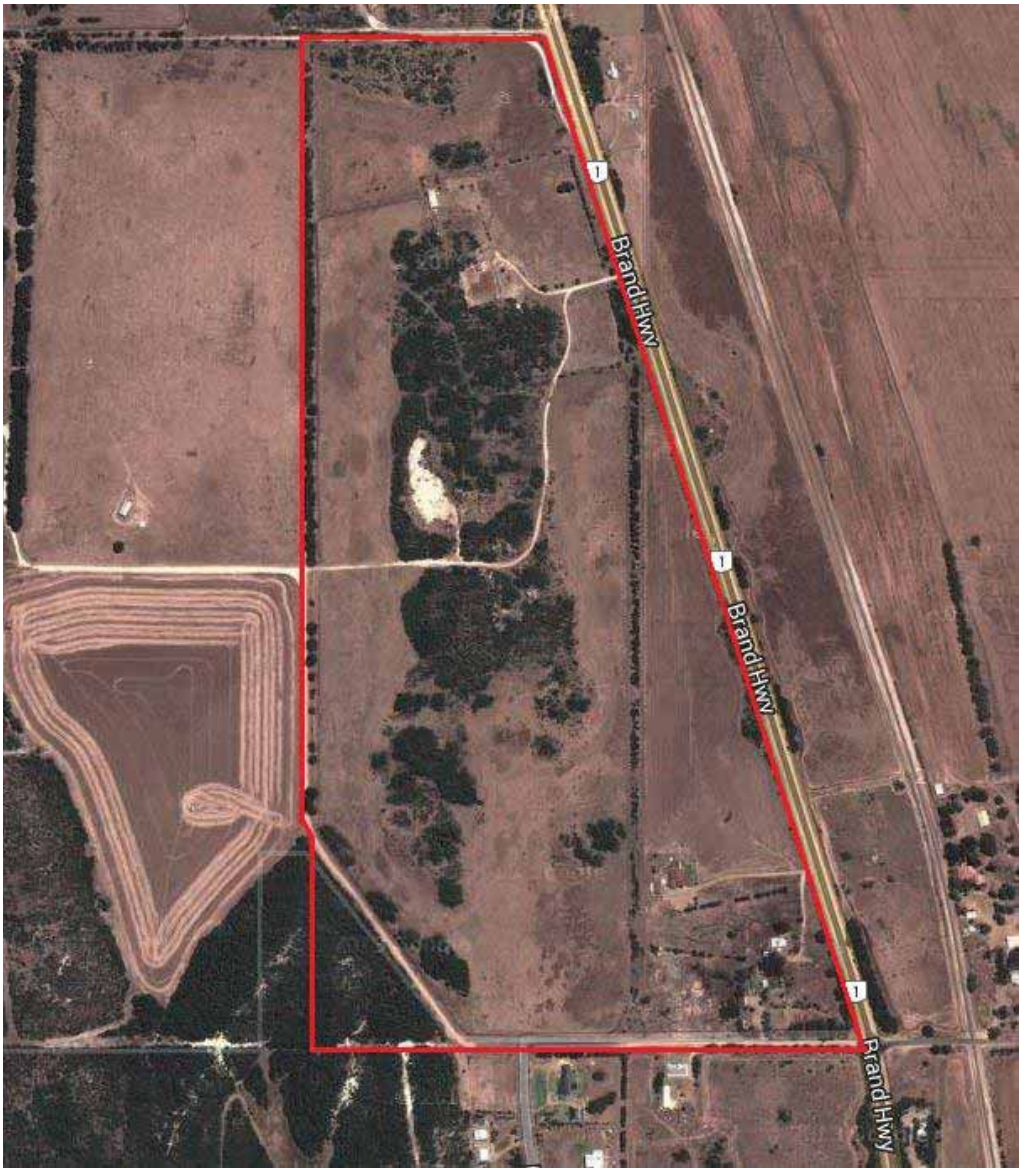
# APPENDIX 8

## Local Water Management Strategy 2014 (Civil Technology Pty Ltd)

# LOCAL WATER MANAGEMENT STRATEGY

## for the proposed subdivision of:

## <u>Lots 4, 5 & 10 Francisco Road, Bonniefield</u>





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*Revision 5: 29th May 2014*

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# 1 EXECUTIVE SUMMARY

The owners of Lots 4, 5 and 10 located on the corner of Brand Highway and Francisco Road, Bonniefield (located in the Shire of Irwin) have instructed Civil Technology to prepare a Local Water Management Strategy (LWMS) for a proposed Structure Plan prepared by CLE Town Planners and Design (refered to on the Structure Plan as a “Development Concept Plan”).

This LWMS has been prepared for the purpose of being submitted together with the proposed structure plan in accordance to clause 5.35.6.1 (f) viii of Ammendment 15 of the Shire of Irwin Town Planning Scheme No. 5 which requires that a proposed structure plan should include a written report addressing the urban water management of the land the subject of the proposed structure plan.

The existing water environment involves stormwater discharging into the surrounding environment. Due to the topography of the site, stormwater flows to the west and east of the site and discharges into adjacent land.

This LWMS outlines the proposed approach in implementing a drainage design if development were to proceed in accordance with the structure plan and establishing that this can be done without any adverse impacts to the existing local water environments.

It is proposed that stormwater be transported to five discharge points via vegetated road side swales. This is to encourage ground infiltration of the stormwater runoff enroute to the discharge points enabling distributed groundwater recharge over the site.

As the topography of the site need not be altered to any great degree as part of any development, the location of the post development stormwater discharge points are identical to that of the pre development condition with similar flow rates. Due to potable water reticulation being provided which will reduce reliance on groundwater extraction and coupled together with the stormwater hierachy being maintained, impacts on the groundwater environment are likely to be negligable.

This LWMS demostrates that there will be no adverse impacts on the environment as a result of implementing the subdisvion of the proposed structure plan.

# 2 INTRODUCTION

## 2.1 *Subject Site Description*

The subject site is located in Bonniefield, 3 km north of the Dongara town centre, within the Shire of Irwin.

The site is bounded by Brand Highway to the east and local reserves to the south and west. The Indian Ocean is only approximately 1.5km away from the site boundary to the west. The locality of the site is shown in Figure 1.

The north boundary consists of General Farming lots while south boundary comprises Francisco Road and a conservation area. A small rural residential subdivision with lot sizes that range from 1 to 4 hectares is located directly south of the site along Brennand Road. Figure 2 shows a close-up of the subject site.

Total site is approximately 57 hectares in total area and consists of the following lots:

- Lot 4 Francisco Road, Bonniefield (Area 2.4103ha)
- Lot 5 Brand Highway, Bonniefield (Area 8.5761ha)
- Lot 10 Francisco Road, Bonniefield (Area 45.953ha)

Each of these lots has an existing dwelling or structure.

## 2.2 *Design Objectives*

Total water cycle management, also referred to as integrated water cycle management, 'recognises that water supply, stormwater and sewage services are interrelated components of catchment systems and therefore must be dealt with using a holistic water management approach that reflects the principles of ecological sustainability' (Stormwater Management Manual for Western Australia, 2004-07, DoW).

The State planning policy 2.9: Water resources (WAPC, 2004), outlines the key principles of integrated water cycle management as:

- Consideration of all water resources, including wastewater in water planning;

- Integration of water and land use planning;

- The 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 human water use and natural water processes; and

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

The principles and objectives for managing urban water as stated in the Stormwater management manual for Western Australia (DoW, 2004-2007) are as follows:

- **Water quality**: to maintain or improve the surface and groundwater quality within the Development Areas relative to pre-development conditions.

- **Water quantity**: to maintain the total water cycle balance within the Development Areas relative to the predevelopment conditions.

- **Water conservation**: to maximise the reuse of stormwater.

- **Ecosystem health**: to retain natural drainage systems and protect ecosystem health.

- **Economic viability**: to implement stormwater management systems that are economically viable in the long term.

- **Public health**: to minimise the public risk, including risk from injury or loss of life, to the community.

- **Protection of property**: to protect the built environment from flooding and waterlogging.

- **Social values**: to ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.

- **Development**: to ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

### *2.3 Planning Background*

The owners propose to subdivide the land into residential lots ranging in size from approximately 0.4ha to 1.4ha each.

The site was previously zoned “General Farming” under the Shire of Irwin’s Local Planning Scheme No. 5, and on 18th June 2013 was rezoned to “Development” as per Amendment No. 15 of the Shire of Irwin Town Planning Scheme No. 5.

### *2.4 Previous Studies*

The following studies have been carried out in relation to the subject site. Most have been conducted as desktop studies and outline the necessary elements required to support the application for the recent successful rezoning of the land to support subdivisional development.
These include the following:

Land Capability and Geotechnical Assessment: Lots 10, 15, 16 and 17 Francisco Road, Dongara (June 2005). This report, prepared by Landform Research, covers various aspects of the existing environment including Geology and Geomorphology, water availability, alternative land uses, geotechnical factors, and environmental management.

Francisco Road Proposed Rezoning - Desktop Preliminary Engineering Services Review, Revision 3 (June 2012) was prepared by AECOM Australia, Geraldton office. The desktop study briefly addressed aspects of the larger subject site (including Lots 1409 Brand Highway, and Lots 15, 16 and 17 Francisco Road, Bonniefield) dealing with Earthworks and Topography, Drainage and Groundwater, Water Supply, Sewer, Power, Gas and Telecommunications.

Bushfire Management Plan: Francisco Road, Dongara (October 2013) was prepared by York Gum Services on behalf of the developer and addresses the bushfire risk and threat and an action plan.

# 3 PROPOSED DEVELOPMENT

### *3.1 Zoning and Structure Plan*

A proposed structure plan has been prepared by CLE (see figure 3) and which is the subject of this Local Water Management Strategy (LWMS). This LWMS deals with the following land:

- Lot 4 Francisco Road, Bonniefield (Area 2.4103ha)
- Lot 5 Brand Highway, Bonniefield (Area 8.5761ha)
- Lot 10 Francisco Road, Bonniefield (Area 45.953ha)

The revised Structure Plan was lodged together with the application for rezoning from “General Farming” to “Development” as per The Shire of Irwin’s Town Planning Scheme No. 5, Amendment No. 15. The structure plan is yet to be formally adopted by the shire under the provisions of Amendment 15.

### *3.2 Existing Land Use*

An examination of aerial photos (Figure 4) clearly indicates how the site has been extensively cleared and used for various rural / agricultural pursuits, namely cropping and grazing of livestock. Furthermore, each of the lots contains residential dwellings and associated outbuildings.

The aerial photos clearly depict the unmade road reserves and various driveways and tracks that traverse the landholdings.

### *3.3 Landscaping*

As per the Structure Plan, it is proposed to have an adequate amount of landscaping elements incorporated into the design. Although there is no requirement to provide public open space within Rural Residential type subdivisions, the conical hill / landscape feature on the southern boundary is proposed to be retained as public open space (conservation purposes). This will link in with the existing conservation reserve to the south and coastal foreshore reserve to the west. The public open space which is approximately 5.1ha will be bordered by the proposed roads.

In addition to the public open space, the site will be enhanced with street scaping within the road reserves and tree planting and landscaping within the individual Rural Residential home sites.

# 4 DESIGN CRITERIA

The design criteria for this LWMS have been based on the design objectives outlined in the WAPC's Better Urban Water Management document (WAPC, 2008) and also the Shire of Irwin's draft District Water Management Strategy (GHD, 2012).

The following design criteria are to be used as a guide for development of the urban water management system for strategic planning, subdivision and development (unless other specific objectives have been defined in other approved water management plans/strategies).

**Water conservation — potable and wastewater**

*Objective*

Minimising total water use and ensuring that potable water is used as efficiently as possible by sustainable management of all aspects of the water cycle.

*Design criteria*

Consumption target for water of 100 kL/person/yr – as outlined in the *State Water Plan* (2007) – with an aspirational target of not more than 40–60 kL/person/yr scheme water, as provided in *Better urban water management* (2008).

Minimising potable water use outside of buildings by substituting potable water with fit-for purpose water for all non-drinking uses.

Ensuring that all potable water is used as efficiently as possible by recommending all new fittings meet an efficiency rating of 5 stars or more.

Promoting the use of native plants to minimise water consumption

And also recommending rainwater tanks so that the water consumption targets can be achieved and also assist in the storage of stormwater on site.

**Water quantity management**

*Objective*

Post-development annual discharge volume and peak flow be maintained relative to pre-development conditions, unless otherwise established through determination of ecological water requirements for sensitive environments.

*Design criteria*

Ecological protection – For the critical 1-in-1-year ARI storm event, the post-development discharge volume and peak stormwater flow rates shall be maintained relative to predevelopment conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the Department of Water. This will be done using rural style open road shoulder drains and vegetated swales during the subdivision phase of development and during the future domestic phase of development it will be achieved by using soakwells and rainwater tanks.

Serviceability of roads and infrastructure in minor ARI events (up to the 1 in 5 year ARI) – runoff from the entire catchment area generated by up to a 5 year ARI event will be managed using stormwater conveyance systems comprising of rural style open drains and, where road pavements intersect such drains, using piped culverts.

Flood management – Manage the stormwater catchment runoff for up to the 1-in-100-year ARI event within the development area to pre-development peak flows unless otherwise indicated in an approved water management strategy or as negotiated with the relevant drainage service provider.

**Water quality management**

*Objective*

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

*Design criteria*

Contaminated sites – To be managed in accordance with the *Contaminated Sites Act 2003* (WA).

All other land – If the pollutant outputs of the development (measured or modelled concentrations) exceed catchment ambient conditions, the proponent shall achieve water quality improvements within the development area or, alternatively, arrange equivalent water quality improvement offsets within the catchment. If catchment ambient conditions have not been determined, the development should meet relevant water quality guidelines stipulated in the *National water quality management strategy* (AWWA, ANZECC & ARMCANZ, 1994).

Drainage – To ensure that all runoff contained within the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater management manual for Western Australia* (2004–07). Swales/vegetated bio-retention systems (also referred to as rain gardens) are to be sized at 2 per cent of the constructed impervious area from which they receive runoff. In addition, all outflows from subsoils should receive treatment prior to discharge to the stormwater system.

*Stormwater modelling criteria*

If it is proposed to use a computer stormwater modelling tool to demonstrate compliance with design objectives, the following design modelling parameters are recommended.

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

**Disease vector and nuisance insect management**

To reduce the health risk from mosquitoes, retention and detention treatments should be designed to ensure that between the months of November and May, detained immobile stormwater is fully infiltrated within a time period not exceeding 96 hours.

Permanent water bodies are discouraged, but may be accepted by the Department of Water, where issues outlined in the *Interim position statement: Constructed Lakes* (2007) are adequately addressed. Any water body must be designed to maximise predation of mosquito larvae by native fauna.

# 5 PRE-DEVELOPMENT ENVIRONMENT

## *5.1 Site Conditions*

Based upon an examination of contours (derived by aerial mapping) and aerial photos available of the site, it is apparent that the land has undulating topography with open fields and hills. A substantial area in the middle of the site has been cleared for livestock grazing. These are the low lying areas which are generally flat or with gentle slopes.

The site levels range from a RL of 6 to 30. Adjacent to the open field is a steep ridge which runs from north to south, which has an average gradient of 1 in 6 and maximum gradient of 1 in 4.

Geological series maps (Surface Geology of Australia Map Cat. No. 73360 – Geoscience Australia, 2012) indicate that the site characteristics consist of dunes with calcareous and quartz sand, limestone and sandstone which is typical in much of the town of Dongara. Ground conditions are expected to consist of generally deep sand over Tamala Limestone. A small amount of clay may also be present in the subsoils of older dunes due to a breakdown of feldspar grains (Reference: *Land Capability and Geotechnical Assessment – Lots 10, 15, 16 and 17, Francisco Road, Dongara –* Landform Research (June 2005)).

It is anticipated that a desirable site grading suitable for subdivision can be achieved with some earthworks being applied to the site. The potential presence in some areas of limestone and small amounts of clay can be managed during the design and construction phases of the development.

Due to the amount of earthworks and clearing required, site stabilisation will be an important factor that will be considered at detailed design and construction stage to avoid dust nuisance and ground erosion principally from wind.

Figure 5 illustrates the site contour plan.

## *5.2 Climate*

The subject site is located in the mid-west region of Western Australia, where the climate transitions from Mediterranean to semi-arid. The climate is characterised by warm dry summers and mild wet winters. The nearest weather station is located in Mingenew which is approximately 55 km east from Dongara, however as Dongara is located directly on the WA coast the nearest weather station which would have a similar climate is located at Geraldton Airport approximately 65 Km to the north of Dongara. The mean recorded annual rainfall is 442.7mm. Figure A below shows the climatic data for the region. (BOM, 2014)

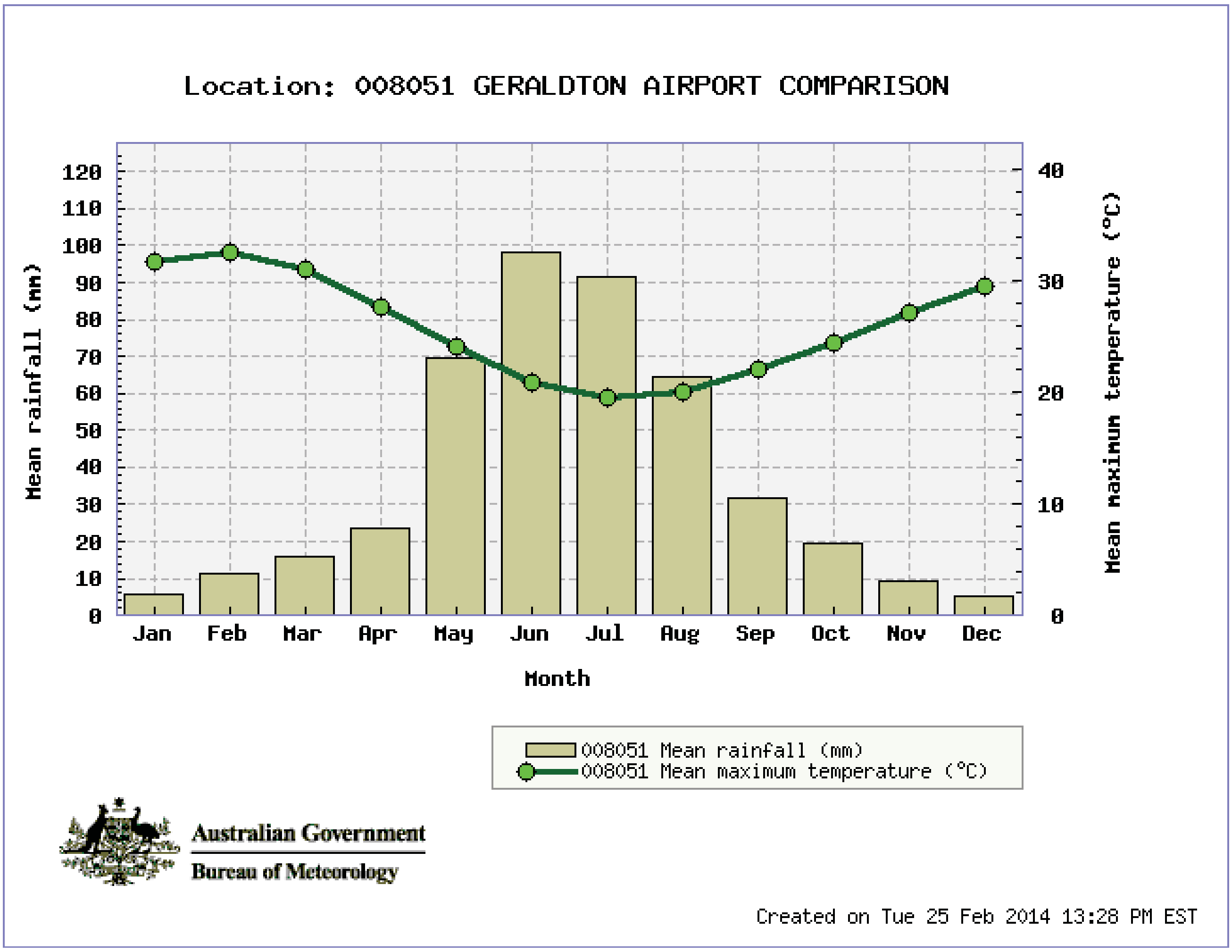


**Figure A: Climatic data of nearest relevant weather station (BOM, 2014)**

### *5.3 Geotechnical Plan*

As previously mentioned in Section 1.4 of this report, all relevant geotechnical information has been covered by the Land Capability and Geotechnical Assessment: Lots 10, 15, 16 and 17 Francisco Road, Dongara (June 2005). This report, prepared by Landform Research, covers various aspects of the existing environment including Geology and Geomorphology, water availability, alternative land uses, geotechnical factors, and environmental management.

### *5.4 Surface Water*

Figure 6 illustrates the catchment delineation for the existing pre-development site with an indication of stormwater flow paths. Due to the highly permeable nature of the soils within the subject site and the existing contours which allow surface water to drain freely across the land it is unlikely to encounter any perched water tables within the proposed development area.

### *5.5 Groundwater*

There is one inactive bore within the site previously installed by the Department of Water. The recorded drill depth was 6.10 metres deep making the water table at about 2 metres AHD. There are also existing Department of Water groundwater bores in operation located on the east side of Brand Highway, and these show water levels between 6 to 8 metres deep. Six metres from groundwater level is considered as sufficient separation distance from the existing surface level.

Despite the proximity of the site from the ocean, it is unlikely to encounter shallow groundwater due to the elevation of the site above the ground water table.

The bore water quality on site has been tested and results indicate a groundwater salinity of 2,475mg/L in the north and 1,705mg/L in the south. (Reference: *Land Capability and Geotechnical Assessment – Lots 10, 15, 16 and 17, Francisco Road, Dongara* – Landform Research (June 2005)).

### *5.6 Acid Sulphate Soils*

The Shire of Irwin's Draft District Water Management Strategy states that Acid Sulphate soils are wetland soils and unconsolidated settlements that contain iron sulphides which form in protected low energy environments such as barrier estuary's, coastal lakes and costal alluvial valleys. It also states there is a high to moderate risk of acid sulphate soils occurring within 3m of the surface along the Irwin River and its banks. This risk extends to approximately 2.5km inland or the river mouth. Given that;

a) The subject site is approximately 3.6 Km north of the Irwin River.
b) There are no nearby wetlands.
c) And due to the dry sandy nature of the soils located in the subject site.

There is a low to no risk of encountering Acid sulphate soils within 3 m of the surface.

# 6 WATER SUSTAINABILITY INITIATIVES

## *6.1 Water Efficiency Measures*

Water-wise landscaping will be maximised throughout the subject site by way of the utilisation of water sensitive measures that maximise efficiency and reduce wastage, spillage and leakage.

These water sensitive measures are to be applied to irrigation requirements for both public and private spaces, as well as water sustainability initiatives within the development. Particular consideration should be made to imported drinking water, rainwater harvesting, groundwater extraction and waste water recycling opportunities.

Road surface runoff is proposed to be collected by roadside swales, running parallel the road, and redirected into bio-retention swales where it is utilised for watering the vegetation and recharging of the groundwater table.

Wastewater is proposed to be treated, using onsite wastewater treatment systems (Alternate Treatment Units), and discharged into the surrounding ground where it will eventually reach the groundwater environment. Although some water will be lost in the wastewater treatment process, due to evapotranspiration, the input of water into each lot being drained from the reticulated water supply into the proposed subdivision should provide a reasonable groundwater balance

## *6.2 Water Supply*

Due to high salinity levels, bore water on site is suitable for stock but is not potable.

Potable water for domestic use can therefore be provided by scheme water, roof water collection tanks, desalination and/or bore water combined with a UV steriliser.

Due to the size of the proposed lots and ther low density residential nature of the proposal, it is unlikely that any significant stocking on the lots will occur.

In turn, the above mentioned factors place a low level of reliance upon groundwater extraction.

Based on information provided by the Water Corporation, a 150mm diameter water main is present on Francisco Road with two water services for Lot 10 and Lot 17. These services have special arrangements in place between the Water Corporation and the subdivider because they do not meet the standards for a normal water supply service for pressure and flow.

The subject site is currently outside Water Corporation’s water supply planning area. The Water Corporation will need to extend its operator’s licence to include the site. The Water Corporation have indicated a willingness to apply to the Regulator for that extension.

Future development sites that are not within the Water Corporation's planning scheme will need to submit an initial request with information regarding the proposed development, such as timing, staging, zoning, number of lots, and other key pieces of information that demonstrate that servicing the site is commercially viable.

This process will need to commence at the start of the land development process to allow time for Water Corporation to review the application, and for the Developer to undertake the requirements, investigations and procedures for the site's inclusion into the water planning schemes. This process should be facilitated now that the site has been rezoned.

The use of rainwater storage tanks for potable water supply is encouraged to reduce the demand on the proposed reticulation water supply.

# 7 STORMWATER MANAGEMENT STRATEGY

The potential presence of deep sands within the development provides for adequate stormwater drainage disposal and, in addition, the opportunity to apply water sensitive stormwater design principles that encourages stormwater to be contained at source as far as practicable.

Some of the drainage controls preferred by the Department of Water include the use of swales, soakwells and landscaped infiltration basins. An effective drainage strategy can be developed for the site given that the high level of soil permeability do not allow for surface drainage to accumulate on the site, with all infiltration moving vertically downwards to the water table. The existing rural subdivision south of the site utilises swales on the road reserve, and a similar arrangement can be adopted for the development of the site.

Predevelopment flow paths will be determined and compared to the re-direction of flows in the post-development scenario as part of this LWMS.

## *7.1 Pre-Development Surface Drainage*

Almost the whole site is well drained by means of ground infiltration, with no risk of inundation or flooding. Figure 6 illustrates the pre-development catchment delineation for the subject site including direction of the surface runoff flow paths.

Catchment characteristics for each of the four pre-development catchments (A, B, C and D) are analysed, including area, mainstream lengths, slope, ground imperviousness, rainfall data, and ultimately the surface runoff flow rates for each design ARI storm event.

These are generated using hydrological analysis based on methodology provided in “Australian Rainfall and Runoff - A Guide to Flood Estimation” (1987). The Rational Method was used together with the Bransby Williams formula for generating times of concentration. This formula incorporates the majority of site specific data and parameters available for hydrological analysis.

Appendix A is a brief write-up explaining the Rational Method used by AR&R (1987) in generating hydrological design data.

Appendix B shows the rainfall IFD data generated for the site using the Bureau of Meteorology website tools. The nearest meteorological location to the subject site was selected by the website tool to be on the edge of the proposed POS area at the south-western corner of the subject site.

Appendix C illustrates the catchment details including the generated equal slope areas and the mainstream profile for each pre-development catchment within the subject site.

Appendix D shows the hydrological and drainage data for all catchments. The following values were used in the generation of peak stormwater flows for the pre-development scenario:

- 1-hour 10-year ARI Intensity, $^{10}I_1$ = 29.4mm/hr
- Pervious Area Runoff Coefficient for 1 in 10 yrs ARI, $C^1_{10}$ = 0.16
- Impervious Fraction of catchment area, *f* = 0.05 (5%)

Table 1 below shows the site-specific pre-development catchment analysis including surface runoff flow rates generated for each design ARI storm event.

**TABLE 1:**
**PRE-DEVELOPMENT CATCHMENT DETAILS**

| CATCH. | Area, A ($m^2$) | Mainstream Length, L (km) | Mainstream Equal Area Slope, s (m/km) | Time of concentration $t_c$ (mins) | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 yrs ARI | 5 yrs ARI | 10 yrs ARI | 20 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **A** | 317,134 | 0.710 | 17 | 26 | **0.51** | **0.73** | **0.87** | **1.07** | **1.39** | **1.65** |
| **B** | 85,582 | 0.260 | 50 | 9 | **0.24** | **0.34** | **0.41** | **0.51** | **0.67** | **0.79** |
| **C** | 171,838 | 0.548 | 18 | 21 | **0.31** | **0.45** | **0.54** | **0.65** | **0.86** | **1.01** |
| **D** | 50,187 | 0.258 | 54 | 9 | **0.14** | **0.20** | **0.24** | **0.30** | **0.39** | **0.46** |

The pre-development receiving environment for the stormwater runoff can be classified into three as follows:

a) *Groundwater*

The groundwater table receives stormwater directly by way of stormwater infiltrating into the ground from all 4 existing surface catchments within the subject site. In the case of the ODP area, the ground surface slopes and soil types are such that it is unlikely to create run-off of any significance and as such all stormwater received by the soils of the site will result in an evenly distributed collection of that stormwater for groundwater recharge.

b) *Public Open Space - Landscape Buffer Zone*

This buffer zone is 20m wide and exists along the entire stretch of subject site boundary along Brand Highway. It receives pre-development stormwater runoff from Catchments B, C and D.

c) *Public Open Space*

This is considered to be the outflow point on the western edge of the subject site boundary, along the north-south stretch of Francisco Road. It receives pre-development stormwater runoff from Catchment A.

The following table analyses the stormwater runoff for the pre-development receiving environment.

**TABLE 2:**
**PRE-DEVELOPMENT RECEIVING ENVIRONMENT**

| RECEIVING ENVIRONMENT | Pre-Development Contributing Catchment/s | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 yrs ARI | 5 yrs ARI | 10 yrs ARI | 20 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **Public Open Space** (western edge of site boundary) | A | 0.51 | 0.73 | 0.87 | 1.07 | 1.39 | 1.65 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.51** | **0.73** | **0.87** | **1.07** | **1.39** | **1.65** |
| **Landscape Buffer Zone** (eastern edge of site boundary) | B | 0.24 | 0.34 | 0.41 | 0.51 | 0.67 | 0.79 |
| | C | 0.31 | 0.45 | 0.54 | 0.65 | 0.86 | 1.01 |
| | D | 0.14 | 0.20 | 0.24 | 0.30 | 0.39 | 0.46 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.69** | **0.99** | **1.19** | **1.46** | **1.92** | **2.26** |

### *7.2 Post-Development Drainage Scenario*

Given the soil conditions on site and the high permeability achieved for all surface runoff, it is inevitable that most of the stormwater received at the surface of the site will infiltrate on site, with the exception of hardstand areas such as roads, footpaths, driveways and paved areas (with an impervious fraction of catchment area, $f$ = 0.8 (80%).

Within individual lots, it is expected to have all stormwater runoff from the roof areas directed into soakwells which enables the infiltration and seepage of stormwater back into the natural groundwater environment. This direct routing of part of the surface runoff within the individual lots into the groundwater will virtually mirror the ground infiltration rate so that it does not differ from the pre-development scenario.

All other stormwater runoff generated within the subject site (including paddocks located within the individual lot areas) has be designed so that it is redirected, using a roadside swale drainage system located in the road shoulder running parallel to the proposed pavements. Where necessary the stormwater will be piped under intersecting road pavements by way of concrete culverts. The system will discharge by way of bubble up pits (with pervious slab bases to allow stormwater to seep through) that overflow into  the bio-infiltration swale located in the Public Open Space to the west and the 20 m landscape buffer to the east. The post-development stormwater runoff will also discharge into a roadside detention swale located parallel to the road fronting proposed Lot 54 where the overflow will then be discharged into the adjacent land to the west by way of a piped culvert under the road (refer to Figure 7). The volume of stormwater discharged into this area is not expected to exceed that of the pre-development condition, this is due to the high permeable nature of the soil and the presence of vegetation in the roadside swales and, as a result, most of the stormwater will be absorbed into the groundwater condition en-route to the discharge point. The stormwater will then, by process of ground infiltration, ultimately find its way into the natural groundwater environment.

This further encourages infiltration and also redirects any runoff from large stormwater events (more than 5yr ARI storms) to the proposed future Public Open Space located on western boundary of the subject site, as well as to the 20m landscape buffer alongside Brand Highway and the roadside detention swale located parallel to the road fronting proposed Lot 54. This is further illustrated in Figure 7.

Table 3 below shows the site-specific pre-development catchment analysis including surface runoff flow rates generated for each design ARI storm event. Also refer to Appendix D for the hydrological and drainage data for all catchments.

**TABLE 3:**
**POST-DEVELOPMENT CATCHMENT DETAILS**

| CATCH. | Area, A ($m^2$) | Mainstream Length, L (km) | Mainstream Equal Area Slope, s (m/km) | Time of concentration $t_c$ (mins) | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 yrs ARI | 5 yrs ARI | 10 yrs ARI | 20 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| 1 | 13,385 | 0.544 | 29 | 24 | 0.09 | 0.12 | 0.15 | 0.18 | 0.23 | 0.27 |
| 2 | 40,191 | 0.762 | 10 | 38 | 0.20 | 0.28 | 0.33 | 0.40 | 0.52 | 0.69 |
| 3 | 6,019 | 0.425 | 24 | 22 | 0.04 | 0.06 | 0.07 | 0.08 | 0.11 | 0.13 |
| 4 | 17,350 | 0.700 | 14 | 35 | 0.09 | 0.13 | 0.15 | 0.18 | 0.24 | 0.28 |
| 5 | 18,051 | 0.785 | 20 | 37 | 0.09 | 0.13 | 0.15 | 0.18 | 0.24 | 0.28 |
| $A_1$ | 239,113 | 0.710 | 17 | 26 | 0.38 | 0.54 | 0.64 | 0.79 | 1.03 | 1.21 |
| $B_1$ | 81,700 | 0.260 | 50 | 9 | 0.23 | 0.33 | 0.39 | 0.48 | 0.64 | 0.76 |
| $C_1$ | 136,703 | 0.548 | 18 | 21 | 0.24 | 0.35 | 0.41 | 0.51 | 0.66 | 0.78 |
| $D_1$ | 34,746 | 0.258 | 54 | 9 | 0.10 | 0.14 | 0.17 | 0.21 | 0.27 | 0.32 |

The post-development receiving environment for the stormwater runoff can also be classified into 4 disposal areas as follows:

a) *Groundwater*

The groundwater will receive stormwater which directly infiltrates into the ground from all the soakwells servicing the proposed new dwellings that will be developed within the individual developed lots within the subject site. Although this cannot be quantitatively assessed through standard hydrological methods until the size of the development in each proposed lot is known, the post development value for ground infiltration would be identical to that of the pre-development scenario for the following reasons:

- The ground composition for the pre-development land and the post-development individual lots is the same, i.e. sandy soil.

- All rainfall and stormwater runoff from the roof areas within the post-development individual lots will be directed into the groundwater via soakwell disposal systems, whereas in the pre-development scenario, the stormwater will directly infiltrate into the ground. Thus the only difference between the post development and pre development scenario will be that there could be point concentration of stormwater where soakwells are located but this will quickly dissipate into the groundwater table below due to the high permeability of the site. This will not affect groundwater condition as the overall volume of infiltration into the groundwater does not change and, given the depth of soil between the surface and the groundwater, the infiltration in the post development condition will distribute evenly through that separation depth.

b) *Public Open Space - Landscape Buffer Zone*

This buffer zone is 20m wide and exists along the entire stretch of subject site boundary along Brand Highway. It will receive post-development stormwater runoff from Catchments 3, 4 and 5 as well as from the surface runoff generated from developed Lots within Catchments $B_1$, $C_1$ and $D_1$.

c) *Public Open Spaces*

At post-development, the future Public Open Space (POS) located on the western boundary of the site is to be considered to provide the most appropriate location for stormwater disposal for the North West portion of the subject site. The creation of an interim swale within this area may be appropriate pending its formal creation as POS. This outflow point is located in approximately the same location as where the stormwater will flow in the pre development scenario. The future POS is proposed to receive post-development stormwater runoff from Catchment 1 and the northern sections of Catchment $A_1$ (as described in Figure 7).

d) Roadside Detention Swale

A roadside detention swale is to be located parallel to the road fronting proposed Lot 54 where the topographical low point for the subject site is located. Lot 54 is located on the western edge of the subject site which has frontage to Francisco Road. The roadside detention swale is to receive post-development stormwater runoff from Catchment 2 and Catchment A1 (refer to Figure 7). The overflow will then be discharged into the adjacent land to the west by way of a piped culvert under the road (refer to Figure 7). This will not alter the predevelopment drainage condition as this is the natural flow path for stormwater runoff over the land. Further, due to the highly permeable nature of the land, natural surface flows are not likely to be exceeded at this location in the post development condition.

The following table analyses the stormwater runoff for the pre-development receiving environment.

**TABLE 4:**
**POST-DEVELOPMENT RECEIVING ENVIRONMENT**

| RECEIVING ENVIRONMENT | Post-Development Contributing Catchment/s | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 yrs ARI | 5 yrs ARI | 10 yrs ARI | 20 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **Public Open Spaces** (western edge of site boundary and south-western corner of subject site) | **1** | 0.09 | 0.12 | 0.15 | 0.18 | 0.23 | 0.27 |
| | **2** | 0.20 | 0.28 | 0.33 | 0.40 | 0.52 | 0.69 |
| | **$A_1$** | 0.38 | 0.54 | 0.64 | 0.79 | 1.03 | 1.21 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.67** | **0.94** | **1.12** | **1.37** | **1.78** | **2.17** |
| **Landscape Buffer Zone** (eastern edge of site boundary) | **3** | 0.04 | 0.06 | 0.07 | 0.08 | 0.11 | 0.13 |
| | **4** | 0.09 | 0.13 | 0.15 | 0.18 | 0.24 | 0.28 |
| | **5** | 0.09 | 0.13 | 0.15 | 0.18 | 0.24 | 0.28 |
| | **$B_1$** | 0.23 | 0.33 | 0.39 | 0.48 | 0.64 | 0.76 |
| | **$C_1$** | 0.24 | 0.35 | 0.41 | 0.51 | 0.66 | 0.78 |
| | **$D_1$** | 0.10 | 0.14 | 0.17 | 0.21 | 0.27 | 0.32 |
| | **TOTAL FLOW, Q ($m^3/s$)** | **0.79** | **1.14** | **1.34** | **1.64** | **2.16** | **2.55** |

### *7.3 Water Quantity Management*

From the above analyses of pre-development versus post-development scenarios, a comparison is made between the two for each category of receiving environment, in order to ascertain the stormwater management objective of achieving water quantity management. The following table demonstrates this comparison.

**TABLE 5:**
**WATER QUANTITY MANAGEMENT AT RECEIVING ENVIRONMENTS**

| RECEIVING ENVIRONMENT | SCENARIOS | PEAK STORMWATER FLOW, Q ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 yrs ARI | 5 yrs ARI | 10 yrs ARI | 20 yrs ARI | 50 yrs ARI | 100 yrs ARI |
| **Public Open Spaces** (western edge of site boundary and south-western corner of subject site) | **Pre-Development** | 0.51 | 0.73 | 0.87 | 1.07 | 1.39 | 1.65 |
| | **Post-Development** | 0.67 | 0.94 | 1.12 | 1.37 | 1.78 | 2.17 |
| **Landscape Buffer Zone** (eastern edge of site boundary) | **Pre-Development** | 0.69 | 0.99 | 1.19 | 1.46 | 1.92 | 2.26 |
| | **Post-Development** | 0.79 | 1.14 | 1.34 | 1.64 | 2.16 | 2.55 |

This comparison clearly shows that as far as the overland stormwater runoff to the POS areas is concerned, the post-development peak flows are to a certain extent maintained, and are relatively comparable to the pre-development condition.

As far as the Landscape Buffer Zone is concerned, the relative peak flows are also maintained and relatively comparable to pre-development conditions.

Since groundwater comprises a major component of the receiving environment, it can be deduced that the overall receiving environment (including POS areas, Landscape Buffer Zones and Groundwater) would not be affected in terms of stormwater quantity maintenance when comparing the pre-development condition to the post-development scenario.

### *7.4 Water Quality Management & Disposal Strategies*

Given that the general topographical environment, geological formation (i.e. sandy soils) and stormwater re-direction strategies will not be significantly altered between the pre-development conditions to the post-development scenario, it is reasonable to deduce that the surface water and groundwater quality will be maintained.

However, it is preferable to improve the water leaving the development area, especially from those hardstand areas that are created as part of the development, such as internal roads, footpaths, driveways and paved areas so that the water quality does not diminish below the pre-development quality. As illustrated in Figure 7, all the stormwater generated from these areas will initially be redirected to bubble-up pits before eventually being discharged into the receiving environment through bio-retention swales and vegetated Public Open Spaces. These are to be sized at 2% of the constructed impervious area from which they receive runoff.

Furthermore, the soakwell disposal systems within the individual lots will provide a means of stormwater detention and filtration before final disposal into the groundwater environment through gradual seepage and infiltration.

In this manner, stormwater management objective of achieving water quality management is achieved by ensuring that runoff contained within the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the *Stormwater Management Manual for Western Australia (2004-07)*.

# 8 MONITORING

## *8.1 Monitoring and Contingencies*

### 8.1.1 Surface Water Monitoring

The existence of surface water in the bio-infiltration swales will be ephemeral, and therefore only opportunistic sampling and testing of surface water from the bio-infiltration swales will be possible. This will be conducted as and when practicable, and the results monitored to ensure continuing quality improvement.

### 8.1.2 Groundwater Quality Monitoring

A monitoring program will be implemented to provide an ongoing assessment of development impacts on groundwater levels and groundwater quality.

Monitoring will be undertaken by the sub-divider quarterly during each year that the development is being constructed plus an additional period of two years in order to assess the impact of water quality arising from urbanization of the Site.

Groundwater will be extracted from bore locations as used in the original baseline testing, and tested for pollutants.

The monitoring program sets performance criteria against which the results of monitoring can be assessed, and identifies contingency actions to be taken in the event that any of the criteria is breached. If any result reaches the trigger level an additional test will be conducted. If confirmed, appropriate action will be taken in consultation with a suitably qualified environmental consultant.

The proposed monitoring program is shown in Table 6.

**TABLE 6:**
**MONITORING SCHEDULE & REPORTING**

| Monitoring Type | Parameter | Source Location | Method | Frequency & Timeframe |
|---|---|---|---|---|
| Groundwater Level | Water level (m AHD) | Groundwater sampling from monitoring bores | Electrical depth probe or similar | Monthly from start of project until 2 years post completion of subdivision |
| Groundwater Quality | pH, EC, TSS, Nitrogen, Phosphorus | | | Quarterly from start of project until 2 years post completion of subdivision |

An annual report will be submitted by the sub-divider to the Department of Water and Shire of Irwin for the duration of the development-related monitoring program.

Following handover it will be the responsibility of the Shire of Irwin to determine an appropriate monitoring frequency.

### 8.1.3 Bio-infiltration Swale Soil Monitoring

The bio-infiltration swales will be inspected after every significant storm event (or at least quarterly) by the subdivider for signs of sediment accumulation, weed invasion and poor plant health, and remedial action will be taken to remove sediment and weeds and replace diseased and deceased plants.

Responsibility for the bio-infiltration swale soil monitoring will revert to the Shire of Irwin after a period of 24 months from completion of the relevant stage of the project where the bio-infiltration swale/s have, as part of that stage, been constructed.

# 9 IMPLEMENTATION AND MAINTENANCE

## 9.1 *Implementation*

The subdivider shall be responsible for the implementation of an Urban Water Management Plan (once subdivision of the land is approved), implementation of the monitoring program and maintenance in accordance with Table 7 below.

## 9.2 *Ongoing Maintenance*

It is proposed that the Shire of Irwin will assume responsibility for the ongoing operation and maintenance of the proposed drainage system following a period of 24 months from the completion of the site works, with the subdivider being responsible for maintaining the system during the 24 month prior period.

The maintenance regime will include erosion control, sediment removal, weed control, plant inspection and plant replacement in the bio-infiltration swale.

## 9.3 *Maintenance Schedule*

Table 7 below provides a maintenance schedule for the infrastructure proposed to be installed as part of the subdivision.

**TABLE 7:**
**MAINTENANCE SCHEDULE - DRAINAGE**

| Maintenance Requirement | Specific Requirement | Responsibility |
|---|---|---|
| Pits and gullies | Inspect after significant storm events or quarterly as a minimum to ensure correct functioning. | Subdivider up until final inspection of roadworks, then Shire of Irwin |
| Street sweeping | Remove silt from road surface at completion of the roads constructed in the subdivision | As per pits and gullies |
| Monitoring plants | Inspect monthly, remove invading exotic plants and weeds, and re-plant as required. | Subdivider for a period of 24 months, then Shire of Irwin |
| Bio-infiltration swale | Inspect monthly and remove excess sediment and litter as required to maintain function | Subdivider for a period of 24 months, then Shire of Irwin |

# 10 SUMMARY

Previous studies indicate the extensive sandy nature of the soils, which promotes ground infiltration of stormwater runoff into the groundwater table. Soakwells located within the individual lots of the proposed subdivision will further ensure that the stormwater runoff from rooftops will be redirected into the groundwater receiving environment.

The topography of the subject site will result in similar catchment delineations as between the pre-development and post-development scenarios. The comparisons of peak design stormwater flow rates show a similarity between the pre-development and post-development conditions.

To ensure that there is sufficient area for nutrient management and stormwater runoff disposal for the proposed development; two disposal points have been created on the western edge of Lot 10, one being located in the proposed Public Open Space and the other on Francesco road opposite the location of proposed Lot 55. These two disposal points will service the western half of the proposed development. This will be achieve through the construction of a roadside swale drainage system (with piped culverts where the drains need to pass under road/footpath pavements) connected to bubble up pits located within the vegetated disposal points.
Similarly, the eastern half of the proposed development will have its post-development surface runoff directed to the 20m landscape buffer area between the proposed development and Brand Highway. Stormwater runoff disposal management will also be achieved within this landscape buffer zone by first directing the runoff through a roadside swale drainage system (again with piped culverts where the drains need to pass under road/footpath pavements) connected to bubble-up pits, then discharging into bio-retention swales within the buffer zone.

An ongoing monitoring and maintenance schedule coupled with the proposed development infrastructure will aid in providing an ongoing assessment of development impacts on groundwater levels and groundwater quality.

# 11 CONCLUSION

The proposed development of Lots 4, 5 and 10 Francisco Road, Bonniefield is sustainable from a water management perspective. Given the existing ground and environmental conditions of the subject site, a total water cycle management is achievable by integrating the various components of the stormwater drainage system directing runoff into the receiving public open space environment in a controlled and sustainable way.

This is achieved by using a stormwater management system which will maintain water quantity and quality matching that of the pre-development condition in accordance with the principles and objectives outlined in this Local Water Management Strategy.

Signed by:

Christopher Elms *(BSc. Civil Eng. (Hons))*
Design Manager

Date:  15 May 2014

Signed by:

Ian McKellar
Project Manager

Date:  15 May 2014

# 12 REFERENCES


1. Bureau of Meteorology (2013). *Climate Statistics for Australian Locations: Geraldton Airport Comparison. http://www.bom.gov.au/jsp/ncc/cdio/cvg/av*

2. Department of Water (2004-2007). *Stormwater Management Manual for Western Australia*. Perth.

3. Department of Water (2004a). *Perth Groundwater Atlas. Second Edition*. Perth.

4. Department of Water (2004-7). *Decision Process for Stormwater Management in WA*.

5. Chappell, Lambert Everett (October 2010). *Shire of Irwin Local Planning Scheme No. 5, Amendment No. 10 – Scheme Amendment Report.*

6. GHD (2012). *Dongara Draft District Structure Plan: District Water Management Strategy. Shire of Irwin. http://www.irwin.wa.gov.au/Planning.aspx*

7. Landform Research (June 2005). *Land Capability and Geotechnical Assessment – Lots 10, 15, 16 and 17, Francisco Road, Dongara.*

8. WAPC (October 2008). *Better Urban Water Management*.

9. WAPC (June 2013). *Approved Local Planning Scheme Amendment, Shire of Irwin, Local Planning Scheme No. 5 – Amendment No. 15 (TPS/1014).*

10. AECOM (June 2012). *Francisco Road Proposed Rezoning – Desktop Preliminary Engineering Services Review; Revision 3.*

11. York Gum Services (October 2013). *Bushfire Management Plan: Francisco Road, Dongara.*

12. Department of Water (December 2008). *Interim: Developing a local water management strategy.*

13. Pilgrim, DH, (ed)., *Australian Rainfall and Runoff - A Guide to Flood Estimation,* Institution of Engineers, Australia, Barton, ACT, 1987.

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## 14 APPENDICES:

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**APPENDIX C:** Pre-Development Catchment Data

**APPENDIX D:** Hydrology & Drainage Design Data

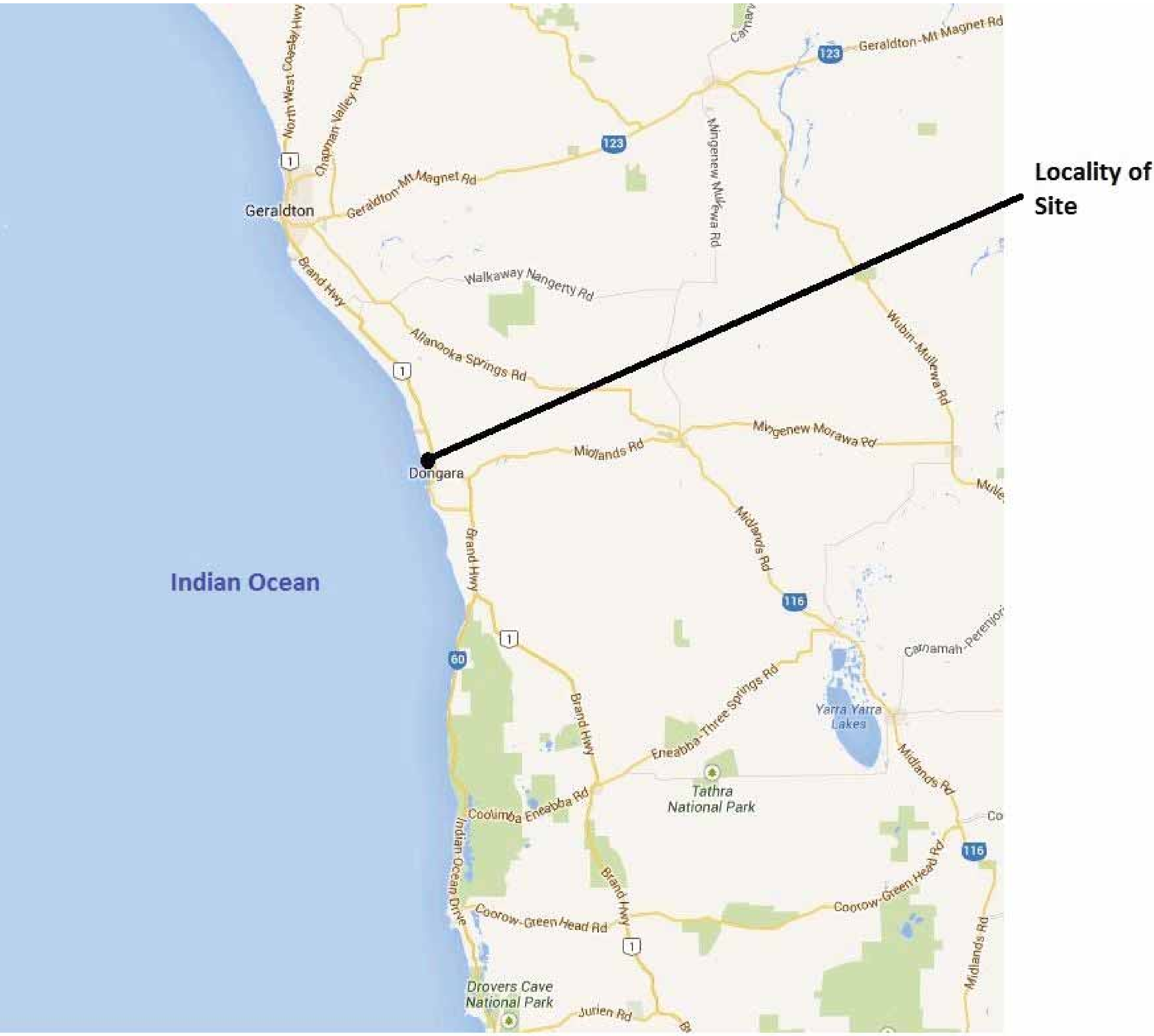



Figure 1: Locality of Subject Site

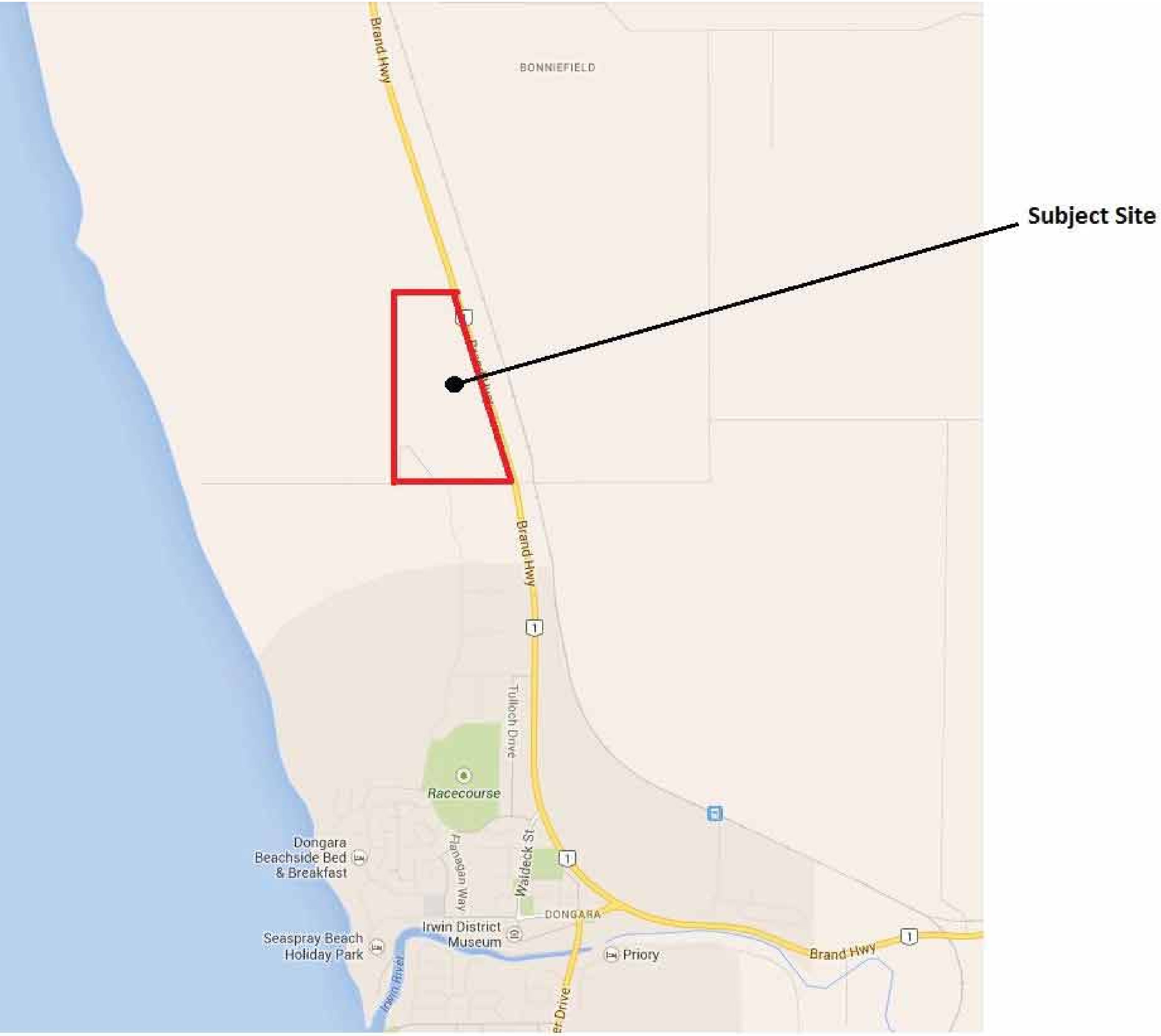



Figure 2: Subject Site Boundary


DE□ELOPMEN□CONCEP□PLAN

2172-□4B-01 (07.05.2014), nts

Francisco Road, Dongara□Figure 8

**Figure 3: Development Concept Plan** *(courtesy CLE - 2014)*

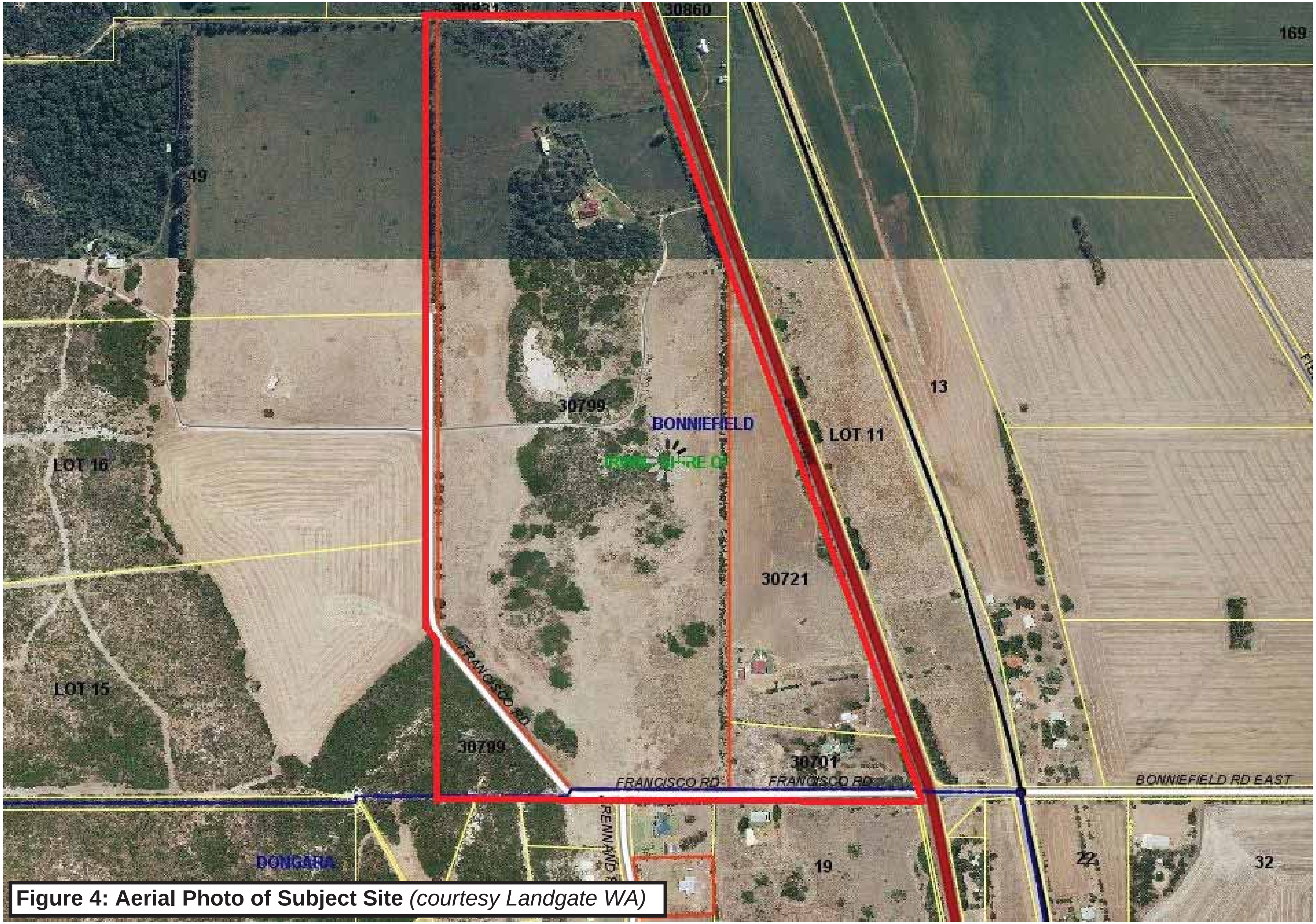
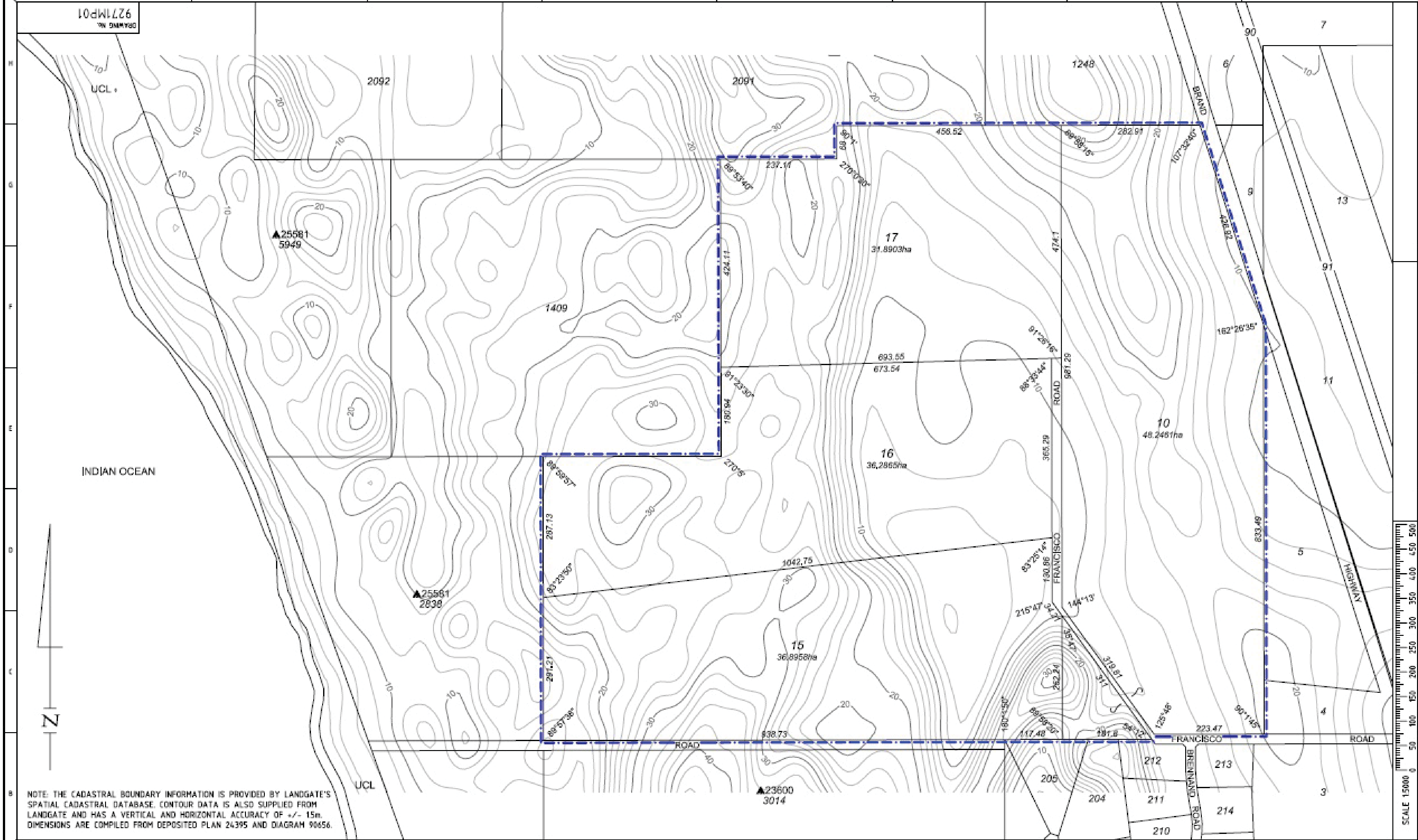



Figure 4: Aerial Photo of Subject Site *(courtesy Landgate WA)*




NOTE: THE CADASTRAL BOUNDARY INFORMATION IS PROVIDED BY LANDGATE'S SPATIAL CADASTRAL DATABASE. CONTOUR DATA IS ALSO SUPPLIED FROM LANDGATE AND HAS A VERTICAL AND HORIZONTAL ACCURACY OF +/- 15m. DIMENSIONS ARE COMPILED FROM DEPOSITED PLAN 24395 AND DIAGRAM 90656.

CLIENT

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| DRAWN | S. D'MELLO | 21/07/2009 |
| CHECKED | R. HUNT | 21/07/2009 |
| APPROVED | R. HUNT | 21/07/2009 |

PROJECT

TITLE
CONTOUR PLAN
LOTS 10, 15, 16 & 17
FRANCISCO ROAD,
BONNIEFIELD

| | | |
|---|---|---|
| DRAWING No. 9271MP01 | | |
| JOB No. 9271 | SCALE 1:5000 @ A2 | REV. |
| HORIZONTAL DATUM MGA ZONE 50 | VERTICAL DATUM A.H.D | |
| FIELD BOOK | LEVEL BOOK | |
| ADDITIONAL INFORMATION | | |

**Figure 5: Site Contour Plan**
*(courtesy Quantum Surveys - 2009)*

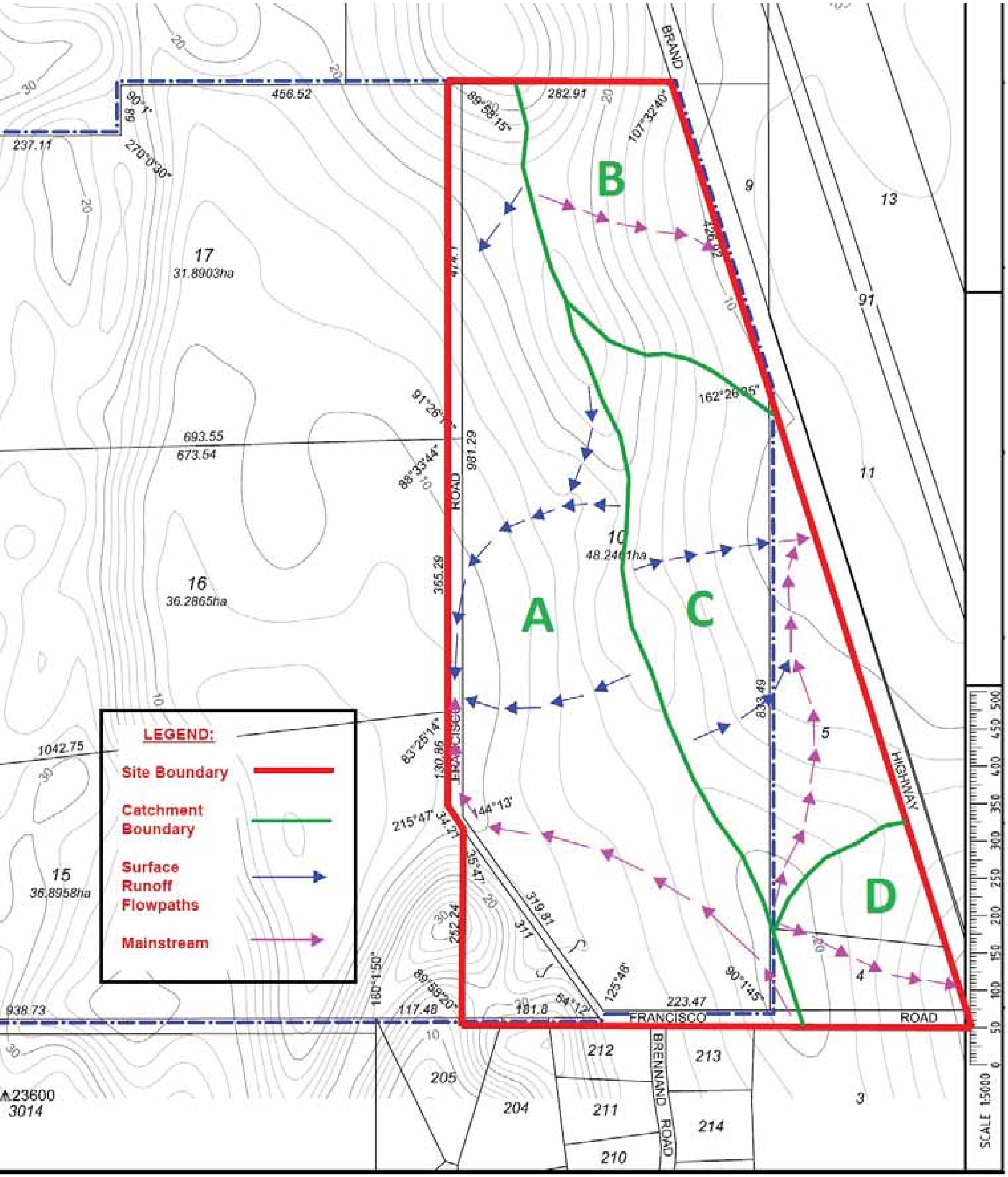
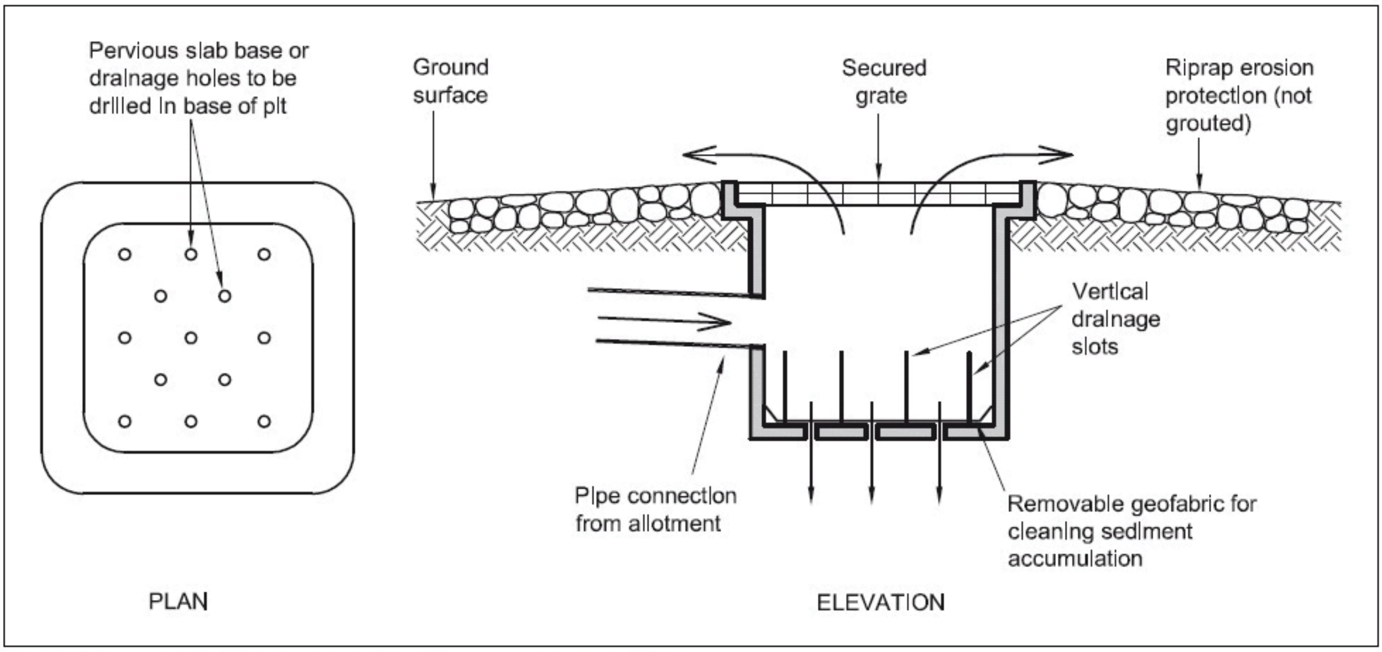
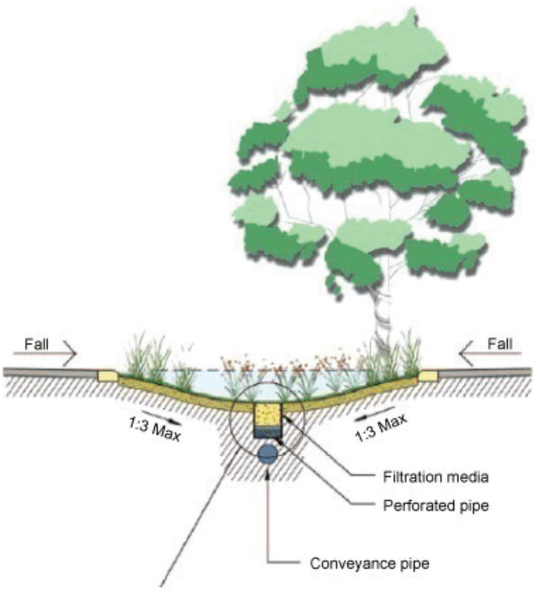



**Figure 6: Pre-development Catchment Delineation and Surface Runoff**


**Figure 7: Post-development Surface Runoff and Disposal**




*Bubble-up structure for discharge to a swale*




*Typical cross-section of a bio-retention swale*

**Figure 8: Typical Bubble-up Structure and Bio-retention Swale Details** *(courtesy DoW - 2007)*

# APPENDIX A: Brief Write-up on Rational Method Used as per AR&R 1987.

# Brief write-up on the Rational Method used as per AR&R 1987

*by John Rostom (2013)*

The Rational Method is a relatively conservative method for analysing stormwater surface runoff flows for various storm events. It is also the most commonly used approach. It is a probabilistic or statistical method for estimating design floods and peak flows of selected Average Recurrence Intervals (ARI) from an average rainfall intensity.

The peak flow rate ($m^3/s$) of average recurrence interval (ARI) of $Y$ years, $Q_y$, is derived using the following equation:

$$Q_y = C_y \cdot I_{tc\,,\,y} \cdot A$$

where $C_y$ = runoff coefficient (dimensionless) for ARI of Y years;
$I_{tc\,,\,y}$ = average rainfall intensity ($mm/h$) for design duration of $t_c$ hours and ARI of $Y$ years;
$A$ = area of catchment ($km^2$).

***Selection of $C_y$:***

Runoff coefficient $C$ for urban stormwater drainage can be interpreted in different ways. Fig. 14.13 of AR&R (1987) illustrates the preferred runoff coefficient relationship based on experience of drainage authorities and evidenced gauging from urban catchments. It relates the coefficient for a 10 year ARI, $C_{10}$, to the pervious and impervious fractions of the catchment, and to its rainfall climate, expressed through the 10 year ARI, 1 hour duration rainfall intensity, ${}^{10}I_1$.

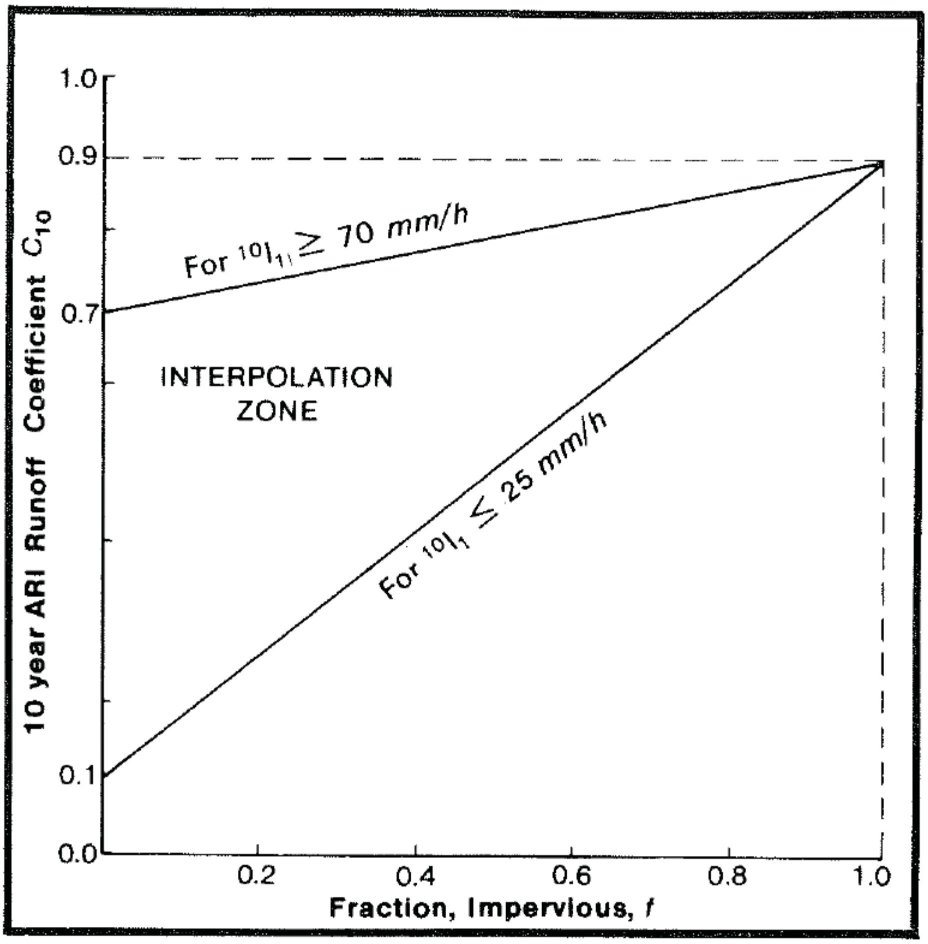



**Figure 14.13 – Runoff Coefficients**

The Runoff coefficient $C$ is calculated as follows:

$$C_y = F_y \cdot C_{10}$$

where $F_y$ = Frequency Factor for Rational Method Runoff Coefficients;
$C_{10}$ = Runoff Coefficient for a 10 year ARI.

$F_y$ is selected from the following table:

| ARI (*years*) | Frequency Factor, $F_y$ |
|---|---|
| 1 | 0.8 |
| 2 | 0.85 |
| 5 | 0.95 |
| 10 | 1.0 |
| 20 | 1.05 |
| 50 | 1.15 |
| 100 | 1.2 |

$C_{10}$ is calculated as follows:

$$C_{10} = 0.9 \text{ x } f + C^1_{10} \text{ x } (1 - f)$$

and

$$C^1_{10} = 0.1 + 0.0133 \text{ x } ({}^{10}I_1 - 25)$$

where $C^1_{10}$ = Pervious Area Runoff Coefficients;
${}^{10}I_1$ = Fraction Impervious (0.0 to 1.0).

***Selection of $I_{tc,y}$:***

Over the years, various procedures have been used to estimate the value of $t_c$, which is considered to be the travel time from the most remote point on the catchment to the outlet, or the time taken from the start of rainfall until all of the catchment is simultaneously contributing flow to the outlet. The procedure considered for the Rational Method analysis is the Bransby Williams procedure.

The following formula is used for deriving $t_c$:

$$t_c = \frac{58L}{A^{0.1} S_e^{0.2}}$$

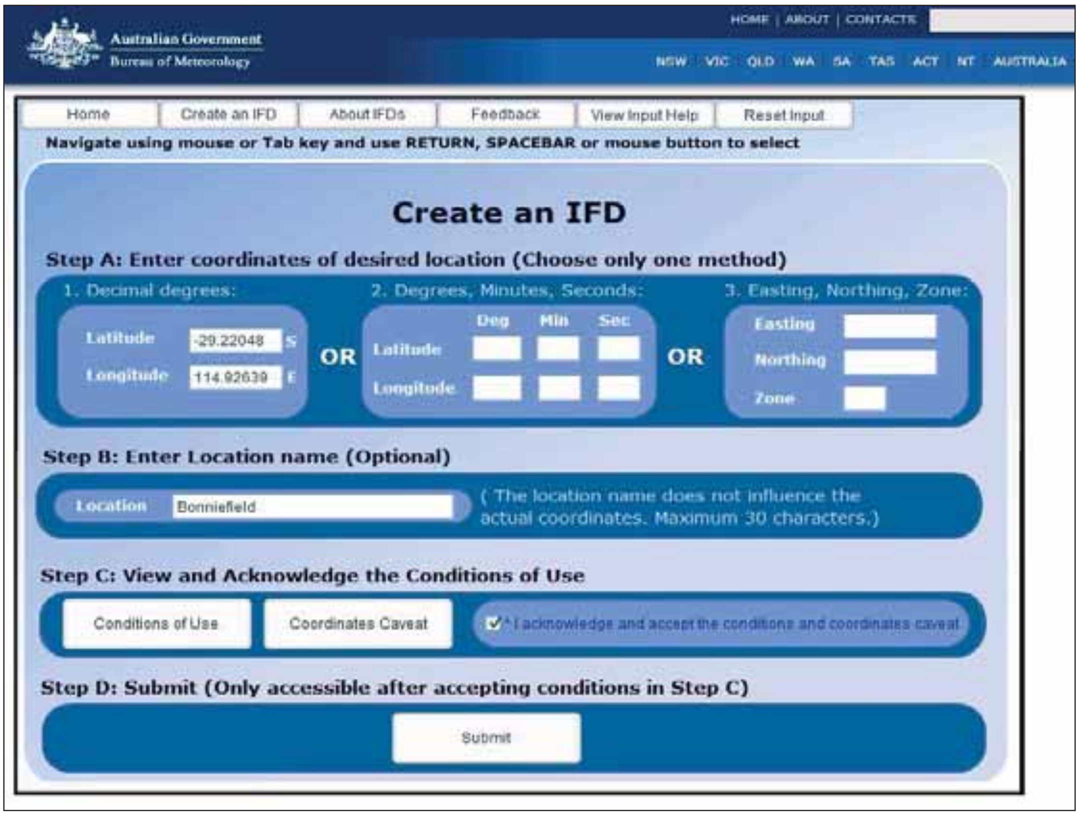
where $t_c$ = time of concentration (*min.*)
$L$ = mainstream length measured to the catchment divide (*km*)
$A$ = catchment area ($km^2$)
$S_e$ = equal area slope of the mainstream projected to the catchment divide (*m/km*)

For the procedure above, a unique $I_{tc,y}$ value is selected depending on the estimated $t_c$ and $C_y$ values.

# APPENDIX B: Design IFD Rainfall Data – Bureau of Meteorology

## Design Intensity-Frequency-Duration (IFD) Rainfall Data

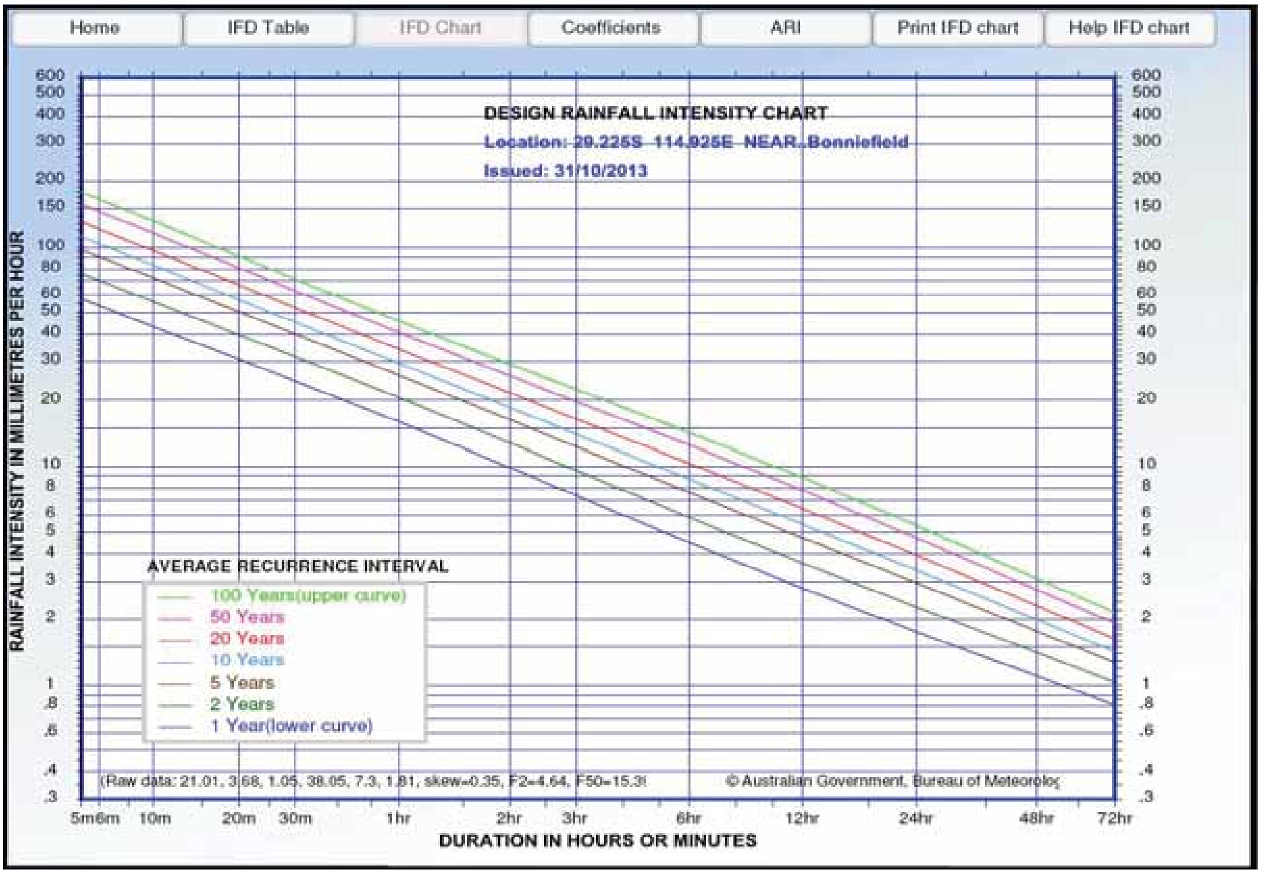
| | | | | |
|---|---|---|---|---|
| **By:** | John Rostom | | | |
| **Date:** | 31st October 2013 | | | |
| | | | | |
| **Source:** | Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System | | | |
| **Location:** | Bonniefield | | | |
| | | | *Latitude* | *Longitude* |
| **Inputs:** | **Geographic Coordinates:** | Decimal Degrees: | -29.22048° S | 114.92639° E |
| **IFD Tool Selection:** | **Geographic Coordinates:** | Decimal Degrees: | -29.225° S | 114.925° E |



**Design Intensity-Frequency-Duration (IFD) Rainfall Data**

**By:** John Rostom
**Date:** 31st October 2013

**Source:** Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System
**Location:** Bonniefield



## Design Intensity-Frequency-Duration (IFD) Rainfall Data

**By:** John Rostom
**Date:** 31st October 2013

**Source:** Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System
**Location:** Bonniefield

### Polynomial Coefficients Table

Location: 29.225S 114.925E NEAR.. Bonniefield Issued: 31/10/2013

List of coefficients to equations of the form

$$\log_e(I) = A + B \times (\log_e(T)) + C \times (\log_e(T))^2 + D \times (\log_e(T))^3 + E \times (\log_e(T))^4 + F \times (\log_e(T))^5 + G \times (\log_e(T))^6$$

T = Time in hours and I = Intensity in millimetres per hour

| YEARS | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | 2.7653331757 | -6.5761656E-1 | -4.6487994E-2 | 8.4572183E-3 | 2.0212787E-3 | -1.9751323E-4 | -6.0452916E-5 |
| 2 | 3.02054739 | -6.5514797E-1 | -4.2871047E-2 | 7.3963557E-3 | 1.7703272E-3 | -6.6952320E-5 | -7.8525030E-5 |
| 5 | 3.255695343 | -6.5385479E-1 | -3.2302871E-2 | 8.9688348E-3 | 2.8445110E-4 | -2.7972783E-4 | -4.1769400E-6 |
| 10 | 3.3803436756 | -6.5240002E-1 | -2.6748074E-2 | 9.2602381E-3 | -4.0829750E-4 | -3.2711477E-4 | 2.1444281E-5 |
| 20 | 3.5300955772 | -6.5121728E-1 | -2.1613294E-2 | 9.6158953E-3 | -1.0782350E-3 | -3.7923179E-4 | 4.7622714E-5 |
| 50 | 3.7057449818 | -6.4978689E-1 | -1.5788674E-2 | 9.9562742E-3 | -1.8504282E-3 | -4.3431760E-4 | 7.8021709E-5 |
| 100 | 3.8266773224 | -6.4937431E-1 | -1.1371864E-2 | 1.0492197E-2 | -2.4563114E-3 | -5.0131162E-4 | 1.0521018E-4 |

(Raw data: 21.01, 3.68, 1.05, 38.05, 7.3, 1.81, skew=0.35, F2=4.64, F50=15.39)



| ARI in years | coefficient A | coefficient B | coefficient C | coefficient D | coefficient E | coefficient F | coefficient G |
|---|---|---|---|---|---|---|---|
| 1 | 2.7653331757E+00 | -6.5761656000E-01 | -4.6487994000E-02 | 8.4572183000E-03 | 2.0212787000E-03 | -1.9751323000E-04 | -6.0452916000E-05 |
| 2 | 3.0205473900E+00 | -6.5514797000E-01 | -4.2871047000E-02 | 7.3963557000E-03 | 1.7703272000E-03 | -6.6952320000E-05 | -7.8525030000E-05 |
| 5 | 3.2556953430E+00 | -6.5385479000E-01 | -3.2302871000E-02 | 8.9688348000E-03 | 2.8445110000E-04 | -2.7972783000E-04 | -4.1769400000E-06 |
| 10 | 3.3803436756E+00 | -6.5240002000E-01 | -2.6748074000E-02 | 9.2602381000E-03 | -4.0829750000E-04 | -3.2711477000E-04 | 2.1444281000E-05 |
| 20 | 3.5300955772E+00 | -6.5121728000E-01 | -2.1613294000E-02 | 9.6158953000E-03 | -1.0782350000E-03 | -3.7923179000E-04 | 4.7622714000E-05 |
| 50 | 3.7057449818E+00 | -6.4978689000E-01 | -1.5788674000E-02 | 9.9562742000E-03 | -1.8504282000E-03 | -4.3431760000E-04 | 7.8021709000E-05 |
| 100 | 3.8266773224E+00 | -6.4937431000E-01 | -1.1371864000E-02 | 1.0492197000E-02 | -2.4563114000E-03 | -5.0131162000E-04 | 1.0521018000E-04 |

## Design Intensity-Frequency-Duration (IFD) Rainfall Data

**By:** John Rostom
**Date:** 31st October 2013

**Source:** Bureau of Meteorology: Web-based Tool: Rainfall IFD Data System
**Location:** Bonniefield

### Intensity-Frequency-Duration Table

Location: 29.225S 114.925E NEAR.. Bonniefield Issued: 31/10/2013

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

| Duration | 1 YEAR | 2 YEARS | 5 YEARS | 10 YEARS | 20 YEARS | 50 YEARS | 100 YEARS |
|---|---|---|---|---|---|---|---|
| 5Mins | 58.2 | 75.6 | 97.5 | 112 | 131 | 157 | 179 |
| 6Mins | 54.1 | 70.4 | 90.6 | 104 | 121 | 146 | 166 |
| 10Mins | 43.3 | 56.3 | 72.2 | 82.5 | 96.5 | 116 | 132 |
| 20Mins | 30.7 | 39.7 | 50.6 | 57.5 | 67.1 | 80.3 | 90.9 |
| 30Mins | 24.4 | 31.6 | 40.1 | 45.4 | 52.9 | 63.1 | 71.3 |
| 1Hr | 15.9 | 20.5 | 25.9 | 29.4 | 34.1 | 40.7 | 45.9 |
| 2Hrs | 9.88 | 12.8 | 16.3 | 18.5 | 21.6 | 25.8 | 29.2 |
| 3Hrs | 7.39 | 9.59 | 12.3 | 14.0 | 16.4 | 19.7 | 22.4 |
| 6Hrs | 4.49 | 5.85 | 7.61 | 8.75 | 10.3 | 12.5 | 14.2 |
| 12Hrs | 2.77 | 3.61 | 4.72 | 5.44 | 6.42 | 7.79 | 8.91 |
| 24Hrs | 1.75 | 2.27 | 2.93 | 3.35 | 3.92 | 4.72 | 5.37 |
| 48Hrs | 1.10 | 1.41 | 1.76 | 1.99 | 2.30 | 2.72 | 3.06 |
| 72Hrs | .809 | 1.03 | 1.27 | 1.42 | 1.63 | 1.92 | 2.15 |

(Raw data: 21.01, 3.68, 1.05, 38.05, 7.3, 1.81, skew=0.35, F2=4.64, F50=15.39)

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 1 | 0.02 | -4.094 | 100.3 | 107.9 | 173.8 | 206.5 | 252.6 | 319.1 | 386.4 |
| 2 | 0.03 | -3.401 | 81.3 | 100.3 | 135.9 | 156.5 | 184.7 | 224.1 | 258.1 |
| 3 | 0.05 | -2.996 | 70.6 | 90.2 | 118.0 | 135.3 | 158.8 | 191.5 | 218.6 |
| 4 | 0.07 | -2.708 | 63.5 | 82.1 | 106.2 | 121.7 | 142.6 | 171.8 | 195.6 |
| **5** | **0.08** | **-2.485** | **58.2** | **75.6** | **97.5** | **111.6** | **130.8** | **157.5** | **179.1** |
| **6** | **0.10** | **-2.303** | **54.1** | **70.4** | **90.6** | **103.6** | **121.4** | **146.1** | **166.1** |
| 7 | 0.12 | -2.148 | 50.7 | 66.0 | 84.8 | 97.0 | 113.7 | 136.8 | 155.4 |
| 8 | 0.13 | -2.015 | 47.9 | 62.3 | 80.0 | 91.5 | 107.1 | 128.8 | 146.4 |
| 9 | 0.15 | -1.897 | 45.4 | 59.1 | 75.9 | 86.7 | 101.5 | 122.0 | 138.6 |
| **10** | **0.17** | **-1.792** | **43.3** | **56.3** | **72.2** | **82.5** | **96.5** | **116.0** | **131.7** |
| 11 | 0.18 | -1.696 | 41.4 | 53.9 | 69.0 | 78.8 | 92.1 | 110.7 | 125.7 |
| 12 | 0.20 | -1.609 | 39.8 | 51.6 | 66.1 | 75.5 | 88.2 | 105.9 | 120.2 |
| 13 | 0.22 | -1.529 | 38.2 | 49.7 | 63.6 | 72.5 | 84.7 | 101.6 | 115.3 |
| 14 | 0.23 | -1.455 | 36.9 | 47.8 | 61.2 | 69.8 | 81.5 | 97.8 | 110.9 |
| 15 | 0.25 | -1.386 | 35.6 | 46.2 | 59.1 | 67.3 | 78.6 | 94.2 | 106.8 |
| 16 | 0.27 | -1.322 | 34.5 | 44.7 | 57.1 | 65.0 | 75.9 | 91.0 | 103.1 |
| 17 | 0.28 | -1.261 | 33.4 | 43.3 | 55.3 | 62.9 | 73.4 | 88.0 | 99.7 |
| 18 | 0.30 | -1.204 | 32.4 | 42.0 | 53.6 | 61.0 | 71.2 | 85.2 | 96.6 |
| 19 | 0.32 | -1.150 | 31.5 | 40.8 | 52.1 | 59.2 | 69.0 | 82.7 | 93.6 |
| **20** | **0.33** | **-1.099** | **30.7** | **39.7** | **50.6** | **57.5** | **67.1** | **80.3** | **90.9** |
| 21 | 0.35 | -1.050 | 29.9 | 38.7 | 49.2 | 56.0 | 65.2 | 78.1 | 88.4 |
| 22 | 0.37 | -1.003 | 29.1 | 37.7 | 48.0 | 54.5 | 63.5 | 76.0 | 86.0 |
| 23 | 0.38 | -0.959 | 28.4 | 36.8 | 46.8 | 53.1 | 61.9 | 74.0 | 83.8 |
| 24 | 0.40 | -0.916 | 27.8 | 35.9 | 45.7 | 51.9 | 60.4 | 72.2 | 81.7 |
| 25 | 0.42 | -0.875 | 27.1 | 35.1 | 44.6 | 50.6 | 59.0 | 70.5 | 79.7 |
| 26 | 0.43 | -0.836 | 26.5 | 34.3 | 43.6 | 49.5 | 57.6 | 68.8 | 77.8 |
| 27 | 0.45 | -0.799 | 26.0 | 33.6 | 42.6 | 48.4 | 56.3 | 67.3 | 76.1 |
| 28 | 0.47 | -0.762 | 25.4 | 32.9 | 41.7 | 47.4 | 55.1 | 65.8 | 74.4 |
| 29 | 0.48 | -0.727 | 24.9 | 32.2 | 40.9 | 46.4 | 54.0 | 64.4 | 72.8 |
| **30** | **0.50** | **-0.693** | **24.4** | **31.6** | **40.1** | **45.4** | **52.9** | **63.1** | **71.3** |
| 31 | 0.52 | -0.660 | 24.0 | 31.0 | 39.3 | 44.6 | 51.8 | 61.9 | 69.9 |
| 32 | 0.53 | -0.629 | 23.5 | 30.4 | 38.5 | 43.7 | 50.8 | 60.7 | 68.5 |
| 33 | 0.55 | -0.598 | 23.1 | 29.8 | 37.8 | 42.9 | 49.9 | 59.5 | 67.2 |
| 34 | 0.57 | -0.568 | 22.7 | 29.3 | 37.2 | 42.1 | 49.0 | 58.4 | 66.0 |
| 35 | 0.58 | -0.539 | 22.3 | 28.8 | 36.5 | 41.4 | 48.1 | 57.4 | 64.8 |
| 36 | 0.60 | -0.511 | 21.9 | 28.3 | 35.9 | 40.7 | 47.3 | 56.4 | 63.7 |
| 37 | 0.62 | -0.483 | 21.6 | 27.8 | 35.3 | 40.0 | 46.5 | 55.4 | 62.6 |
| 38 | 0.63 | -0.457 | 21.2 | 27.4 | 34.7 | 39.3 | 45.7 | 54.5 | 61.5 |
| 39 | 0.65 | -0.431 | 20.9 | 27.0 | 34.1 | 38.7 | 45.0 | 53.6 | 60.5 |
| 40 | 0.67 | -0.405 | 20.6 | 26.5 | 33.6 | 38.1 | 44.3 | 52.8 | 59.6 |
| 41 | 0.68 | -0.381 | 20.3 | 26.1 | 33.1 | 37.5 | 43.6 | 52.0 | 58.7 |
| 42 | 0.70 | -0.357 | 20.0 | 25.8 | 32.6 | 36.9 | 42.9 | 51.2 | 57.8 |
| 43 | 0.72 | -0.333 | 19.7 | 25.4 | 32.1 | 36.4 | 42.3 | 50.4 | 56.9 |
| 44 | 0.73 | -0.310 | 19.4 | 25.0 | 31.7 | 35.9 | 41.7 | 49.7 | 56.1 |
| 45 | 0.75 | -0.288 | 19.1 | 24.7 | 31.2 | 35.4 | 41.1 | 49.0 | 55.3 |
| 46 | 0.77 | -0.266 | 18.9 | 24.3 | 30.8 | 34.9 | 40.5 | 48.3 | 54.5 |
| 47 | 0.78 | -0.244 | 18.6 | 24.0 | 30.4 | 34.4 | 40.0 | 47.6 | 53.8 |
| 48 | 0.80 | -0.223 | 18.4 | 23.7 | 30.0 | 33.9 | 39.4 | 47.0 | 53.0 |
| 49 | 0.82 | -0.203 | 18.1 | 23.4 | 29.6 | 33.5 | 38.9 | 46.4 | 52.3 |
| 50 | 0.83 | -0.182 | 17.9 | 23.1 | 29.2 | 33.1 | 38.4 | 45.8 | 51.7 |
| 51 | 0.85 | -0.163 | 17.7 | 22.8 | 28.8 | 32.6 | 37.9 | 45.2 | 51.0 |
| 52 | 0.87 | -0.143 | 17.4 | 22.5 | 28.5 | 32.2 | 37.4 | 44.6 | 50.4 |
| 53 | 0.88 | -0.124 | 17.2 | 22.2 | 28.1 | 31.8 | 37.0 | 44.1 | 49.8 |
| 54 | 0.90 | -0.105 | 17.0 | 22.0 | 27.8 | 31.5 | 36.5 | 43.6 | 49.2 |
| 55 | 0.92 | -0.087 | 16.8 | 21.7 | 27.4 | 31.1 | 36.1 | 43.0 | 48.6 |
| 56 | 0.93 | -0.069 | 16.6 | 21.4 | 27.1 | 30.7 | 35.7 | 42.5 | 48.0 |
| 57 | 0.95 | -0.051 | 16.4 | 21.2 | 26.8 | 30.4 | 35.3 | 42.1 | 47.5 |
| 58 | 0.97 | -0.034 | 16.2 | 21.0 | 26.5 | 30.0 | 34.9 | 41.6 | 46.9 |
| 59 | 0.98 | -0.017 | 16.1 | 20.7 | 26.2 | 29.7 | 34.5 | 41.1 | 46.4 |
| **60** | **1.00** | **0.000** | **15.9** | **20.5** | **25.9** | **29.4** | **34.1** | **40.7** | **45.9** |
| 61 | 1.02 | 0.017 | 15.7 | 20.3 | 25.7 | 29.1 | 33.8 | 40.2 | 45.4 |
| 62 | 1.03 | 0.033 | 15.5 | 20.1 | 25.4 | 28.8 | 33.4 | 39.8 | 44.9 |
| 63 | 1.05 | 0.049 | 15.4 | 19.9 | 25.1 | 28.5 | 33.1 | 39.4 | 44.5 |
| 64 | 1.07 | 0.065 | 15.2 | 19.7 | 24.9 | 28.2 | 32.7 | 39.0 | 44.0 |
| 65 | 1.08 | 0.080 | 15.1 | 19.4 | 24.6 | 27.9 | 32.4 | 38.6 | 43.6 |
| 66 | 1.10 | 0.095 | 14.9 | 19.3 | 24.4 | 27.6 | 32.1 | 38.2 | 43.2 |
| 67 | 1.12 | 0.110 | 14.8 | 19.1 | 24.1 | 27.3 | 31.8 | 37.9 | 42.7 |

| Duration, T (minutes) | Duration, T (hours) | *ln* T | Design Average Rainfall Intensities (mm/hr) ARI (yrs): 1 | 2 | 5 | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| 68 | 1.13 | 0.125 | 14.6 | 18.9 | 23.9 | 27.1 | 31.4 | 37.5 | 42.3 |
| 69 | 1.15 | 0.140 | 14.5 | 18.7 | 23.7 | 26.8 | 31.1 | 37.1 | 41.9 |
| 70 | 1.17 | 0.154 | 14.3 | 18.5 | 23.4 | 26.6 | 30.9 | 36.8 | 41.5 |
| 71 | 1.18 | 0.168 | 14.2 | 18.3 | 23.2 | 26.3 | 30.6 | 36.5 | 41.1 |
| 72 | 1.20 | 0.182 | 14.1 | 18.2 | 23.0 | 26.1 | 30.3 | 36.1 | 40.8 |
| 73 | 1.22 | 0.196 | 13.9 | 18.0 | 22.8 | 25.8 | 30.0 | 35.8 | 40.4 |
| 74 | 1.23 | 0.210 | 13.8 | 17.8 | 22.6 | 25.6 | 29.7 | 35.5 | 40.0 |
| 75 | 1.25 | 0.223 | 13.7 | 17.7 | 22.4 | 25.4 | 29.5 | 35.2 | 39.7 |
| 76 | 1.27 | 0.236 | 13.6 | 17.5 | 22.2 | 25.1 | 29.2 | 34.9 | 39.4 |
| 77 | 1.28 | 0.249 | 13.4 | 17.4 | 22.0 | 24.9 | 29.0 | 34.6 | 39.0 |
| 78 | 1.30 | 0.262 | 13.3 | 17.2 | 21.8 | 24.7 | 28.7 | 34.3 | 38.7 |
| 79 | 1.32 | 0.275 | 13.2 | 17.1 | 21.6 | 24.5 | 28.5 | 34.0 | 38.4 |
| 80 | 1.33 | 0.288 | 13.1 | 16.9 | 21.4 | 24.3 | 28.3 | 33.7 | 38.1 |
| 81 | 1.35 | 0.300 | 13.0 | 16.8 | 21.3 | 24.1 | 28.0 | 33.4 | 37.8 |
| 82 | 1.37 | 0.312 | 12.9 | 16.6 | 21.1 | 23.9 | 27.8 | 33.2 | 37.5 |
| 83 | 1.38 | 0.324 | 12.8 | 16.5 | 20.9 | 23.7 | 27.6 | 32.9 | 37.2 |
| 84 | 1.40 | 0.336 | 12.7 | 16.4 | 20.7 | 23.5 | 27.4 | 32.6 | 36.9 |
| 85 | 1.42 | 0.348 | 12.6 | 16.2 | 20.6 | 23.3 | 27.1 | 32.4 | 36.6 |
| 86 | 1.43 | 0.360 | 12.5 | 16.1 | 20.4 | 23.2 | 26.9 | 32.1 | 36.3 |
| 87 | 1.45 | 0.372 | 12.4 | 16.0 | 20.3 | 23.0 | 26.7 | 31.9 | 36.0 |
| 88 | 1.47 | 0.383 | 12.3 | 15.9 | 20.1 | 22.8 | 26.5 | 31.7 | 35.8 |
| 89 | 1.48 | 0.394 | 12.2 | 15.7 | 20.0 | 22.6 | 26.3 | 31.4 | 35.5 |
| 90 | 1.50 | 0.405 | 12.1 | 15.6 | 19.8 | 22.5 | 26.1 | 31.2 | 35.2 |
| 91 | 1.52 | 0.417 | 12.0 | 15.5 | 19.7 | 22.3 | 25.9 | 31.0 | 35.0 |
| 92 | 1.53 | 0.427 | 11.9 | 15.4 | 19.5 | 22.1 | 25.8 | 30.7 | 34.7 |
| 93 | 1.55 | 0.438 | 11.8 | 15.3 | 19.4 | 22.0 | 25.6 | 30.5 | 34.5 |
| 94 | 1.57 | 0.449 | 11.7 | 15.2 | 19.2 | 21.8 | 25.4 | 30.3 | 34.3 |
| 95 | 1.58 | 0.460 | 11.6 | 15.0 | 19.1 | 21.7 | 25.2 | 30.1 | 34.0 |
| 96 | 1.60 | 0.470 | 11.6 | 14.9 | 19.0 | 21.5 | 25.0 | 29.9 | 33.8 |
| 97 | 1.62 | 0.480 | 11.5 | 14.8 | 18.8 | 21.4 | 24.9 | 29.7 | 33.6 |
| 98 | 1.63 | 0.491 | 11.4 | 14.7 | 18.7 | 21.2 | 24.7 | 29.5 | 33.3 |
| 99 | 1.65 | 0.501 | 11.3 | 14.6 | 18.6 | 21.1 | 24.5 | 29.3 | 33.1 |
| 100 | 1.67 | 0.511 | 11.2 | 14.5 | 18.4 | 20.9 | 24.4 | 29.1 | 32.9 |
| 101 | 1.68 | 0.521 | 11.2 | 14.4 | 18.3 | 20.8 | 24.2 | 28.9 | 32.7 |
| 102 | 1.70 | 0.531 | 11.1 | 14.3 | 18.2 | 20.7 | 24.0 | 28.7 | 32.5 |
| 103 | 1.72 | 0.540 | 11.0 | 14.2 | 18.1 | 20.5 | 23.9 | 28.5 | 32.3 |
| 104 | 1.73 | 0.550 | 10.9 | 14.1 | 18.0 | 20.4 | 23.7 | 28.4 | 32.1 |
| 105 | 1.75 | 0.560 | 10.9 | 14.0 | 17.8 | 20.3 | 23.6 | 28.2 | 31.9 |
| 106 | 1.77 | 0.569 | 10.8 | 13.9 | 17.7 | 20.1 | 23.4 | 28.0 | 31.7 |
| 107 | 1.78 | 0.578 | 10.7 | 13.9 | 17.6 | 20.0 | 23.3 | 27.8 | 31.5 |
| 108 | 1.80 | 0.588 | 10.6 | 13.8 | 17.5 | 19.9 | 23.1 | 27.7 | 31.3 |
| 109 | 1.82 | 0.597 | 10.6 | 13.7 | 17.4 | 19.8 | 23.0 | 27.5 | 31.1 |
| 110 | 1.83 | 0.606 | 10.5 | 13.6 | 17.3 | 19.6 | 22.9 | 27.3 | 30.9 |
| 111 | 1.85 | 0.615 | 10.4 | 13.5 | 17.2 | 19.5 | 22.7 | 27.2 | 30.7 |
| 112 | 1.87 | 0.624 | 10.4 | 13.4 | 17.1 | 19.4 | 22.6 | 27.0 | 30.5 |
| 113 | 1.88 | 0.633 | 10.3 | 13.3 | 17.0 | 19.3 | 22.5 | 26.8 | 30.4 |
| 114 | 1.90 | 0.642 | 10.2 | 13.3 | 16.9 | 19.2 | 22.3 | 26.7 | 30.2 |
| 115 | 1.92 | 0.651 | 10.2 | 13.2 | 16.8 | 19.0 | 22.2 | 26.5 | 30.0 |
| 116 | 1.93 | 0.659 | 10.1 | 13.1 | 16.7 | 18.9 | 22.1 | 26.4 | 29.8 |
| 117 | 1.95 | 0.668 | 10.1 | 13.0 | 16.6 | 18.8 | 21.9 | 26.2 | 29.7 |
| 118 | 1.97 | 0.676 | 10.0 | 12.9 | 16.5 | 18.7 | 21.8 | 26.1 | 29.5 |
| 119 | 1.98 | 0.685 | 9.9 | 12.9 | 16.4 | 18.6 | 21.7 | 25.9 | 29.4 |
| **120** | **2.00** | **0.693** | **9.9** | **12.8** | **16.3** | **18.5** | **21.6** | **25.8** | **29.2** |
| 121 | 2.02 | 0.701 | 9.8 | 12.7 | 16.2 | 18.4 | 21.4 | 25.7 | 29.0 |
| 122 | 2.03 | 0.710 | 9.8 | 12.6 | 16.1 | 18.3 | 21.3 | 25.5 | 28.9 |
| 123 | 2.05 | 0.718 | 9.7 | 12.6 | 16.0 | 18.2 | 21.2 | 25.4 | 28.7 |
| 124 | 2.07 | 0.726 | 9.7 | 12.5 | 15.9 | 18.1 | 21.1 | 25.3 | 28.6 |
| 125 | 2.08 | 0.734 | 9.6 | 12.4 | 15.8 | 18.0 | 21.0 | 25.1 | 28.4 |
| 126 | 2.10 | 0.742 | 9.5 | 12.4 | 15.7 | 17.9 | 20.9 | 25.0 | 28.3 |
| 127 | 2.12 | 0.750 | 9.5 | 12.3 | 15.7 | 17.8 | 20.8 | 24.9 | 28.1 |
| 128 | 2.13 | 0.758 | 9.4 | 12.2 | 15.6 | 17.7 | 20.7 | 24.7 | 28.0 |
| 129 | 2.15 | 0.765 | 9.4 | 12.2 | 15.5 | 17.6 | 20.5 | 24.6 | 27.8 |
| 130 | 2.17 | 0.773 | 9.3 | 12.1 | 15.4 | 17.5 | 20.4 | 24.5 | 27.7 |
| 131 | 2.18 | 0.781 | 9.3 | 12.0 | 15.3 | 17.4 | 20.3 | 24.4 | 27.6 |
| 132 | 2.20 | 0.788 | 9.2 | 12.0 | 15.2 | 17.4 | 20.2 | 24.2 | 27.4 |
| 133 | 2.22 | 0.796 | 9.2 | 11.9 | 15.2 | 17.3 | 20.1 | 24.1 | 27.3 |
| 134 | 2.23 | 0.803 | 9.1 | 11.8 | 15.1 | 17.2 | 20.0 | 24.0 | 27.2 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 135 | 2.25 | 0.811 | 9.1 | 11.8 | 15.0 | 17.1 | 19.9 | 23.9 | 27.0 |
| 136 | 2.27 | 0.818 | 9.0 | 11.7 | 14.9 | 17.0 | 19.8 | 23.8 | 26.9 |
| 137 | 2.28 | 0.826 | 9.0 | 11.7 | 14.9 | 16.9 | 19.7 | 23.6 | 26.8 |
| 138 | 2.30 | 0.833 | 8.9 | 11.6 | 14.8 | 16.8 | 19.6 | 23.5 | 26.6 |
| 139 | 2.32 | 0.840 | 8.9 | 11.5 | 14.7 | 16.8 | 19.5 | 23.4 | 26.5 |
| 140 | 2.33 | 0.847 | 8.9 | 11.5 | 14.6 | 16.7 | 19.5 | 23.3 | 26.4 |
| 141 | 2.35 | 0.854 | 8.8 | 11.4 | 14.6 | 16.6 | 19.4 | 23.2 | 26.3 |
| 142 | 2.37 | 0.861 | 8.8 | 11.4 | 14.5 | 16.5 | 19.3 | 23.1 | 26.2 |
| 143 | 2.38 | 0.869 | 8.7 | 11.3 | 14.4 | 16.4 | 19.2 | 23.0 | 26.0 |
| 144 | 2.40 | 0.875 | 8.7 | 11.2 | 14.4 | 16.4 | 19.1 | 22.9 | 25.9 |
| 145 | 2.42 | 0.882 | 8.6 | 11.2 | 14.3 | 16.3 | 19.0 | 22.8 | 25.8 |
| 146 | 2.43 | 0.889 | 8.6 | 11.1 | 14.2 | 16.2 | 18.9 | 22.7 | 25.7 |
| 147 | 2.45 | 0.896 | 8.6 | 11.1 | 14.2 | 16.1 | 18.8 | 22.6 | 25.6 |
| 148 | 2.47 | 0.903 | 8.5 | 11.0 | 14.1 | 16.1 | 18.7 | 22.5 | 25.5 |
| 149 | 2.48 | 0.910 | 8.5 | 11.0 | 14.0 | 16.0 | 18.7 | 22.4 | 25.3 |
| 150 | 2.50 | 0.916 | 8.4 | 10.9 | 14.0 | 15.9 | 18.6 | 22.3 | 25.2 |
| 151 | 2.52 | 0.923 | 8.4 | 10.9 | 13.9 | 15.8 | 18.5 | 22.2 | 25.1 |
| 152 | 2.53 | 0.930 | 8.3 | 10.8 | 13.8 | 15.8 | 18.4 | 22.1 | 25.0 |
| 153 | 2.55 | 0.936 | 8.3 | 10.8 | 13.8 | 15.7 | 18.3 | 22.0 | 24.9 |
| 154 | 2.57 | 0.943 | 8.3 | 10.7 | 13.7 | 15.6 | 18.2 | 21.9 | 24.8 |
| 155 | 2.58 | 0.949 | 8.2 | 10.7 | 13.6 | 15.6 | 18.2 | 21.8 | 24.7 |
| 156 | 2.60 | 0.956 | 8.2 | 10.6 | 13.6 | 15.5 | 18.1 | 21.7 | 24.6 |
| 157 | 2.62 | 0.962 | 8.2 | 10.6 | 13.5 | 15.4 | 18.0 | 21.6 | 24.5 |
| 158 | 2.63 | 0.968 | 8.1 | 10.5 | 13.5 | 15.4 | 17.9 | 21.5 | 24.4 |
| 159 | 2.65 | 0.975 | 8.1 | 10.5 | 13.4 | 15.3 | 17.9 | 21.4 | 24.3 |
| 160 | 2.67 | 0.981 | 8.0 | 10.4 | 13.4 | 15.2 | 17.8 | 21.3 | 24.2 |
| 161 | 2.68 | 0.987 | 8.0 | 10.4 | 13.3 | 15.2 | 17.7 | 21.3 | 24.1 |
| 162 | 2.70 | 0.993 | 8.0 | 10.3 | 13.2 | 15.1 | 17.6 | 21.2 | 24.0 |
| 163 | 2.72 | 0.999 | 7.9 | 10.3 | 13.2 | 15.0 | 17.6 | 21.1 | 23.9 |
| 164 | 2.73 | 1.006 | 7.9 | 10.3 | 13.1 | 15.0 | 17.5 | 21.0 | 23.8 |
| 165 | 2.75 | 1.012 | 7.9 | 10.2 | 13.1 | 14.9 | 17.4 | 20.9 | 23.7 |
| 166 | 2.77 | 1.018 | 7.8 | 10.2 | 13.0 | 14.8 | 17.4 | 20.8 | 23.6 |
| 167 | 2.78 | 1.024 | 7.8 | 10.1 | 13.0 | 14.8 | 17.3 | 20.7 | 23.5 |
| 168 | 2.80 | 1.030 | 7.8 | 10.1 | 12.9 | 14.7 | 17.2 | 20.7 | 23.4 |
| 169 | 2.82 | 1.036 | 7.7 | 10.0 | 12.9 | 14.7 | 17.1 | 20.6 | 23.3 |
| 170 | 2.83 | 1.041 | 7.7 | 10.0 | 12.8 | 14.6 | 17.1 | 20.5 | 23.3 |
| 171 | 2.85 | 1.047 | 7.7 | 10.0 | 12.8 | 14.5 | 17.0 | 20.4 | 23.2 |
| 172 | 2.87 | 1.053 | 7.6 | 9.9 | 12.7 | 14.5 | 16.9 | 20.3 | 23.1 |
| 173 | 2.88 | 1.059 | 7.6 | 9.9 | 12.7 | 14.4 | 16.9 | 20.3 | 23.0 |
| 174 | 2.90 | 1.065 | 7.6 | 9.8 | 12.6 | 14.4 | 16.8 | 20.2 | 22.9 |
| 175 | 2.92 | 1.070 | 7.5 | 9.8 | 12.6 | 14.3 | 16.7 | 20.1 | 22.8 |
| 176 | 2.93 | 1.076 | 7.5 | 9.7 | 12.5 | 14.3 | 16.7 | 20.0 | 22.7 |
| 177 | 2.95 | 1.082 | 7.5 | 9.7 | 12.5 | 14.2 | 16.6 | 20.0 | 22.7 |
| 178 | 2.97 | 1.087 | 7.5 | 9.7 | 12.4 | 14.2 | 16.6 | 19.9 | 22.6 |
| 179 | 2.98 | 1.093 | 7.4 | 9.6 | 12.4 | 14.1 | 16.5 | 19.8 | 22.5 |
| **180** | **3.00** | **1.099** | **7.4** | **9.6** | **12.3** | **14.0** | **16.4** | **19.7** | **22.4** |
| 181 | 3.02 | 1.104 | 7.4 | 9.6 | 12.3 | 14.0 | 16.4 | 19.7 | 22.3 |
| 182 | 3.03 | 1.110 | 7.3 | 9.5 | 12.2 | 13.9 | 16.3 | 19.6 | 22.2 |
| 183 | 3.05 | 1.115 | 7.3 | 9.5 | 12.2 | 13.9 | 16.3 | 19.5 | 22.2 |
| 184 | 3.07 | 1.121 | 7.3 | 9.4 | 12.1 | 13.8 | 16.2 | 19.5 | 22.1 |
| 185 | 3.08 | 1.126 | 7.2 | 9.4 | 12.1 | 13.8 | 16.1 | 19.4 | 22.0 |
| 186 | 3.10 | 1.131 | 7.2 | 9.4 | 12.0 | 13.7 | 16.1 | 19.3 | 21.9 |
| 187 | 3.12 | 1.137 | 7.2 | 9.3 | 12.0 | 13.7 | 16.0 | 19.3 | 21.9 |
| 188 | 3.13 | 1.142 | 7.2 | 9.3 | 11.9 | 13.6 | 16.0 | 19.2 | 21.8 |
| 189 | 3.15 | 1.147 | 7.1 | 9.3 | 11.9 | 13.6 | 15.9 | 19.1 | 21.7 |
| 190 | 3.17 | 1.153 | 7.1 | 9.2 | 11.9 | 13.5 | 15.8 | 19.0 | 21.6 |
| 191 | 3.18 | 1.158 | 7.1 | 9.2 | 11.8 | 13.5 | 15.8 | 19.0 | 21.6 |
| 192 | 3.20 | 1.163 | 7.1 | 9.2 | 11.8 | 13.4 | 15.7 | 18.9 | 21.5 |
| 193 | 3.22 | 1.168 | 7.0 | 9.1 | 11.7 | 13.4 | 15.7 | 18.9 | 21.4 |
| 194 | 3.23 | 1.174 | 7.0 | 9.1 | 11.7 | 13.3 | 15.6 | 18.8 | 21.3 |
| 195 | 3.25 | 1.179 | 7.0 | 9.1 | 11.6 | 13.3 | 15.6 | 18.7 | 21.3 |
| 196 | 3.27 | 1.184 | 7.0 | 9.0 | 11.6 | 13.3 | 15.5 | 18.7 | 21.2 |
| 197 | 3.28 | 1.189 | 6.9 | 9.0 | 11.6 | 13.2 | 15.5 | 18.6 | 21.1 |
| 198 | 3.30 | 1.194 | 6.9 | 9.0 | 11.5 | 13.2 | 15.4 | 18.5 | 21.1 |
| 199 | 3.32 | 1.199 | 6.9 | 8.9 | 11.5 | 13.1 | 15.4 | 18.5 | 21.0 |
| 200 | 3.33 | 1.204 | 6.9 | 8.9 | 11.4 | 13.1 | 15.3 | 18.4 | 20.9 |
| 201 | 3.35 | 1.209 | 6.8 | 8.9 | 11.4 | 13.0 | 15.3 | 18.4 | 20.8 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 202 | 3.37 | 1.214 | 6.8 | 8.8 | 11.4 | 13.0 | 15.2 | 18.3 | 20.8 |
| 203 | 3.38 | 1.219 | 6.8 | 8.8 | 11.3 | 12.9 | 15.2 | 18.2 | 20.7 |
| 204 | 3.40 | 1.224 | 6.8 | 8.8 | 11.3 | 12.9 | 15.1 | 18.2 | 20.6 |
| 205 | 3.42 | 1.229 | 6.7 | 8.7 | 11.2 | 12.9 | 15.1 | 18.1 | 20.6 |
| 206 | 3.43 | 1.234 | 6.7 | 8.7 | 11.2 | 12.8 | 15.0 | 18.1 | 20.5 |
| 207 | 3.45 | 1.238 | 6.7 | 8.7 | 11.2 | 12.8 | 15.0 | 18.0 | 20.5 |
| 208 | 3.47 | 1.243 | 6.7 | 8.7 | 11.1 | 12.7 | 14.9 | 17.9 | 20.4 |
| 209 | 3.48 | 1.248 | 6.6 | 8.6 | 11.1 | 12.7 | 14.9 | 17.9 | 20.3 |
| 210 | 3.50 | 1.253 | 6.6 | 8.6 | 11.1 | 12.6 | 14.8 | 17.8 | 20.3 |
| 211 | 3.52 | 1.258 | 6.6 | 8.6 | 11.0 | 12.6 | 14.8 | 17.8 | 20.2 |
| 212 | 3.53 | 1.262 | 6.6 | 8.5 | 11.0 | 12.6 | 14.7 | 17.7 | 20.1 |
| 213 | 3.55 | 1.267 | 6.5 | 8.5 | 11.0 | 12.5 | 14.7 | 17.7 | 20.1 |
| 214 | 3.57 | 1.272 | 6.5 | 8.5 | 10.9 | 12.5 | 14.6 | 17.6 | 20.0 |
| 215 | 3.58 | 1.276 | 6.5 | 8.4 | 10.9 | 12.4 | 14.6 | 17.6 | 20.0 |
| 216 | 3.60 | 1.281 | 6.5 | 8.4 | 10.8 | 12.4 | 14.5 | 17.5 | 19.9 |
| 217 | 3.62 | 1.286 | 6.5 | 8.4 | 10.8 | 12.4 | 14.5 | 17.4 | 19.8 |
| 218 | 3.63 | 1.290 | 6.4 | 8.4 | 10.8 | 12.3 | 14.4 | 17.4 | 19.8 |
| 219 | 3.65 | 1.295 | 6.4 | 8.3 | 10.7 | 12.3 | 14.4 | 17.3 | 19.7 |
| 220 | 3.67 | 1.299 | 6.4 | 8.3 | 10.7 | 12.3 | 14.4 | 17.3 | 19.7 |
| 221 | 3.68 | 1.304 | 6.4 | 8.3 | 10.7 | 12.2 | 14.3 | 17.2 | 19.6 |
| 222 | 3.70 | 1.308 | 6.4 | 8.3 | 10.6 | 12.2 | 14.3 | 17.2 | 19.5 |
| 223 | 3.72 | 1.313 | 6.3 | 8.2 | 10.6 | 12.1 | 14.2 | 17.1 | 19.5 |
| 224 | 3.73 | 1.317 | 6.3 | 8.2 | 10.6 | 12.1 | 14.2 | 17.1 | 19.4 |
| 225 | 3.75 | 1.322 | 6.3 | 8.2 | 10.5 | 12.1 | 14.1 | 17.0 | 19.4 |
| 226 | 3.77 | 1.326 | 6.3 | 8.2 | 10.5 | 12.0 | 14.1 | 17.0 | 19.3 |
| 227 | 3.78 | 1.331 | 6.3 | 8.1 | 10.5 | 12.0 | 14.1 | 16.9 | 19.3 |
| 228 | 3.80 | 1.335 | 6.2 | 8.1 | 10.4 | 12.0 | 14.0 | 16.9 | 19.2 |
| 229 | 3.82 | 1.339 | 6.2 | 8.1 | 10.4 | 11.9 | 14.0 | 16.8 | 19.1 |
| 230 | 3.83 | 1.344 | 6.2 | 8.1 | 10.4 | 11.9 | 13.9 | 16.8 | 19.1 |
| 231 | 3.85 | 1.348 | 6.2 | 8.0 | 10.4 | 11.8 | 13.9 | 16.7 | 19.0 |
| 232 | 3.87 | 1.352 | 6.2 | 8.0 | 10.3 | 11.8 | 13.9 | 16.7 | 19.0 |
| 233 | 3.88 | 1.357 | 6.1 | 8.0 | 10.3 | 11.8 | 13.8 | 16.6 | 18.9 |
| 234 | 3.90 | 1.361 | 6.1 | 8.0 | 10.3 | 11.7 | 13.8 | 16.6 | 18.9 |
| 235 | 3.92 | 1.365 | 6.1 | 7.9 | 10.2 | 11.7 | 13.7 | 16.6 | 18.8 |
| 236 | 3.93 | 1.369 | 6.1 | 7.9 | 10.2 | 11.7 | 13.7 | 16.5 | 18.8 |
| 237 | 3.95 | 1.374 | 6.1 | 7.9 | 10.2 | 11.6 | 13.7 | 16.5 | 18.7 |
| 238 | 3.97 | 1.378 | 6.0 | 7.9 | 10.1 | 11.6 | 13.6 | 16.4 | 18.7 |
| 239 | 3.98 | 1.382 | 6.0 | 7.8 | 10.1 | 11.6 | 13.6 | 16.4 | 18.6 |
| 240 | 4.00 | 1.386 | 6.0 | 7.8 | 10.1 | 11.5 | 13.5 | 16.3 | 18.6 |
| 241 | 4.02 | 1.390 | 6.0 | 7.8 | 10.1 | 11.5 | 13.5 | 16.3 | 18.5 |
| 242 | 4.03 | 1.395 | 6.0 | 7.8 | 10.0 | 11.5 | 13.5 | 16.2 | 18.5 |
| 243 | 4.05 | 1.399 | 6.0 | 7.7 | 10.0 | 11.4 | 13.4 | 16.2 | 18.4 |
| 244 | 4.07 | 1.403 | 5.9 | 7.7 | 10.0 | 11.4 | 13.4 | 16.1 | 18.4 |
| 245 | 4.08 | 1.407 | 5.9 | 7.7 | 9.9 | 11.4 | 13.4 | 16.1 | 18.3 |
| 246 | 4.10 | 1.411 | 5.9 | 7.7 | 9.9 | 11.4 | 13.3 | 16.1 | 18.3 |
| 247 | 4.12 | 1.415 | 5.9 | 7.6 | 9.9 | 11.3 | 13.3 | 16.0 | 18.2 |
| 248 | 4.13 | 1.419 | 5.9 | 7.6 | 9.9 | 11.3 | 13.2 | 16.0 | 18.2 |
| 249 | 4.15 | 1.423 | 5.8 | 7.6 | 9.8 | 11.3 | 13.2 | 15.9 | 18.1 |
| 250 | 4.17 | 1.427 | 5.8 | 7.6 | 9.8 | 11.2 | 13.2 | 15.9 | 18.1 |
| 251 | 4.18 | 1.431 | 5.8 | 7.6 | 9.8 | 11.2 | 13.1 | 15.8 | 18.0 |
| 252 | 4.20 | 1.435 | 5.8 | 7.5 | 9.7 | 11.2 | 13.1 | 15.8 | 18.0 |
| 253 | 4.22 | 1.439 | 5.8 | 7.5 | 9.7 | 11.1 | 13.1 | 15.8 | 17.9 |
| 254 | 4.23 | 1.443 | 5.8 | 7.5 | 9.7 | 11.1 | 13.0 | 15.7 | 17.9 |
| 255 | 4.25 | 1.447 | 5.7 | 7.5 | 9.7 | 11.1 | 13.0 | 15.7 | 17.9 |
| 256 | 4.27 | 1.451 | 5.7 | 7.5 | 9.6 | 11.0 | 13.0 | 15.6 | 17.8 |
| 257 | 4.28 | 1.455 | 5.7 | 7.4 | 9.6 | 11.0 | 12.9 | 15.6 | 17.8 |
| 258 | 4.30 | 1.459 | 5.7 | 7.4 | 9.6 | 11.0 | 12.9 | 15.6 | 17.7 |
| 259 | 4.32 | 1.462 | 5.7 | 7.4 | 9.6 | 11.0 | 12.9 | 15.5 | 17.7 |
| 260 | 4.33 | 1.466 | 5.7 | 7.4 | 9.5 | 10.9 | 12.8 | 15.5 | 17.6 |
| 261 | 4.35 | 1.470 | 5.7 | 7.4 | 9.5 | 10.9 | 12.8 | 15.4 | 17.6 |
| 262 | 4.37 | 1.474 | 5.6 | 7.3 | 9.5 | 10.9 | 12.8 | 15.4 | 17.5 |
| 263 | 4.38 | 1.478 | 5.6 | 7.3 | 9.5 | 10.8 | 12.7 | 15.4 | 17.5 |
| 264 | 4.40 | 1.482 | 5.6 | 7.3 | 9.4 | 10.8 | 12.7 | 15.3 | 17.5 |
| 265 | 4.42 | 1.485 | 5.6 | 7.3 | 9.4 | 10.8 | 12.7 | 15.3 | 17.4 |
| 266 | 4.43 | 1.489 | 5.6 | 7.3 | 9.4 | 10.8 | 12.6 | 15.2 | 17.4 |
| 267 | 4.45 | 1.493 | 5.6 | 7.2 | 9.4 | 10.7 | 12.6 | 15.2 | 17.3 |
| 268 | 4.47 | 1.497 | 5.5 | 7.2 | 9.3 | 10.7 | 12.6 | 15.2 | 17.3 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 269 | 4.48 | 1.500 | 5.5 | 7.2 | 9.3 | 10.7 | 12.5 | 15.1 | 17.2 |
| 270 | 4.50 | 1.504 | 5.5 | 7.2 | 9.3 | 10.7 | 12.5 | 15.1 | 17.2 |
| 271 | 4.52 | 1.508 | 5.5 | 7.2 | 9.3 | 10.6 | 12.5 | 15.1 | 17.2 |
| 272 | 4.53 | 1.511 | 5.5 | 7.1 | 9.2 | 10.6 | 12.4 | 15.0 | 17.1 |
| 273 | 4.55 | 1.515 | 5.5 | 7.1 | 9.2 | 10.6 | 12.4 | 15.0 | 17.1 |
| 274 | 4.57 | 1.519 | 5.5 | 7.1 | 9.2 | 10.5 | 12.4 | 15.0 | 17.0 |
| 275 | 4.58 | 1.522 | 5.4 | 7.1 | 9.2 | 10.5 | 12.4 | 14.9 | 17.0 |
| 276 | 4.60 | 1.526 | 5.4 | 7.1 | 9.1 | 10.5 | 12.3 | 14.9 | 17.0 |
| 277 | 4.62 | 1.530 | 5.4 | 7.0 | 9.1 | 10.5 | 12.3 | 14.8 | 16.9 |
| 278 | 4.63 | 1.533 | 5.4 | 7.0 | 9.1 | 10.4 | 12.3 | 14.8 | 16.9 |
| 279 | 4.65 | 1.537 | 5.4 | 7.0 | 9.1 | 10.4 | 12.2 | 14.8 | 16.8 |
| 280 | 4.67 | 1.540 | 5.4 | 7.0 | 9.1 | 10.4 | 12.2 | 14.7 | 16.8 |
| 281 | 4.68 | 1.544 | 5.4 | 7.0 | 9.0 | 10.4 | 12.2 | 14.7 | 16.8 |
| 282 | 4.70 | 1.548 | 5.3 | 7.0 | 9.0 | 10.3 | 12.1 | 14.7 | 16.7 |
| 283 | 4.72 | 1.551 | 5.3 | 6.9 | 9.0 | 10.3 | 12.1 | 14.6 | 16.7 |
| 284 | 4.73 | 1.555 | 5.3 | 6.9 | 9.0 | 10.3 | 12.1 | 14.6 | 16.6 |
| 285 | 4.75 | 1.558 | 5.3 | 6.9 | 8.9 | 10.3 | 12.1 | 14.6 | 16.6 |
| 286 | 4.77 | 1.562 | 5.3 | 6.9 | 8.9 | 10.2 | 12.0 | 14.5 | 16.6 |
| 287 | 4.78 | 1.565 | 5.3 | 6.9 | 8.9 | 10.2 | 12.0 | 14.5 | 16.5 |
| 288 | 4.80 | 1.569 | 5.3 | 6.9 | 8.9 | 10.2 | 12.0 | 14.5 | 16.5 |
| 289 | 4.82 | 1.572 | 5.3 | 6.8 | 8.9 | 10.2 | 12.0 | 14.4 | 16.4 |
| 290 | 4.83 | 1.576 | 5.2 | 6.8 | 8.8 | 10.1 | 11.9 | 14.4 | 16.4 |
| 291 | 4.85 | 1.579 | 5.2 | 6.8 | 8.8 | 10.1 | 11.9 | 14.4 | 16.4 |
| 292 | 4.87 | 1.582 | 5.2 | 6.8 | 8.8 | 10.1 | 11.9 | 14.3 | 16.3 |
| 293 | 4.88 | 1.586 | 5.2 | 6.8 | 8.8 | 10.1 | 11.8 | 14.3 | 16.3 |
| 294 | 4.90 | 1.589 | 5.2 | 6.8 | 8.8 | 10.0 | 11.8 | 14.3 | 16.3 |
| 295 | 4.92 | 1.593 | 5.2 | 6.7 | 8.7 | 10.0 | 11.8 | 14.2 | 16.2 |
| 296 | 4.93 | 1.596 | 5.2 | 6.7 | 8.7 | 10.0 | 11.8 | 14.2 | 16.2 |
| 297 | 4.95 | 1.599 | 5.2 | 6.7 | 8.7 | 10.0 | 11.7 | 14.2 | 16.2 |
| 298 | 4.97 | 1.603 | 5.1 | 6.7 | 8.7 | 10.0 | 11.7 | 14.1 | 16.1 |
| 299 | 4.98 | 1.606 | 5.1 | 6.7 | 8.7 | 9.9 | 11.7 | 14.1 | 16.1 |
| 300 | 5.00 | 1.609 | 5.1 | 6.7 | 8.6 | 9.9 | 11.7 | 14.1 | 16.1 |
| 301 | 5.02 | 1.613 | 5.1 | 6.6 | 8.6 | 9.9 | 11.6 | 14.0 | 16.0 |
| 302 | 5.03 | 1.616 | 5.1 | 6.6 | 8.6 | 9.9 | 11.6 | 14.0 | 16.0 |
| 303 | 5.05 | 1.619 | 5.1 | 6.6 | 8.6 | 9.8 | 11.6 | 14.0 | 15.9 |
| 304 | 5.07 | 1.623 | 5.1 | 6.6 | 8.6 | 9.8 | 11.5 | 14.0 | 15.9 |
| 305 | 5.08 | 1.626 | 5.1 | 6.6 | 8.5 | 9.8 | 11.5 | 13.9 | 15.9 |
| 306 | 5.10 | 1.629 | 5.0 | 6.6 | 8.5 | 9.8 | 11.5 | 13.9 | 15.8 |
| 307 | 5.12 | 1.633 | 5.0 | 6.5 | 8.5 | 9.8 | 11.5 | 13.9 | 15.8 |
| 308 | 5.13 | 1.636 | 5.0 | 6.5 | 8.5 | 9.7 | 11.4 | 13.8 | 15.8 |
| 309 | 5.15 | 1.639 | 5.0 | 6.5 | 8.5 | 9.7 | 11.4 | 13.8 | 15.7 |
| 310 | 5.17 | 1.642 | 5.0 | 6.5 | 8.4 | 9.7 | 11.4 | 13.8 | 15.7 |
| 311 | 5.18 | 1.645 | 5.0 | 6.5 | 8.4 | 9.7 | 11.4 | 13.7 | 15.7 |
| 312 | 5.20 | 1.649 | 5.0 | 6.5 | 8.4 | 9.7 | 11.3 | 13.7 | 15.6 |
| 313 | 5.22 | 1.652 | 5.0 | 6.5 | 8.4 | 9.6 | 11.3 | 13.7 | 15.6 |
| 314 | 5.23 | 1.655 | 5.0 | 6.4 | 8.4 | 9.6 | 11.3 | 13.7 | 15.6 |
| 315 | 5.25 | 1.658 | 4.9 | 6.4 | 8.3 | 9.6 | 11.3 | 13.6 | 15.5 |
| 316 | 5.27 | 1.661 | 4.9 | 6.4 | 8.3 | 9.6 | 11.3 | 13.6 | 15.5 |
| 317 | 5.28 | 1.665 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.6 | 15.5 |
| 318 | 5.30 | 1.668 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.5 | 15.4 |
| 319 | 5.32 | 1.671 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.5 | 15.4 |
| 320 | 5.33 | 1.674 | 4.9 | 6.4 | 8.3 | 9.5 | 11.2 | 13.5 | 15.4 |
| 321 | 5.35 | 1.677 | 4.9 | 6.3 | 8.2 | 9.5 | 11.1 | 13.5 | 15.4 |
| 322 | 5.37 | 1.680 | 4.9 | 6.3 | 8.2 | 9.4 | 11.1 | 13.4 | 15.3 |
| 323 | 5.38 | 1.683 | 4.9 | 6.3 | 8.2 | 9.4 | 11.1 | 13.4 | 15.3 |
| 324 | 5.40 | 1.686 | 4.8 | 6.3 | 8.2 | 9.4 | 11.1 | 13.4 | 15.3 |
| 325 | 5.42 | 1.689 | 4.8 | 6.3 | 8.2 | 9.4 | 11.0 | 13.4 | 15.2 |
| 326 | 5.43 | 1.693 | 4.8 | 6.3 | 8.2 | 9.4 | 11.0 | 13.3 | 15.2 |
| 327 | 5.45 | 1.696 | 4.8 | 6.3 | 8.1 | 9.3 | 11.0 | 13.3 | 15.2 |
| 328 | 5.47 | 1.699 | 4.8 | 6.2 | 8.1 | 9.3 | 11.0 | 13.3 | 15.1 |
| 329 | 5.48 | 1.702 | 4.8 | 6.2 | 8.1 | 9.3 | 11.0 | 13.2 | 15.1 |
| 330 | 5.50 | 1.705 | 4.8 | 6.2 | 8.1 | 9.3 | 10.9 | 13.2 | 15.1 |
| 331 | 5.52 | 1.708 | 4.8 | 6.2 | 8.1 | 9.3 | 10.9 | 13.2 | 15.0 |
| 332 | 5.53 | 1.711 | 4.8 | 6.2 | 8.1 | 9.2 | 10.9 | 13.2 | 15.0 |
| 333 | 5.55 | 1.714 | 4.7 | 6.2 | 8.0 | 9.2 | 10.9 | 13.1 | 15.0 |
| 334 | 5.57 | 1.717 | 4.7 | 6.2 | 8.0 | 9.2 | 10.8 | 13.1 | 15.0 |
| 335 | 5.58 | 1.720 | 4.7 | 6.2 | 8.0 | 9.2 | 10.8 | 13.1 | 14.9 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 336 | 5.60 | 1.723 | 4.7 | 6.1 | 8.0 | 9.2 | 10.8 | 13.1 | 14.9 |
| 337 | 5.62 | 1.726 | 4.7 | 6.1 | 8.0 | 9.2 | 10.8 | 13.0 | 14.9 |
| 338 | 5.63 | 1.729 | 4.7 | 6.1 | 8.0 | 9.1 | 10.8 | 13.0 | 14.8 |
| 339 | 5.65 | 1.732 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 13.0 | 14.8 |
| 340 | 5.67 | 1.735 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 13.0 | 14.8 |
| 341 | 5.68 | 1.738 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 12.9 | 14.8 |
| 342 | 5.70 | 1.740 | 4.7 | 6.1 | 7.9 | 9.1 | 10.7 | 12.9 | 14.7 |
| 343 | 5.72 | 1.743 | 4.6 | 6.1 | 7.9 | 9.0 | 10.6 | 12.9 | 14.7 |
| 344 | 5.73 | 1.746 | 4.6 | 6.0 | 7.9 | 9.0 | 10.6 | 12.9 | 14.7 |
| 345 | 5.75 | 1.749 | 4.6 | 6.0 | 7.8 | 9.0 | 10.6 | 12.8 | 14.6 |
| 346 | 5.77 | 1.752 | 4.6 | 6.0 | 7.8 | 9.0 | 10.6 | 12.8 | 14.6 |
| 347 | 5.78 | 1.755 | 4.6 | 6.0 | 7.8 | 9.0 | 10.6 | 12.8 | 14.6 |
| 348 | 5.80 | 1.758 | 4.6 | 6.0 | 7.8 | 9.0 | 10.5 | 12.8 | 14.6 |
| 349 | 5.82 | 1.761 | 4.6 | 6.0 | 7.8 | 8.9 | 10.5 | 12.7 | 14.5 |
| 350 | 5.83 | 1.764 | 4.6 | 6.0 | 7.8 | 8.9 | 10.5 | 12.7 | 14.5 |
| 351 | 5.85 | 1.766 | 4.6 | 6.0 | 7.7 | 8.9 | 10.5 | 12.7 | 14.5 |
| 352 | 5.87 | 1.769 | 4.6 | 5.9 | 7.7 | 8.9 | 10.5 | 12.7 | 14.5 |
| 353 | 5.88 | 1.772 | 4.6 | 5.9 | 7.7 | 8.9 | 10.4 | 12.6 | 14.4 |
| 354 | 5.90 | 1.775 | 4.5 | 5.9 | 7.7 | 8.9 | 10.4 | 12.6 | 14.4 |
| 355 | 5.92 | 1.778 | 4.5 | 5.9 | 7.7 | 8.8 | 10.4 | 12.6 | 14.4 |
| 356 | 5.93 | 1.781 | 4.5 | 5.9 | 7.7 | 8.8 | 10.4 | 12.6 | 14.3 |
| 357 | 5.95 | 1.783 | 4.5 | 5.9 | 7.7 | 8.8 | 10.4 | 12.5 | 14.3 |
| 358 | 5.97 | 1.786 | 4.5 | 5.9 | 7.6 | 8.8 | 10.3 | 12.5 | 14.3 |
| 359 | 5.98 | 1.789 | 4.5 | 5.9 | 7.6 | 8.8 | 10.3 | 12.5 | 14.3 |
| **360** | **6.00** | **1.792** | **4.5** | **5.8** | **7.6** | **8.8** | **10.3** | **12.5** | **14.2** |
| 361 | 6.02 | 1.795 | 4.5 | 5.8 | 7.6 | 8.7 | 10.3 | 12.4 | 14.2 |
| 362 | 6.03 | 1.797 | 4.5 | 5.8 | 7.6 | 8.7 | 10.3 | 12.4 | 14.2 |
| 363 | 6.05 | 1.800 | 4.5 | 5.8 | 7.6 | 8.7 | 10.2 | 12.4 | 14.2 |
| 364 | 6.07 | 1.803 | 4.5 | 5.8 | 7.6 | 8.7 | 10.2 | 12.4 | 14.1 |
| 365 | 6.08 | 1.806 | 4.4 | 5.8 | 7.5 | 8.7 | 10.2 | 12.4 | 14.1 |
| 366 | 6.10 | 1.808 | 4.4 | 5.8 | 7.5 | 8.7 | 10.2 | 12.3 | 14.1 |
| 367 | 6.12 | 1.811 | 4.4 | 5.8 | 7.5 | 8.6 | 10.2 | 12.3 | 14.1 |
| 368 | 6.13 | 1.814 | 4.4 | 5.8 | 7.5 | 8.6 | 10.2 | 12.3 | 14.0 |
| 369 | 6.15 | 1.816 | 4.4 | 5.7 | 7.5 | 8.6 | 10.1 | 12.3 | 14.0 |
| 370 | 6.17 | 1.819 | 4.4 | 5.7 | 7.5 | 8.6 | 10.1 | 12.2 | 14.0 |
| 371 | 6.18 | 1.822 | 4.4 | 5.7 | 7.5 | 8.6 | 10.1 | 12.2 | 14.0 |
| 372 | 6.20 | 1.825 | 4.4 | 5.7 | 7.4 | 8.6 | 10.1 | 12.2 | 13.9 |
| 373 | 6.22 | 1.827 | 4.4 | 5.7 | 7.4 | 8.5 | 10.1 | 12.2 | 13.9 |
| 374 | 6.23 | 1.830 | 4.4 | 5.7 | 7.4 | 8.5 | 10.0 | 12.2 | 13.9 |
| 375 | 6.25 | 1.833 | 4.4 | 5.7 | 7.4 | 8.5 | 10.0 | 12.1 | 13.9 |
| 376 | 6.27 | 1.835 | 4.4 | 5.7 | 7.4 | 8.5 | 10.0 | 12.1 | 13.8 |
| 377 | 6.28 | 1.838 | 4.3 | 5.7 | 7.4 | 8.5 | 10.0 | 12.1 | 13.8 |
| 378 | 6.30 | 1.841 | 4.3 | 5.6 | 7.4 | 8.5 | 10.0 | 12.1 | 13.8 |
| 379 | 6.32 | 1.843 | 4.3 | 5.6 | 7.3 | 8.4 | 10.0 | 12.1 | 13.8 |
| 380 | 6.33 | 1.846 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 381 | 6.35 | 1.848 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 382 | 6.37 | 1.851 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 383 | 6.38 | 1.854 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 12.0 | 13.7 |
| 384 | 6.40 | 1.856 | 4.3 | 5.6 | 7.3 | 8.4 | 9.9 | 11.9 | 13.6 |
| 385 | 6.42 | 1.859 | 4.3 | 5.6 | 7.3 | 8.4 | 9.8 | 11.9 | 13.6 |
| 386 | 6.43 | 1.861 | 4.3 | 5.6 | 7.3 | 8.3 | 9.8 | 11.9 | 13.6 |
| 387 | 6.45 | 1.864 | 4.3 | 5.6 | 7.2 | 8.3 | 9.8 | 11.9 | 13.6 |
| 388 | 6.47 | 1.867 | 4.3 | 5.5 | 7.2 | 8.3 | 9.8 | 11.9 | 13.6 |
| 389 | 6.48 | 1.869 | 4.2 | 5.5 | 7.2 | 8.3 | 9.8 | 11.8 | 13.5 |
| 390 | 6.50 | 1.872 | 4.2 | 5.5 | 7.2 | 8.3 | 9.8 | 11.8 | 13.5 |
| 391 | 6.52 | 1.874 | 4.2 | 5.5 | 7.2 | 8.3 | 9.7 | 11.8 | 13.5 |
| 392 | 6.53 | 1.877 | 4.2 | 5.5 | 7.2 | 8.3 | 9.7 | 11.8 | 13.5 |
| 393 | 6.55 | 1.879 | 4.2 | 5.5 | 7.2 | 8.2 | 9.7 | 11.8 | 13.4 |
| 394 | 6.57 | 1.882 | 4.2 | 5.5 | 7.2 | 8.2 | 9.7 | 11.7 | 13.4 |
| 395 | 6.58 | 1.885 | 4.2 | 5.5 | 7.1 | 8.2 | 9.7 | 11.7 | 13.4 |
| 396 | 6.60 | 1.887 | 4.2 | 5.5 | 7.1 | 8.2 | 9.7 | 11.7 | 13.4 |
| 397 | 6.62 | 1.890 | 4.2 | 5.5 | 7.1 | 8.2 | 9.6 | 11.7 | 13.3 |
| 398 | 6.63 | 1.892 | 4.2 | 5.4 | 7.1 | 8.2 | 9.6 | 11.7 | 13.3 |
| 399 | 6.65 | 1.895 | 4.2 | 5.4 | 7.1 | 8.2 | 9.6 | 11.6 | 13.3 |
| 400 | 6.67 | 1.897 | 4.2 | 5.4 | 7.1 | 8.1 | 9.6 | 11.6 | 13.3 |
| 401 | 6.68 | 1.900 | 4.2 | 5.4 | 7.1 | 8.1 | 9.6 | 11.6 | 13.3 |
| 402 | 6.70 | 1.902 | 4.2 | 5.4 | 7.1 | 8.1 | 9.6 | 11.6 | 13.2 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 403 | 6.72 | 1.905 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.6 | 13.2 |
| 404 | 6.73 | 1.907 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.5 | 13.2 |
| 405 | 6.75 | 1.910 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.5 | 13.2 |
| 406 | 6.77 | 1.912 | 4.1 | 5.4 | 7.0 | 8.1 | 9.5 | 11.5 | 13.1 |
| 407 | 6.78 | 1.914 | 4.1 | 5.4 | 7.0 | 8.0 | 9.5 | 11.5 | 13.1 |
| 408 | 6.80 | 1.917 | 4.1 | 5.4 | 7.0 | 8.0 | 9.5 | 11.5 | 13.1 |
| 409 | 6.82 | 1.919 | 4.1 | 5.3 | 7.0 | 8.0 | 9.5 | 11.5 | 13.1 |
| 410 | 6.83 | 1.922 | 4.1 | 5.3 | 7.0 | 8.0 | 9.4 | 11.4 | 13.1 |
| 411 | 6.85 | 1.924 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 412 | 6.87 | 1.927 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 413 | 6.88 | 1.929 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 414 | 6.90 | 1.932 | 4.1 | 5.3 | 6.9 | 8.0 | 9.4 | 11.4 | 13.0 |
| 415 | 6.92 | 1.934 | 4.1 | 5.3 | 6.9 | 7.9 | 9.4 | 11.3 | 13.0 |
| 416 | 6.93 | 1.936 | 4.1 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 417 | 6.95 | 1.939 | 4.0 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 418 | 6.97 | 1.941 | 4.0 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 419 | 6.98 | 1.944 | 4.0 | 5.3 | 6.9 | 7.9 | 9.3 | 11.3 | 12.9 |
| 420 | 7.00 | 1.946 | 4.0 | 5.2 | 6.8 | 7.9 | 9.3 | 11.3 | 12.9 |
| 421 | 7.02 | 1.948 | 4.0 | 5.2 | 6.8 | 7.9 | 9.3 | 11.2 | 12.8 |
| 422 | 7.03 | 1.951 | 4.0 | 5.2 | 6.8 | 7.9 | 9.3 | 11.2 | 12.8 |
| 423 | 7.05 | 1.953 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.2 | 12.8 |
| 424 | 7.07 | 1.955 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.2 | 12.8 |
| 425 | 7.08 | 1.958 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.2 | 12.8 |
| 426 | 7.10 | 1.960 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.1 | 12.7 |
| 427 | 7.12 | 1.962 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.1 | 12.7 |
| 428 | 7.13 | 1.965 | 4.0 | 5.2 | 6.8 | 7.8 | 9.2 | 11.1 | 12.7 |
| 429 | 7.15 | 1.967 | 4.0 | 5.2 | 6.7 | 7.8 | 9.2 | 11.1 | 12.7 |
| 430 | 7.17 | 1.969 | 4.0 | 5.2 | 6.7 | 7.8 | 9.1 | 11.1 | 12.7 |
| 431 | 7.18 | 1.972 | 4.0 | 5.1 | 6.7 | 7.7 | 9.1 | 11.1 | 12.6 |
| 432 | 7.20 | 1.974 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 433 | 7.22 | 1.976 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 434 | 7.23 | 1.979 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 435 | 7.25 | 1.981 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.6 |
| 436 | 7.27 | 1.983 | 3.9 | 5.1 | 6.7 | 7.7 | 9.1 | 11.0 | 12.5 |
| 437 | 7.28 | 1.986 | 3.9 | 5.1 | 6.7 | 7.7 | 9.0 | 11.0 | 12.5 |
| 438 | 7.30 | 1.988 | 3.9 | 5.1 | 6.6 | 7.7 | 9.0 | 10.9 | 12.5 |
| 439 | 7.32 | 1.990 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.5 |
| 440 | 7.33 | 1.992 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.5 |
| 441 | 7.35 | 1.995 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.4 |
| 442 | 7.37 | 1.997 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.4 |
| 443 | 7.38 | 1.999 | 3.9 | 5.1 | 6.6 | 7.6 | 9.0 | 10.9 | 12.4 |
| 444 | 7.40 | 2.001 | 3.9 | 5.0 | 6.6 | 7.6 | 8.9 | 10.8 | 12.4 |
| 445 | 7.42 | 2.004 | 3.9 | 5.0 | 6.6 | 7.6 | 8.9 | 10.8 | 12.4 |
| 446 | 7.43 | 2.006 | 3.9 | 5.0 | 6.6 | 7.6 | 8.9 | 10.8 | 12.4 |
| 447 | 7.45 | 2.008 | 3.9 | 5.0 | 6.6 | 7.5 | 8.9 | 10.8 | 12.3 |
| 448 | 7.47 | 2.010 | 3.8 | 5.0 | 6.5 | 7.5 | 8.9 | 10.8 | 12.3 |
| 449 | 7.48 | 2.013 | 3.8 | 5.0 | 6.5 | 7.5 | 8.9 | 10.8 | 12.3 |
| 450 | 7.50 | 2.015 | 3.8 | 5.0 | 6.5 | 7.5 | 8.9 | 10.7 | 12.3 |
| 451 | 7.52 | 2.017 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.3 |
| 452 | 7.53 | 2.019 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 453 | 7.55 | 2.022 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 454 | 7.57 | 2.024 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 455 | 7.58 | 2.026 | 3.8 | 5.0 | 6.5 | 7.5 | 8.8 | 10.7 | 12.2 |
| 456 | 7.60 | 2.028 | 3.8 | 4.9 | 6.5 | 7.4 | 8.8 | 10.6 | 12.2 |
| 457 | 7.62 | 2.030 | 3.8 | 4.9 | 6.5 | 7.4 | 8.8 | 10.6 | 12.2 |
| 458 | 7.63 | 2.033 | 3.8 | 4.9 | 6.4 | 7.4 | 8.8 | 10.6 | 12.1 |
| 459 | 7.65 | 2.035 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 460 | 7.67 | 2.037 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 461 | 7.68 | 2.039 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 462 | 7.70 | 2.041 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.6 | 12.1 |
| 463 | 7.72 | 2.043 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.5 | 12.0 |
| 464 | 7.73 | 2.046 | 3.8 | 4.9 | 6.4 | 7.4 | 8.7 | 10.5 | 12.0 |
| 465 | 7.75 | 2.048 | 3.7 | 4.9 | 6.4 | 7.3 | 8.7 | 10.5 | 12.0 |
| 466 | 7.77 | 2.050 | 3.7 | 4.9 | 6.4 | 7.3 | 8.7 | 10.5 | 12.0 |
| 467 | 7.78 | 2.052 | 3.7 | 4.9 | 6.4 | 7.3 | 8.6 | 10.5 | 12.0 |
| 468 | 7.80 | 2.054 | 3.7 | 4.9 | 6.4 | 7.3 | 8.6 | 10.5 | 12.0 |
| 469 | 7.82 | 2.056 | 3.7 | 4.9 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 470 | 7.83 | 2.058 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 471 | 7.85 | 2.061 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 472 | 7.87 | 2.063 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 473 | 7.88 | 2.065 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 474 | 7.90 | 2.067 | 3.7 | 4.8 | 6.3 | 7.3 | 8.6 | 10.4 | 11.9 |
| 475 | 7.92 | 2.069 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.4 | 11.8 |
| 476 | 7.93 | 2.071 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.3 | 11.8 |
| 477 | 7.95 | 2.073 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.3 | 11.8 |
| 478 | 7.97 | 2.075 | 3.7 | 4.8 | 6.3 | 7.2 | 8.5 | 10.3 | 11.8 |
| 479 | 7.98 | 2.077 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.8 |
| 480 | 8.00 | 2.079 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.8 |
| 481 | 8.02 | 2.082 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.7 |
| 482 | 8.03 | 2.084 | 3.7 | 4.8 | 6.2 | 7.2 | 8.5 | 10.3 | 11.7 |
| 483 | 8.05 | 2.086 | 3.6 | 4.8 | 6.2 | 7.2 | 8.4 | 10.2 | 11.7 |
| 484 | 8.07 | 2.088 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.7 |
| 485 | 8.08 | 2.090 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.7 |
| 486 | 8.10 | 2.092 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.7 |
| 487 | 8.12 | 2.094 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.6 |
| 488 | 8.13 | 2.096 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.6 |
| 489 | 8.15 | 2.098 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.2 | 11.6 |
| 490 | 8.17 | 2.100 | 3.6 | 4.7 | 6.2 | 7.1 | 8.4 | 10.1 | 11.6 |
| 491 | 8.18 | 2.102 | 3.6 | 4.7 | 6.1 | 7.1 | 8.4 | 10.1 | 11.6 |
| 492 | 8.20 | 2.104 | 3.6 | 4.7 | 6.1 | 7.1 | 8.3 | 10.1 | 11.6 |
| 493 | 8.22 | 2.106 | 3.6 | 4.7 | 6.1 | 7.1 | 8.3 | 10.1 | 11.5 |
| 494 | 8.23 | 2.108 | 3.6 | 4.7 | 6.1 | 7.1 | 8.3 | 10.1 | 11.5 |
| 495 | 8.25 | 2.110 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.1 | 11.5 |
| 496 | 8.27 | 2.112 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.1 | 11.5 |
| 497 | 8.28 | 2.114 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.0 | 11.5 |
| 498 | 8.30 | 2.116 | 3.6 | 4.7 | 6.1 | 7.0 | 8.3 | 10.0 | 11.5 |
| 499 | 8.32 | 2.118 | 3.6 | 4.6 | 6.1 | 7.0 | 8.3 | 10.0 | 11.5 |
| 500 | 8.33 | 2.120 | 3.6 | 4.6 | 6.1 | 7.0 | 8.2 | 10.0 | 11.4 |
| 501 | 8.35 | 2.122 | 3.6 | 4.6 | 6.1 | 7.0 | 8.2 | 10.0 | 11.4 |
| 502 | 8.37 | 2.124 | 3.5 | 4.6 | 6.1 | 7.0 | 8.2 | 10.0 | 11.4 |
| 503 | 8.38 | 2.126 | 3.5 | 4.6 | 6.0 | 7.0 | 8.2 | 10.0 | 11.4 |
| 504 | 8.40 | 2.128 | 3.5 | 4.6 | 6.0 | 7.0 | 8.2 | 10.0 | 11.4 |
| 505 | 8.42 | 2.130 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.4 |
| 506 | 8.43 | 2.132 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.3 |
| 507 | 8.45 | 2.134 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.3 |
| 508 | 8.47 | 2.136 | 3.5 | 4.6 | 6.0 | 6.9 | 8.2 | 9.9 | 11.3 |
| 509 | 8.48 | 2.138 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.9 | 11.3 |
| 510 | 8.50 | 2.140 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.9 | 11.3 |
| 511 | 8.52 | 2.142 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.9 | 11.3 |
| 512 | 8.53 | 2.144 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.8 | 11.3 |
| 513 | 8.55 | 2.146 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.8 | 11.2 |
| 514 | 8.57 | 2.148 | 3.5 | 4.6 | 6.0 | 6.9 | 8.1 | 9.8 | 11.2 |
| 515 | 8.58 | 2.150 | 3.5 | 4.5 | 5.9 | 6.9 | 8.1 | 9.8 | 11.2 |
| 516 | 8.60 | 2.152 | 3.5 | 4.5 | 5.9 | 6.8 | 8.1 | 9.8 | 11.2 |
| 517 | 8.62 | 2.154 | 3.5 | 4.5 | 5.9 | 6.8 | 8.1 | 9.8 | 11.2 |
| 518 | 8.63 | 2.156 | 3.5 | 4.5 | 5.9 | 6.8 | 8.1 | 9.8 | 11.2 |
| 519 | 8.65 | 2.158 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.8 | 11.2 |
| 520 | 8.67 | 2.159 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 521 | 8.68 | 2.161 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 522 | 8.70 | 2.163 | 3.5 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 523 | 8.72 | 2.165 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 524 | 8.73 | 2.167 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 525 | 8.75 | 2.169 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 526 | 8.77 | 2.171 | 3.4 | 4.5 | 5.9 | 6.8 | 8.0 | 9.7 | 11.1 |
| 527 | 8.78 | 2.173 | 3.4 | 4.5 | 5.9 | 6.7 | 8.0 | 9.7 | 11.0 |
| 528 | 8.80 | 2.175 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 529 | 8.82 | 2.177 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 530 | 8.83 | 2.179 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 531 | 8.85 | 2.180 | 3.4 | 4.5 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 532 | 8.87 | 2.182 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 533 | 8.88 | 2.184 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 11.0 |
| 534 | 8.90 | 2.186 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 10.9 |
| 535 | 8.92 | 2.188 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.6 | 10.9 |
| 536 | 8.93 | 2.190 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.5 | 10.9 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 537 | 8.95 | 2.192 | 3.4 | 4.4 | 5.8 | 6.7 | 7.9 | 9.5 | 10.9 |
| 538 | 8.97 | 2.194 | 3.4 | 4.4 | 5.8 | 6.7 | 7.8 | 9.5 | 10.9 |
| 539 | 8.98 | 2.195 | 3.4 | 4.4 | 5.8 | 6.6 | 7.8 | 9.5 | 10.9 |
| 540 | 9.00 | 2.197 | 3.4 | 4.4 | 5.8 | 6.6 | 7.8 | 9.5 | 10.9 |
| 541 | 9.02 | 2.199 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.5 | 10.8 |
| 542 | 9.03 | 2.201 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.5 | 10.8 |
| 543 | 9.05 | 2.203 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.5 | 10.8 |
| 544 | 9.07 | 2.205 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 545 | 9.08 | 2.206 | 3.4 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 546 | 9.10 | 2.208 | 3.3 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 547 | 9.12 | 2.210 | 3.3 | 4.4 | 5.7 | 6.6 | 7.8 | 9.4 | 10.8 |
| 548 | 9.13 | 2.212 | 3.3 | 4.4 | 5.7 | 6.6 | 7.7 | 9.4 | 10.8 |
| 549 | 9.15 | 2.214 | 3.3 | 4.3 | 5.7 | 6.6 | 7.7 | 9.4 | 10.7 |
| 550 | 9.17 | 2.216 | 3.3 | 4.3 | 5.7 | 6.6 | 7.7 | 9.4 | 10.7 |
| 551 | 9.18 | 2.217 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.4 | 10.7 |
| 552 | 9.20 | 2.219 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.4 | 10.7 |
| 553 | 9.22 | 2.221 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.3 | 10.7 |
| 554 | 9.23 | 2.223 | 3.3 | 4.3 | 5.7 | 6.5 | 7.7 | 9.3 | 10.7 |
| 555 | 9.25 | 2.225 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.7 |
| 556 | 9.27 | 2.226 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.6 |
| 557 | 9.28 | 2.228 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.6 |
| 558 | 9.30 | 2.230 | 3.3 | 4.3 | 5.6 | 6.5 | 7.7 | 9.3 | 10.6 |
| 559 | 9.32 | 2.232 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.3 | 10.6 |
| 560 | 9.33 | 2.234 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.3 | 10.6 |
| 561 | 9.35 | 2.235 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.3 | 10.6 |
| 562 | 9.37 | 2.237 | 3.3 | 4.3 | 5.6 | 6.5 | 7.6 | 9.2 | 10.6 |
| 563 | 9.38 | 2.239 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.6 |
| 564 | 9.40 | 2.241 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 565 | 9.42 | 2.242 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 566 | 9.43 | 2.244 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 567 | 9.45 | 2.246 | 3.3 | 4.3 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 568 | 9.47 | 2.248 | 3.3 | 4.2 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 569 | 9.48 | 2.250 | 3.3 | 4.2 | 5.6 | 6.4 | 7.6 | 9.2 | 10.5 |
| 570 | 9.50 | 2.251 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.2 | 10.5 |
| 571 | 9.52 | 2.253 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.5 |
| 572 | 9.53 | 2.255 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 573 | 9.55 | 2.257 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 574 | 9.57 | 2.258 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 575 | 9.58 | 2.260 | 3.2 | 4.2 | 5.5 | 6.4 | 7.5 | 9.1 | 10.4 |
| 576 | 9.60 | 2.262 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 577 | 9.62 | 2.263 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 578 | 9.63 | 2.265 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 579 | 9.65 | 2.267 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.1 | 10.4 |
| 580 | 9.67 | 2.269 | 3.2 | 4.2 | 5.5 | 6.3 | 7.5 | 9.0 | 10.3 |
| 581 | 9.68 | 2.270 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 582 | 9.70 | 2.272 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 583 | 9.72 | 2.274 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 584 | 9.73 | 2.276 | 3.2 | 4.2 | 5.5 | 6.3 | 7.4 | 9.0 | 10.3 |
| 585 | 9.75 | 2.277 | 3.2 | 4.2 | 5.4 | 6.3 | 7.4 | 9.0 | 10.3 |
| 586 | 9.77 | 2.279 | 3.2 | 4.2 | 5.4 | 6.3 | 7.4 | 9.0 | 10.3 |
| 587 | 9.78 | 2.281 | 3.2 | 4.2 | 5.4 | 6.3 | 7.4 | 9.0 | 10.3 |
| 588 | 9.80 | 2.282 | 3.2 | 4.1 | 5.4 | 6.3 | 7.4 | 9.0 | 10.2 |
| 589 | 9.82 | 2.284 | 3.2 | 4.1 | 5.4 | 6.3 | 7.4 | 8.9 | 10.2 |
| 590 | 9.83 | 2.286 | 3.2 | 4.1 | 5.4 | 6.2 | 7.4 | 8.9 | 10.2 |
| 591 | 9.85 | 2.287 | 3.2 | 4.1 | 5.4 | 6.2 | 7.4 | 8.9 | 10.2 |
| 592 | 9.87 | 2.289 | 3.2 | 4.1 | 5.4 | 6.2 | 7.4 | 8.9 | 10.2 |
| 593 | 9.88 | 2.291 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 594 | 9.90 | 2.293 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 595 | 9.92 | 2.294 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 596 | 9.93 | 2.296 | 3.2 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.2 |
| 597 | 9.95 | 2.298 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.1 |
| 598 | 9.97 | 2.299 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.9 | 10.1 |
| 599 | 9.98 | 2.301 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.8 | 10.1 |
| 600 | 10.00 | 2.303 | 3.1 | 4.1 | 5.4 | 6.2 | 7.3 | 8.8 | 10.1 |
| 601 | 10.02 | 2.304 | 3.1 | 4.1 | 5.3 | 6.2 | 7.3 | 8.8 | 10.1 |
| 602 | 10.03 | 2.306 | 3.1 | 4.1 | 5.3 | 6.2 | 7.3 | 8.8 | 10.1 |
| 603 | 10.05 | 2.308 | 3.1 | 4.1 | 5.3 | 6.2 | 7.3 | 8.8 | 10.1 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 604 | 10.07 | 2.309 | 3.1 | 4.1 | 5.3 | 6.1 | 7.3 | 8.8 | 10.1 |
| 605 | 10.08 | 2.311 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.1 |
| 606 | 10.10 | 2.313 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.0 |
| 607 | 10.12 | 2.314 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.0 |
| 608 | 10.13 | 2.316 | 3.1 | 4.1 | 5.3 | 6.1 | 7.2 | 8.8 | 10.0 |
| 609 | 10.15 | 2.317 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 610 | 10.17 | 2.319 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 611 | 10.18 | 2.321 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 612 | 10.20 | 2.322 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 613 | 10.22 | 2.324 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 614 | 10.23 | 2.326 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 10.0 |
| 615 | 10.25 | 2.327 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 9.9 |
| 616 | 10.27 | 2.329 | 3.1 | 4.0 | 5.3 | 6.1 | 7.2 | 8.7 | 9.9 |
| 617 | 10.28 | 2.331 | 3.1 | 4.0 | 5.3 | 6.1 | 7.1 | 8.7 | 9.9 |
| 618 | 10.30 | 2.332 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.7 | 9.9 |
| 619 | 10.32 | 2.334 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 620 | 10.33 | 2.335 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 621 | 10.35 | 2.337 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 622 | 10.37 | 2.339 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 623 | 10.38 | 2.340 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.9 |
| 624 | 10.40 | 2.342 | 3.1 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 625 | 10.42 | 2.343 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 626 | 10.43 | 2.345 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 627 | 10.45 | 2.347 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 628 | 10.47 | 2.348 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 629 | 10.48 | 2.350 | 3.0 | 4.0 | 5.2 | 6.0 | 7.1 | 8.6 | 9.8 |
| 630 | 10.50 | 2.351 | 3.0 | 4.0 | 5.2 | 6.0 | 7.0 | 8.5 | 9.8 |
| 631 | 10.52 | 2.353 | 3.0 | 4.0 | 5.2 | 6.0 | 7.0 | 8.5 | 9.8 |
| 632 | 10.53 | 2.355 | 3.0 | 3.9 | 5.2 | 6.0 | 7.0 | 8.5 | 9.8 |
| 633 | 10.55 | 2.356 | 3.0 | 3.9 | 5.2 | 5.9 | 7.0 | 8.5 | 9.7 |
| 634 | 10.57 | 2.358 | 3.0 | 3.9 | 5.2 | 5.9 | 7.0 | 8.5 | 9.7 |
| 635 | 10.58 | 2.359 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 636 | 10.60 | 2.361 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 637 | 10.62 | 2.362 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 638 | 10.63 | 2.364 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 639 | 10.65 | 2.366 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 640 | 10.67 | 2.367 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.5 | 9.7 |
| 641 | 10.68 | 2.369 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.4 | 9.7 |
| 642 | 10.70 | 2.370 | 3.0 | 3.9 | 5.1 | 5.9 | 7.0 | 8.4 | 9.6 |
| 643 | 10.72 | 2.372 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 644 | 10.73 | 2.373 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 645 | 10.75 | 2.375 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 646 | 10.77 | 2.376 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 647 | 10.78 | 2.378 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 648 | 10.80 | 2.380 | 3.0 | 3.9 | 5.1 | 5.9 | 6.9 | 8.4 | 9.6 |
| 649 | 10.82 | 2.381 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.4 | 9.6 |
| 650 | 10.83 | 2.383 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.4 | 9.6 |
| 651 | 10.85 | 2.384 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.4 | 9.6 |
| 652 | 10.87 | 2.386 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.3 | 9.5 |
| 653 | 10.88 | 2.387 | 3.0 | 3.9 | 5.1 | 5.8 | 6.9 | 8.3 | 9.5 |
| 654 | 10.90 | 2.389 | 3.0 | 3.9 | 5.0 | 5.8 | 6.9 | 8.3 | 9.5 |
| 655 | 10.92 | 2.390 | 3.0 | 3.9 | 5.0 | 5.8 | 6.9 | 8.3 | 9.5 |
| 656 | 10.93 | 2.392 | 2.9 | 3.8 | 5.0 | 5.8 | 6.9 | 8.3 | 9.5 |
| 657 | 10.95 | 2.393 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 658 | 10.97 | 2.395 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 659 | 10.98 | 2.396 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 660 | 11.00 | 2.398 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 661 | 11.02 | 2.399 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.5 |
| 662 | 11.03 | 2.401 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.3 | 9.4 |
| 663 | 11.05 | 2.402 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.2 | 9.4 |
| 664 | 11.07 | 2.404 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.2 | 9.4 |
| 665 | 11.08 | 2.405 | 2.9 | 3.8 | 5.0 | 5.8 | 6.8 | 8.2 | 9.4 |
| 666 | 11.10 | 2.407 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 667 | 11.12 | 2.408 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 668 | 11.13 | 2.410 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 669 | 11.15 | 2.411 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |
| 670 | 11.17 | 2.413 | 2.9 | 3.8 | 5.0 | 5.7 | 6.8 | 8.2 | 9.4 |

| Duration, T (minutes) | Duration, T (hours) | *ln* T | Design Average Rainfall Intensities (mm/hr) ARI (yrs): 1 | 2 | 5 | 10 | 20 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| 671 | 11.18 | 2.414 | 2.9 | 3.8 | 5.0 | 5.7 | 6.7 | 8.2 | 9.4 |
| 672 | 11.20 | 2.416 | 2.9 | 3.8 | 5.0 | 5.7 | 6.7 | 8.2 | 9.4 |
| 673 | 11.22 | 2.417 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.2 | 9.3 |
| 674 | 11.23 | 2.419 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.2 | 9.3 |
| 675 | 11.25 | 2.420 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 676 | 11.27 | 2.422 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 677 | 11.28 | 2.423 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 678 | 11.30 | 2.425 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 679 | 11.32 | 2.426 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 680 | 11.33 | 2.428 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 681 | 11.35 | 2.429 | 2.9 | 3.8 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 682 | 11.37 | 2.431 | 2.9 | 3.7 | 4.9 | 5.7 | 6.7 | 8.1 | 9.3 |
| 683 | 11.38 | 2.432 | 2.9 | 3.7 | 4.9 | 5.6 | 6.7 | 8.1 | 9.2 |
| 684 | 11.40 | 2.434 | 2.9 | 3.7 | 4.9 | 5.6 | 6.7 | 8.1 | 9.2 |
| 685 | 11.42 | 2.435 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.1 | 9.2 |
| 686 | 11.43 | 2.437 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.1 | 9.2 |
| 687 | 11.45 | 2.438 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 688 | 11.47 | 2.439 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 689 | 11.48 | 2.441 | 2.9 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 690 | 11.50 | 2.442 | 2.8 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 691 | 11.52 | 2.444 | 2.8 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 692 | 11.53 | 2.445 | 2.8 | 3.7 | 4.9 | 5.6 | 6.6 | 8.0 | 9.2 |
| 693 | 11.55 | 2.447 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.2 |
| 694 | 11.57 | 2.448 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 695 | 11.58 | 2.450 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 696 | 11.60 | 2.451 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 697 | 11.62 | 2.452 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 698 | 11.63 | 2.454 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 699 | 11.65 | 2.455 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 8.0 | 9.1 |
| 700 | 11.67 | 2.457 | 2.8 | 3.7 | 4.8 | 5.6 | 6.6 | 7.9 | 9.1 |
| 701 | 11.68 | 2.458 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 702 | 11.70 | 2.460 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 703 | 11.72 | 2.461 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 704 | 11.73 | 2.462 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.1 |
| 705 | 11.75 | 2.464 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 706 | 11.77 | 2.465 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 707 | 11.78 | 2.467 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 708 | 11.80 | 2.468 | 2.8 | 3.7 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 709 | 11.82 | 2.470 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 710 | 11.83 | 2.471 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 711 | 11.85 | 2.472 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 712 | 11.87 | 2.474 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.9 | 9.0 |
| 713 | 11.88 | 2.475 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.8 | 9.0 |
| 714 | 11.90 | 2.477 | 2.8 | 3.6 | 4.8 | 5.5 | 6.5 | 7.8 | 9.0 |
| 715 | 11.92 | 2.478 | 2.8 | 3.6 | 4.7 | 5.5 | 6.5 | 7.8 | 9.0 |
| 716 | 11.93 | 2.479 | 2.8 | 3.6 | 4.7 | 5.5 | 6.4 | 7.8 | 8.9 |
| 717 | 11.95 | 2.481 | 2.8 | 3.6 | 4.7 | 5.5 | 6.4 | 7.8 | 8.9 |
| 718 | 11.97 | 2.482 | 2.8 | 3.6 | 4.7 | 5.5 | 6.4 | 7.8 | 8.9 |
| 719 | 11.98 | 2.484 | 2.8 | 3.6 | 4.7 | 5.4 | 6.4 | 7.8 | 8.9 |
| **720** | **12.00** | **2.485** | **2.8** | **3.6** | **4.7** | **5.4** | **6.4** | **7.8** | **8.9** |
| 730 | 12.17 | 2.499 | 2.7 | 3.6 | 4.7 | 5.4 | 6.4 | 7.7 | 8.8 |
| 740 | 12.33 | 2.512 | 2.7 | 3.5 | 4.6 | 5.3 | 6.3 | 7.6 | 8.7 |
| 750 | 12.50 | 2.526 | 2.7 | 3.5 | 4.6 | 5.3 | 6.2 | 7.6 | 8.7 |
| 760 | 12.67 | 2.539 | 2.7 | 3.5 | 4.6 | 5.2 | 6.2 | 7.5 | 8.6 |
| 770 | 12.83 | 2.552 | 2.6 | 3.5 | 4.5 | 5.2 | 6.1 | 7.4 | 8.5 |
| 780 | 13.00 | 2.565 | 2.6 | 3.4 | 4.5 | 5.2 | 6.1 | 7.4 | 8.4 |
| 790 | 13.17 | 2.578 | 2.6 | 3.4 | 4.4 | 5.1 | 6.0 | 7.3 | 8.4 |
| 800 | 13.33 | 2.590 | 2.6 | 3.4 | 4.4 | 5.1 | 6.0 | 7.2 | 8.3 |
| 810 | 13.50 | 2.603 | 2.6 | 3.3 | 4.4 | 5.0 | 5.9 | 7.2 | 8.2 |
| 820 | 13.67 | 2.615 | 2.5 | 3.3 | 4.3 | 5.0 | 5.9 | 7.1 | 8.1 |
| 830 | 13.83 | 2.627 | 2.5 | 3.3 | 4.3 | 4.9 | 5.8 | 7.1 | 8.1 |
| 840 | 14.00 | 2.639 | 2.5 | 3.3 | 4.2 | 4.9 | 5.8 | 7.0 | 8.0 |
| 850 | 14.17 | 2.651 | 2.5 | 3.2 | 4.2 | 4.9 | 5.7 | 6.9 | 7.9 |
| 860 | 14.33 | 2.663 | 2.5 | 3.2 | 4.2 | 4.8 | 5.7 | 6.9 | 7.9 |
| 870 | 14.50 | 2.674 | 2.4 | 3.2 | 4.1 | 4.8 | 5.6 | 6.8 | 7.8 |
| 880 | 14.67 | 2.686 | 2.4 | 3.2 | 4.1 | 4.7 | 5.6 | 6.8 | 7.7 |
| 890 | 14.83 | 2.697 | 2.4 | 3.1 | 4.1 | 4.7 | 5.5 | 6.7 | 7.7 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 900 | 15.00 | 2.708 | 2.4 | 3.1 | 4.1 | 4.7 | 5.5 | 6.7 | 7.6 |
| 910 | 15.17 | 2.719 | 2.4 | 3.1 | 4.0 | 4.6 | 5.5 | 6.6 | 7.6 |
| 920 | 15.33 | 2.730 | 2.3 | 3.1 | 4.0 | 4.6 | 5.4 | 6.6 | 7.5 |
| 930 | 15.50 | 2.741 | 2.3 | 3.0 | 4.0 | 4.6 | 5.4 | 6.5 | 7.4 |
| 940 | 15.67 | 2.752 | 2.3 | 3.0 | 3.9 | 4.5 | 5.3 | 6.5 | 7.4 |
| 950 | 15.83 | 2.762 | 2.3 | 3.0 | 3.9 | 4.5 | 5.3 | 6.4 | 7.3 |
| 960 | 16.00 | 2.773 | 2.3 | 3.0 | 3.9 | 4.5 | 5.3 | 6.4 | 7.3 |
| 970 | 16.17 | 2.783 | 2.3 | 3.0 | 3.8 | 4.4 | 5.2 | 6.3 | 7.2 |
| 980 | 16.33 | 2.793 | 2.2 | 2.9 | 3.8 | 4.4 | 5.2 | 6.3 | 7.2 |
| 990 | 16.50 | 2.803 | 2.2 | 2.9 | 3.8 | 4.4 | 5.1 | 6.2 | 7.1 |
| 1000 | 16.67 | 2.813 | 2.2 | 2.9 | 3.8 | 4.3 | 5.1 | 6.2 | 7.1 |
| 1010 | 16.83 | 2.823 | 2.2 | 2.9 | 3.7 | 4.3 | 5.1 | 6.1 | 7.0 |
| 1020 | 17.00 | 2.833 | 2.2 | 2.9 | 3.7 | 4.3 | 5.0 | 6.1 | 7.0 |
| 1030 | 17.17 | 2.843 | 2.2 | 2.8 | 3.7 | 4.2 | 5.0 | 6.0 | 6.9 |
| 1040 | 17.33 | 2.853 | 2.2 | 2.8 | 3.7 | 4.2 | 5.0 | 6.0 | 6.9 |
| 1050 | 17.50 | 2.862 | 2.1 | 2.8 | 3.6 | 4.2 | 4.9 | 6.0 | 6.8 |
| 1060 | 17.67 | 2.872 | 2.1 | 2.8 | 3.6 | 4.2 | 4.9 | 5.9 | 6.8 |
| 1070 | 17.83 | 2.881 | 2.1 | 2.8 | 3.6 | 4.1 | 4.9 | 5.9 | 6.7 |
| 1080 | 18.00 | 2.890 | 2.1 | 2.8 | 3.6 | 4.1 | 4.8 | 5.8 | 6.7 |
| 1090 | 18.17 | 2.900 | 2.1 | 2.7 | 3.6 | 4.1 | 4.8 | 5.8 | 6.6 |
| 1100 | 18.33 | 2.909 | 2.1 | 2.7 | 3.5 | 4.1 | 4.8 | 5.8 | 6.6 |
| 1110 | 18.50 | 2.918 | 2.1 | 2.7 | 3.5 | 4.0 | 4.7 | 5.7 | 6.5 |
| 1120 | 18.67 | 2.927 | 2.1 | 2.7 | 3.5 | 4.0 | 4.7 | 5.7 | 6.5 |
| 1130 | 18.83 | 2.936 | 2.0 | 2.7 | 3.5 | 4.0 | 4.7 | 5.7 | 6.4 |
| 1140 | 19.00 | 2.944 | 2.0 | 2.7 | 3.4 | 4.0 | 4.6 | 5.6 | 6.4 |
| 1150 | 19.17 | 2.953 | 2.0 | 2.6 | 3.4 | 3.9 | 4.6 | 5.6 | 6.4 |
| 1160 | 19.33 | 2.962 | 2.0 | 2.6 | 3.4 | 3.9 | 4.6 | 5.5 | 6.3 |
| 1170 | 19.50 | 2.970 | 2.0 | 2.6 | 3.4 | 3.9 | 4.6 | 5.5 | 6.3 |
| 1180 | 19.67 | 2.979 | 2.0 | 2.6 | 3.4 | 3.9 | 4.5 | 5.5 | 6.2 |
| 1190 | 19.83 | 2.987 | 2.0 | 2.6 | 3.3 | 3.8 | 4.5 | 5.4 | 6.2 |
| 1200 | 20.00 | 2.996 | 2.0 | 2.6 | 3.3 | 3.8 | 4.5 | 5.4 | 6.2 |
| 1210 | 20.17 | 3.004 | 2.0 | 2.6 | 3.3 | 3.8 | 4.5 | 5.4 | 6.1 |
| 1220 | 20.33 | 3.012 | 1.9 | 2.5 | 3.3 | 3.8 | 4.4 | 5.3 | 6.1 |
| 1230 | 20.50 | 3.020 | 1.9 | 2.5 | 3.3 | 3.7 | 4.4 | 5.3 | 6.1 |
| 1240 | 20.67 | 3.029 | 1.9 | 2.5 | 3.2 | 3.7 | 4.4 | 5.3 | 6.0 |
| 1250 | 20.83 | 3.037 | 1.9 | 2.5 | 3.2 | 3.7 | 4.4 | 5.2 | 6.0 |
| 1260 | 21.00 | 3.045 | 1.9 | 2.5 | 3.2 | 3.7 | 4.3 | 5.2 | 5.9 |
| 1270 | 21.17 | 3.052 | 1.9 | 2.5 | 3.2 | 3.7 | 4.3 | 5.2 | 5.9 |
| 1280 | 21.33 | 3.060 | 1.9 | 2.5 | 3.2 | 3.6 | 4.3 | 5.2 | 5.9 |
| 1290 | 21.50 | 3.068 | 1.9 | 2.4 | 3.2 | 3.6 | 4.3 | 5.1 | 5.8 |
| 1300 | 21.67 | 3.076 | 1.9 | 2.4 | 3.1 | 3.6 | 4.2 | 5.1 | 5.8 |
| 1310 | 21.83 | 3.083 | 1.9 | 2.4 | 3.1 | 3.6 | 4.2 | 5.1 | 5.8 |
| 1320 | 22.00 | 3.091 | 1.8 | 2.4 | 3.1 | 3.6 | 4.2 | 5.0 | 5.7 |
| 1330 | 22.17 | 3.099 | 1.8 | 2.4 | 3.1 | 3.5 | 4.2 | 5.0 | 5.7 |
| 1340 | 22.33 | 3.106 | 1.8 | 2.4 | 3.1 | 3.5 | 4.1 | 5.0 | 5.7 |
| 1350 | 22.50 | 3.114 | 1.8 | 2.4 | 3.1 | 3.5 | 4.1 | 5.0 | 5.6 |
| 1360 | 22.67 | 3.121 | 1.8 | 2.4 | 3.0 | 3.5 | 4.1 | 4.9 | 5.6 |
| 1370 | 22.83 | 3.128 | 1.8 | 2.3 | 3.0 | 3.5 | 4.1 | 4.9 | 5.6 |
| 1380 | 23.00 | 3.135 | 1.8 | 2.3 | 3.0 | 3.5 | 4.0 | 4.9 | 5.5 |
| 1390 | 23.17 | 3.143 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.5 |
| 1400 | 23.33 | 3.150 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.5 |
| 1410 | 23.50 | 3.157 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.5 |
| 1420 | 23.67 | 3.164 | 1.8 | 2.3 | 3.0 | 3.4 | 4.0 | 4.8 | 5.4 |
| 1430 | 23.83 | 3.171 | 1.8 | 2.3 | 2.9 | 3.4 | 3.9 | 4.7 | 5.4 |
| 1440 | 24.00 | 3.178 | 1.7 | 2.3 | 2.9 | 3.3 | 3.9 | 4.7 | 5.4 |
| 1450 | 24.17 | 3.185 | 1.7 | 2.3 | 2.9 | 3.3 | 3.9 | 4.7 | 5.3 |
| 1460 | 24.33 | 3.192 | 1.7 | 2.3 | 2.9 | 3.3 | 3.9 | 4.7 | 5.3 |
| 1470 | 24.50 | 3.199 | 1.7 | 2.2 | 2.9 | 3.3 | 3.9 | 4.6 | 5.3 |
| 1480 | 24.67 | 3.205 | 1.7 | 2.2 | 2.9 | 3.3 | 3.8 | 4.6 | 5.3 |
| 1490 | 24.83 | 3.212 | 1.7 | 2.2 | 2.9 | 3.3 | 3.8 | 4.6 | 5.2 |
| 1500 | 25.00 | 3.219 | 1.7 | 2.2 | 2.8 | 3.3 | 3.8 | 4.6 | 5.2 |
| 1510 | 25.17 | 3.226 | 1.7 | 2.2 | 2.8 | 3.2 | 3.8 | 4.6 | 5.2 |
| 1520 | 25.33 | 3.232 | 1.7 | 2.2 | 2.8 | 3.2 | 3.8 | 4.5 | 5.1 |
| 1530 | 25.50 | 3.239 | 1.7 | 2.2 | 2.8 | 3.2 | 3.8 | 4.5 | 5.1 |
| 1540 | 25.67 | 3.245 | 1.7 | 2.2 | 2.8 | 3.2 | 3.7 | 4.5 | 5.1 |
| 1550 | 25.83 | 3.252 | 1.7 | 2.2 | 2.8 | 3.2 | 3.7 | 4.5 | 5.1 |
| 1560 | 26.00 | 3.258 | 1.7 | 2.2 | 2.8 | 3.2 | 3.7 | 4.4 | 5.0 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 1570 | 26.17 | 3.264 | 1.6 | 2.1 | 2.8 | 3.1 | 3.7 | 4.4 | 5.0 |
| 1580 | 26.33 | 3.271 | 1.6 | 2.1 | 2.7 | 3.1 | 3.7 | 4.4 | 5.0 |
| 1590 | 26.50 | 3.277 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.4 | 5.0 |
| 1600 | 26.67 | 3.283 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.4 | 4.9 |
| 1610 | 26.83 | 3.290 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 1620 | 27.00 | 3.296 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 1630 | 27.17 | 3.302 | 1.6 | 2.1 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 1640 | 27.33 | 3.308 | 1.6 | 2.1 | 2.7 | 3.0 | 3.6 | 4.3 | 4.9 |
| 1650 | 27.50 | 3.314 | 1.6 | 2.1 | 2.7 | 3.0 | 3.5 | 4.3 | 4.8 |
| 1660 | 27.67 | 3.320 | 1.6 | 2.1 | 2.6 | 3.0 | 3.5 | 4.2 | 4.8 |
| 1670 | 27.83 | 3.326 | 1.6 | 2.1 | 2.6 | 3.0 | 3.5 | 4.2 | 4.8 |
| 1680 | 28.00 | 3.332 | 1.6 | 2.1 | 2.6 | 3.0 | 3.5 | 4.2 | 4.8 |
| 1690 | 28.17 | 3.338 | 1.6 | 2.0 | 2.6 | 3.0 | 3.5 | 4.2 | 4.7 |
| 1700 | 28.33 | 3.344 | 1.6 | 2.0 | 2.6 | 3.0 | 3.5 | 4.2 | 4.7 |
| 1710 | 28.50 | 3.350 | 1.6 | 2.0 | 2.6 | 3.0 | 3.5 | 4.1 | 4.7 |
| 1720 | 28.67 | 3.356 | 1.6 | 2.0 | 2.6 | 2.9 | 3.4 | 4.1 | 4.7 |
| 1730 | 28.83 | 3.362 | 1.5 | 2.0 | 2.6 | 2.9 | 3.4 | 4.1 | 4.6 |
| 1740 | 29.00 | 3.367 | 1.5 | 2.0 | 2.6 | 2.9 | 3.4 | 4.1 | 4.6 |
| 1750 | 29.17 | 3.373 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 4.1 | 4.6 |
| 1760 | 29.33 | 3.379 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 4.0 | 4.6 |
| 1770 | 29.50 | 3.384 | 1.5 | 2.0 | 2.5 | 2.9 | 3.4 | 4.0 | 4.6 |
| 1780 | 29.67 | 3.390 | 1.5 | 2.0 | 2.5 | 2.9 | 3.3 | 4.0 | 4.5 |
| 1790 | 29.83 | 3.396 | 1.5 | 2.0 | 2.5 | 2.9 | 3.3 | 4.0 | 4.5 |
| 1800 | 30.00 | 3.401 | 1.5 | 2.0 | 2.5 | 2.8 | 3.3 | 4.0 | 4.5 |
| 1810 | 30.17 | 3.407 | 1.5 | 2.0 | 2.5 | 2.8 | 3.3 | 4.0 | 4.5 |
| 1820 | 30.33 | 3.412 | 1.5 | 1.9 | 2.5 | 2.8 | 3.3 | 3.9 | 4.5 |
| 1830 | 30.50 | 3.418 | 1.5 | 1.9 | 2.5 | 2.8 | 3.3 | 3.9 | 4.4 |
| 1840 | 30.67 | 3.423 | 1.5 | 1.9 | 2.5 | 2.8 | 3.3 | 3.9 | 4.4 |
| 1850 | 30.83 | 3.429 | 1.5 | 1.9 | 2.4 | 2.8 | 3.3 | 3.9 | 4.4 |
| 1860 | 31.00 | 3.434 | 1.5 | 1.9 | 2.4 | 2.8 | 3.2 | 3.9 | 4.4 |
| 1870 | 31.17 | 3.439 | 1.5 | 1.9 | 2.4 | 2.8 | 3.2 | 3.9 | 4.4 |
| 1880 | 31.33 | 3.445 | 1.5 | 1.9 | 2.4 | 2.8 | 3.2 | 3.8 | 4.4 |
| 1890 | 31.50 | 3.450 | 1.5 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1900 | 31.67 | 3.455 | 1.5 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1910 | 31.83 | 3.461 | 1.4 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1920 | 32.00 | 3.466 | 1.4 | 1.9 | 2.4 | 2.7 | 3.2 | 3.8 | 4.3 |
| 1930 | 32.17 | 3.471 | 1.4 | 1.9 | 2.4 | 2.7 | 3.1 | 3.8 | 4.3 |
| 1940 | 32.33 | 3.476 | 1.4 | 1.9 | 2.4 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1950 | 32.50 | 3.481 | 1.4 | 1.9 | 2.4 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1960 | 32.67 | 3.486 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1970 | 32.83 | 3.491 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1980 | 33.00 | 3.497 | 1.4 | 1.8 | 2.3 | 2.7 | 3.1 | 3.7 | 4.2 |
| 1990 | 33.17 | 3.502 | 1.4 | 1.8 | 2.3 | 2.6 | 3.1 | 3.7 | 4.2 |
| 2000 | 33.33 | 3.507 | 1.4 | 1.8 | 2.3 | 2.6 | 3.1 | 3.7 | 4.1 |
| 2010 | 33.50 | 3.512 | 1.4 | 1.8 | 2.3 | 2.6 | 3.1 | 3.6 | 4.1 |
| 2020 | 33.67 | 3.517 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2030 | 33.83 | 3.521 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2040 | 34.00 | 3.526 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2050 | 34.17 | 3.531 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.1 |
| 2060 | 34.33 | 3.536 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.0 |
| 2070 | 34.50 | 3.541 | 1.4 | 1.8 | 2.3 | 2.6 | 3.0 | 3.6 | 4.0 |
| 2080 | 34.67 | 3.546 | 1.4 | 1.8 | 2.2 | 2.6 | 3.0 | 3.5 | 4.0 |
| 2090 | 34.83 | 3.551 | 1.4 | 1.8 | 2.2 | 2.5 | 3.0 | 3.5 | 4.0 |
| 2100 | 35.00 | 3.555 | 1.4 | 1.8 | 2.2 | 2.5 | 3.0 | 3.5 | 4.0 |
| 2110 | 35.17 | 3.560 | 1.4 | 1.8 | 2.2 | 2.5 | 2.9 | 3.5 | 4.0 |
| 2120 | 35.33 | 3.565 | 1.4 | 1.8 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2130 | 35.50 | 3.570 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2140 | 35.67 | 3.574 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2150 | 35.83 | 3.579 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.5 | 3.9 |
| 2160 | 36.00 | 3.584 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.9 |
| 2170 | 36.17 | 3.588 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.9 |
| 2180 | 36.33 | 3.593 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.9 |
| 2190 | 36.50 | 3.597 | 1.3 | 1.7 | 2.2 | 2.5 | 2.9 | 3.4 | 3.8 |
| 2200 | 36.67 | 3.602 | 1.3 | 1.7 | 2.2 | 2.4 | 2.8 | 3.4 | 3.8 |
| 2210 | 36.83 | 3.606 | 1.3 | 1.7 | 2.2 | 2.4 | 2.8 | 3.4 | 3.8 |
| 2220 | 37.00 | 3.611 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.4 | 3.8 |
| 2230 | 37.17 | 3.615 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.4 | 3.8 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 2240 | 37.33 | 3.620 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.8 |
| 2250 | 37.50 | 3.624 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.8 |
| 2260 | 37.67 | 3.629 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2270 | 37.83 | 3.633 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2280 | 38.00 | 3.638 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2290 | 38.17 | 3.642 | 1.3 | 1.7 | 2.1 | 2.4 | 2.8 | 3.3 | 3.7 |
| 2300 | 38.33 | 3.646 | 1.3 | 1.7 | 2.1 | 2.4 | 2.7 | 3.3 | 3.7 |
| 2310 | 38.50 | 3.651 | 1.3 | 1.7 | 2.1 | 2.4 | 2.7 | 3.3 | 3.7 |
| 2320 | 38.67 | 3.655 | 1.3 | 1.6 | 2.1 | 2.4 | 2.7 | 3.2 | 3.7 |
| 2330 | 38.83 | 3.659 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.7 |
| 2340 | 39.00 | 3.664 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2350 | 39.17 | 3.668 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2360 | 39.33 | 3.672 | 1.3 | 1.6 | 2.1 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2370 | 39.50 | 3.676 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2380 | 39.67 | 3.681 | 1.3 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2390 | 39.83 | 3.685 | 1.2 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2400 | 40.00 | 3.689 | 1.2 | 1.6 | 2.0 | 2.3 | 2.7 | 3.2 | 3.6 |
| 2410 | 40.17 | 3.693 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.2 | 3.6 |
| 2420 | 40.33 | 3.697 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2430 | 40.50 | 3.701 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2440 | 40.67 | 3.705 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2450 | 40.83 | 3.709 | 1.2 | 1.6 | 2.0 | 2.3 | 2.6 | 3.1 | 3.5 |
| 2460 | 41.00 | 3.714 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2470 | 41.17 | 3.718 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2480 | 41.33 | 3.722 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2490 | 41.50 | 3.726 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.5 |
| 2500 | 41.67 | 3.730 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.1 | 3.4 |
| 2510 | 41.83 | 3.734 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.0 | 3.4 |
| 2520 | 42.00 | 3.738 | 1.2 | 1.6 | 2.0 | 2.2 | 2.6 | 3.0 | 3.4 |
| 2530 | 42.17 | 3.742 | 1.2 | 1.6 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2540 | 42.33 | 3.746 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2550 | 42.50 | 3.750 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2560 | 42.67 | 3.753 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2570 | 42.83 | 3.757 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2580 | 43.00 | 3.761 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.4 |
| 2590 | 43.17 | 3.765 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.3 |
| 2600 | 43.33 | 3.769 | 1.2 | 1.5 | 1.9 | 2.2 | 2.5 | 3.0 | 3.3 |
| 2610 | 43.50 | 3.773 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 3.0 | 3.3 |
| 2620 | 43.67 | 3.777 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2630 | 43.83 | 3.780 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2640 | 44.00 | 3.784 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2650 | 44.17 | 3.788 | 1.2 | 1.5 | 1.9 | 2.1 | 2.5 | 2.9 | 3.3 |
| 2660 | 44.33 | 3.792 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.3 |
| 2670 | 44.50 | 3.795 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.3 |
| 2680 | 44.67 | 3.799 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2690 | 44.83 | 3.803 | 1.2 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2700 | 45.00 | 3.807 | 1.1 | 1.5 | 1.9 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2710 | 45.17 | 3.810 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2720 | 45.33 | 3.814 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.9 | 3.2 |
| 2730 | 45.50 | 3.818 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2740 | 45.67 | 3.821 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2750 | 45.83 | 3.825 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2760 | 46.00 | 3.829 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2770 | 46.17 | 3.832 | 1.1 | 1.5 | 1.8 | 2.1 | 2.4 | 2.8 | 3.2 |
| 2780 | 46.33 | 3.836 | 1.1 | 1.5 | 1.8 | 2.0 | 2.4 | 2.8 | 3.2 |
| 2790 | 46.50 | 3.839 | 1.1 | 1.4 | 1.8 | 2.0 | 2.4 | 2.8 | 3.1 |
| 2800 | 46.67 | 3.843 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2810 | 46.83 | 3.847 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2820 | 47.00 | 3.850 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2830 | 47.17 | 3.854 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2840 | 47.33 | 3.857 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.8 | 3.1 |
| 2850 | 47.50 | 3.861 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 |
| 2860 | 47.67 | 3.864 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 |
| 2870 | 47.83 | 3.868 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.1 |
| **2880** | **48.00** | **3.871** | **1.1** | **1.4** | **1.8** | **2.0** | **2.3** | **2.7** | **3.1** |
| 2890 | 48.17 | 3.875 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2900 | 48.33 | 3.878 | 1.1 | 1.4 | 1.8 | 2.0 | 2.3 | 2.7 | 3.0 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 2910 | 48.50 | 3.882 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2920 | 48.67 | 3.885 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2930 | 48.83 | 3.888 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2940 | 49.00 | 3.892 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2950 | 49.17 | 3.895 | 1.1 | 1.4 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 |
| 2960 | 49.33 | 3.899 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.7 | 3.0 |
| 2970 | 49.50 | 3.902 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.7 | 3.0 |
| 2980 | 49.67 | 3.905 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 3.0 |
| 2990 | 49.83 | 3.909 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 3.0 |
| 3000 | 50.00 | 3.912 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 3.0 |
| 3010 | 50.17 | 3.915 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3020 | 50.33 | 3.919 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3030 | 50.50 | 3.922 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3040 | 50.67 | 3.925 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3050 | 50.83 | 3.929 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3060 | 51.00 | 3.932 | 1.1 | 1.4 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3070 | 51.17 | 3.935 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3080 | 51.33 | 3.938 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3090 | 51.50 | 3.942 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3100 | 51.67 | 3.945 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3110 | 51.83 | 3.948 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.6 | 2.9 |
| 3120 | 52.00 | 3.951 | 1.0 | 1.3 | 1.7 | 1.9 | 2.2 | 2.5 | 2.9 |
| 3130 | 52.17 | 3.954 | 1.0 | 1.3 | 1.7 | 1.9 | 2.1 | 2.5 | 2.8 |
| 3140 | 52.33 | 3.958 | 1.0 | 1.3 | 1.6 | 1.9 | 2.1 | 2.5 | 2.8 |
| 3150 | 52.50 | 3.961 | 1.0 | 1.3 | 1.6 | 1.9 | 2.1 | 2.5 | 2.8 |
| 3160 | 52.67 | 3.964 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3170 | 52.83 | 3.967 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3180 | 53.00 | 3.970 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3190 | 53.17 | 3.973 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3200 | 53.33 | 3.977 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3210 | 53.50 | 3.980 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3220 | 53.67 | 3.983 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3230 | 53.83 | 3.986 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3240 | 54.00 | 3.989 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3250 | 54.17 | 3.992 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3260 | 54.33 | 3.995 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.5 | 2.8 |
| 3270 | 54.50 | 3.998 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3280 | 54.67 | 4.001 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3290 | 54.83 | 4.004 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3300 | 55.00 | 4.007 | 1.0 | 1.3 | 1.6 | 1.8 | 2.1 | 2.4 | 2.7 |
| 3310 | 55.17 | 4.010 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3320 | 55.33 | 4.013 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3330 | 55.50 | 4.016 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3340 | 55.67 | 4.019 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3350 | 55.83 | 4.022 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3360 | 56.00 | 4.025 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3370 | 56.17 | 4.028 | 1.0 | 1.3 | 1.6 | 1.8 | 2.0 | 2.4 | 2.7 |
| 3380 | 56.33 | 4.031 | 1.0 | 1.3 | 1.6 | 1.7 | 2.0 | 2.4 | 2.7 |
| 3390 | 56.50 | 4.034 | 1.0 | 1.3 | 1.6 | 1.7 | 2.0 | 2.4 | 2.7 |
| 3400 | 56.67 | 4.037 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.7 |
| 3410 | 56.83 | 4.040 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.6 |
| 3420 | 57.00 | 4.043 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.4 | 2.6 |
| 3430 | 57.17 | 4.046 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3440 | 57.33 | 4.049 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3450 | 57.50 | 4.052 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3460 | 57.67 | 4.055 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3470 | 57.83 | 4.058 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3480 | 58.00 | 4.060 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3490 | 58.17 | 4.063 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3500 | 58.33 | 4.066 | 1.0 | 1.2 | 1.5 | 1.7 | 2.0 | 2.3 | 2.6 |
| 3510 | 58.50 | 4.069 | 1.0 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3520 | 58.67 | 4.072 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3530 | 58.83 | 4.075 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3540 | 59.00 | 4.078 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3550 | 59.17 | 4.080 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.6 |
| 3560 | 59.33 | 4.083 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3570 | 59.50 | 4.086 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 3580 | 59.67 | 4.089 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3590 | 59.83 | 4.092 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3600 | 60.00 | 4.094 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.3 | 2.5 |
| 3610 | 60.17 | 4.097 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.2 | 2.5 |
| 3620 | 60.33 | 4.100 | 0.9 | 1.2 | 1.5 | 1.7 | 1.9 | 2.2 | 2.5 |
| 3630 | 60.50 | 4.103 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3640 | 60.67 | 4.105 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3650 | 60.83 | 4.108 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3660 | 61.00 | 4.111 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3670 | 61.17 | 4.114 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3680 | 61.33 | 4.116 | 0.9 | 1.2 | 1.5 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3690 | 61.50 | 4.119 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3700 | 61.67 | 4.122 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3710 | 61.83 | 4.124 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3720 | 62.00 | 4.127 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 3730 | 62.17 | 4.130 | 0.9 | 1.2 | 1.4 | 1.6 | 1.9 | 2.2 | 2.4 |
| 3740 | 62.33 | 4.132 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3750 | 62.50 | 4.135 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3760 | 62.67 | 4.138 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3770 | 62.83 | 4.140 | 0.9 | 1.2 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3780 | 63.00 | 4.143 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3790 | 63.17 | 4.146 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.2 | 2.4 |
| 3800 | 63.33 | 4.148 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3810 | 63.50 | 4.151 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3820 | 63.67 | 4.154 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3830 | 63.83 | 4.156 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3840 | 64.00 | 4.159 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3850 | 64.17 | 4.161 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3860 | 64.33 | 4.164 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3870 | 64.50 | 4.167 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3880 | 64.67 | 4.169 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3890 | 64.83 | 4.172 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3900 | 65.00 | 4.174 | 0.9 | 1.1 | 1.4 | 1.6 | 1.8 | 2.1 | 2.4 |
| 3910 | 65.17 | 4.177 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3920 | 65.33 | 4.180 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3930 | 65.50 | 4.182 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3940 | 65.67 | 4.185 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3950 | 65.83 | 4.187 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3960 | 66.00 | 4.190 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3970 | 66.17 | 4.192 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3980 | 66.33 | 4.195 | 0.9 | 1.1 | 1.4 | 1.5 | 1.8 | 2.1 | 2.3 |
| 3990 | 66.50 | 4.197 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.1 | 2.3 |
| 4000 | 66.67 | 4.200 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.1 | 2.3 |
| 4010 | 66.83 | 4.202 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.1 | 2.3 |
| 4020 | 67.00 | 4.205 | 0.9 | 1.1 | 1.4 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4030 | 67.17 | 4.207 | 0.9 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4040 | 67.33 | 4.210 | 0.9 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4050 | 67.50 | 4.212 | 0.9 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4060 | 67.67 | 4.215 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4070 | 67.83 | 4.217 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4080 | 68.00 | 4.220 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4090 | 68.17 | 4.222 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4100 | 68.33 | 4.224 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.3 |
| 4110 | 68.50 | 4.227 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4120 | 68.67 | 4.229 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4130 | 68.83 | 4.232 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4140 | 69.00 | 4.234 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4150 | 69.17 | 4.237 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4160 | 69.33 | 4.239 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4170 | 69.50 | 4.241 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4180 | 69.67 | 4.244 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4190 | 69.83 | 4.246 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4200 | 70.00 | 4.248 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4210 | 70.17 | 4.251 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4220 | 70.33 | 4.253 | 0.8 | 1.1 | 1.3 | 1.5 | 1.7 | 2.0 | 2.2 |
| 4230 | 70.50 | 4.256 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 2.0 | 2.2 |
| 4240 | 70.67 | 4.258 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 2.0 | 2.2 |

| | | | Design Average Rainfall Intensities (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | ARI (yrs): | | | | | | |
| Duration, T (minutes) | Duration, T (hours) | *ln* T | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| 4250 | 70.83 | 4.260 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 2.0 | 2.2 |
| 4260 | 71.00 | 4.263 | 0.8 | 1.0 | 1.3 | 1.4 | 1.7 | 1.9 | 2.2 |
| 4270 | 71.17 | 4.265 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4280 | 71.33 | 4.267 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4290 | 71.50 | 4.270 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4300 | 71.67 | 4.272 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| 4310 | 71.83 | 4.274 | 0.8 | 1.0 | 1.3 | 1.4 | 1.6 | 1.9 | 2.2 |
| **4320** | **72.00** | **4.277** | **0.8** | **1.0** | **1.3** | **1.4** | **1.6** | **1.9** | **2.2** |

# APPENDIX C: Pre-Development Catchment Data

**Catchment: A**
**Mainstream Parameters**

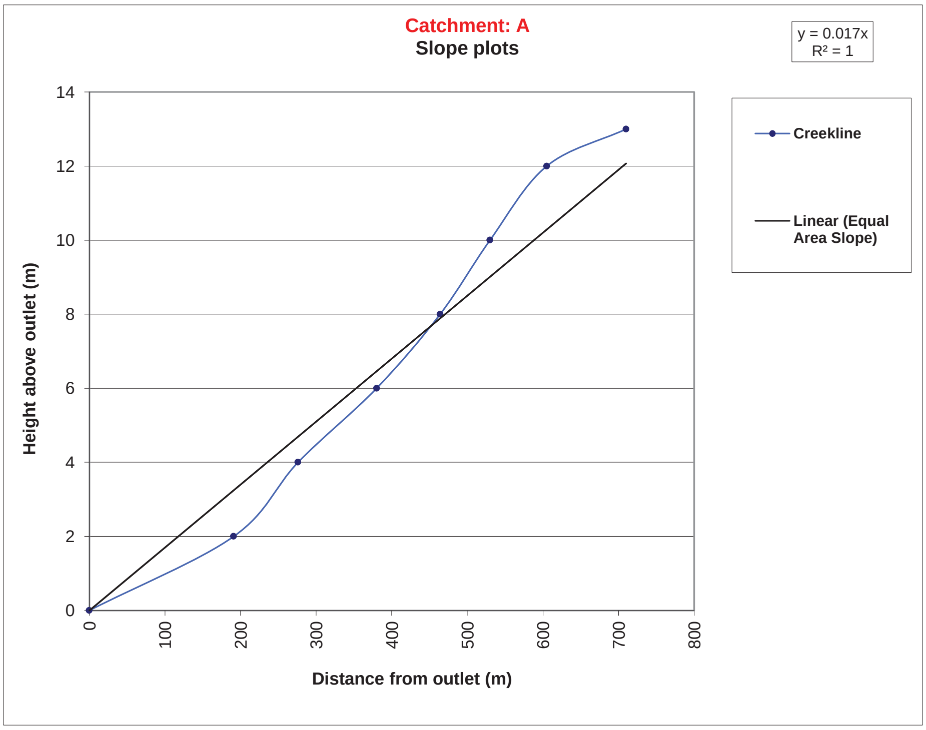
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 191 |
| 191 | 2 | 255 |
| 276 | 4 | 520 |
| 380 | 6 | 588 |
| 464 | 8 | 594 |
| 530 | 10 | 825 |
| 605 | 12 | 1,313 |
| 710 | 13 | **4,286** |

| | | |
|---|---|---|
| Δ L | 0.710 | km |

| | | |
|---|---|---|
| Area | 317,134 | $m^2$ |

| | | |
|---|---|---|
| Se (EQUAL AREA SLOPE) | 17.00 | m/km |
| | 1.7% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 710 | 12 |



Catchment: B
Mainstream Parameters

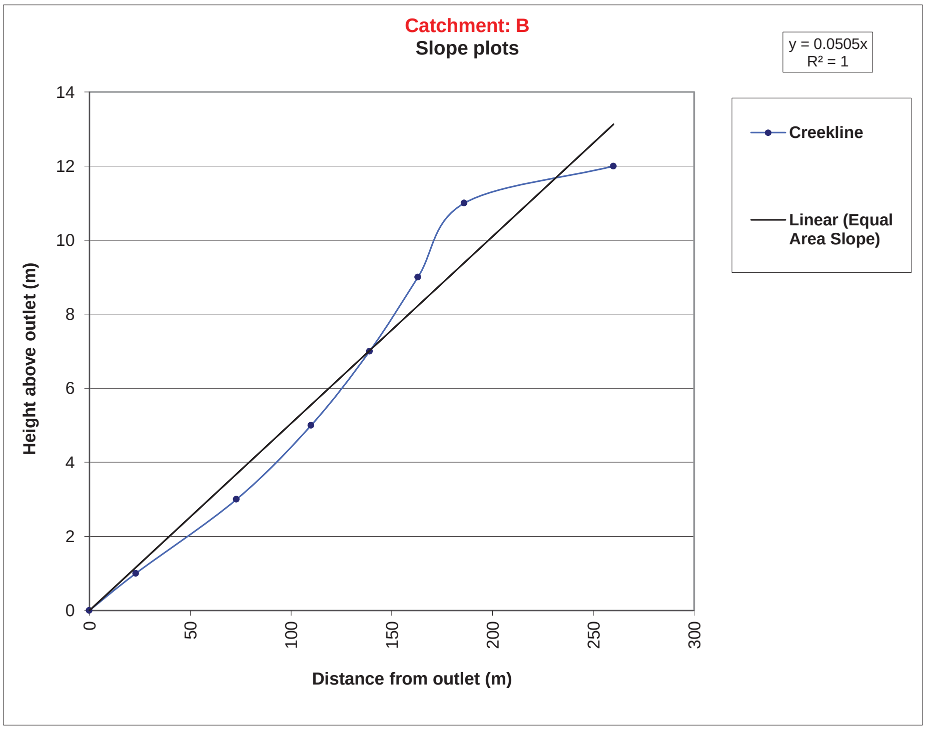
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 12 |
| 23 | 1 | 100 |
| 73 | 3 | 148 |
| 110 | 5 | 174 |
| 139 | 7 | 192 |
| 163 | 9 | 230 |
| 186 | 11 | 851 |
| 260 | 12 | **1,707** |

| | | |
|---|---|---|
| Δ L | 0.260 | km |

| | | |
|---|---|---|
| Area | 85,582 | $m^2$ |

| | | |
|---|---|---|
| Se (EQUAL AREA SLOPE) | 50.49 | m/km |
| | 5.0% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 260 | 13 |



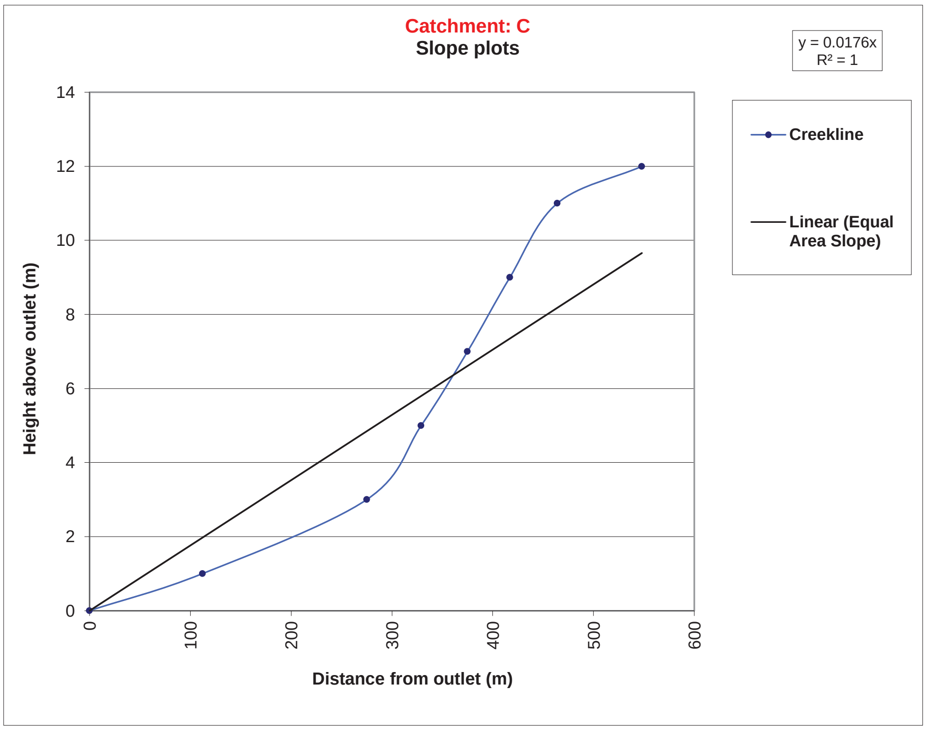
Catchment: C
Mainstream Parameters

| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 56 |
| 112 | 1 | 326 |
| 275 | 3 | 216 |
| 329 | 5 | 276 |
| 375 | 7 | 336 |
| 417 | 9 | 470 |
| 464 | 11 | 966 |
| 548 | 12 | **2,646** |

| | | |
|---|---|---|
| Δ L | 0.548 | km |
| Se (EQUAL AREA SLOPE) | 17.62 | m/km |
| | 1.8% | % |

| | | |
|---|---|---|
| Area | 171,838 | $m^2$ |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 548 | 10 |



Catchment: D
Mainstream Parameters

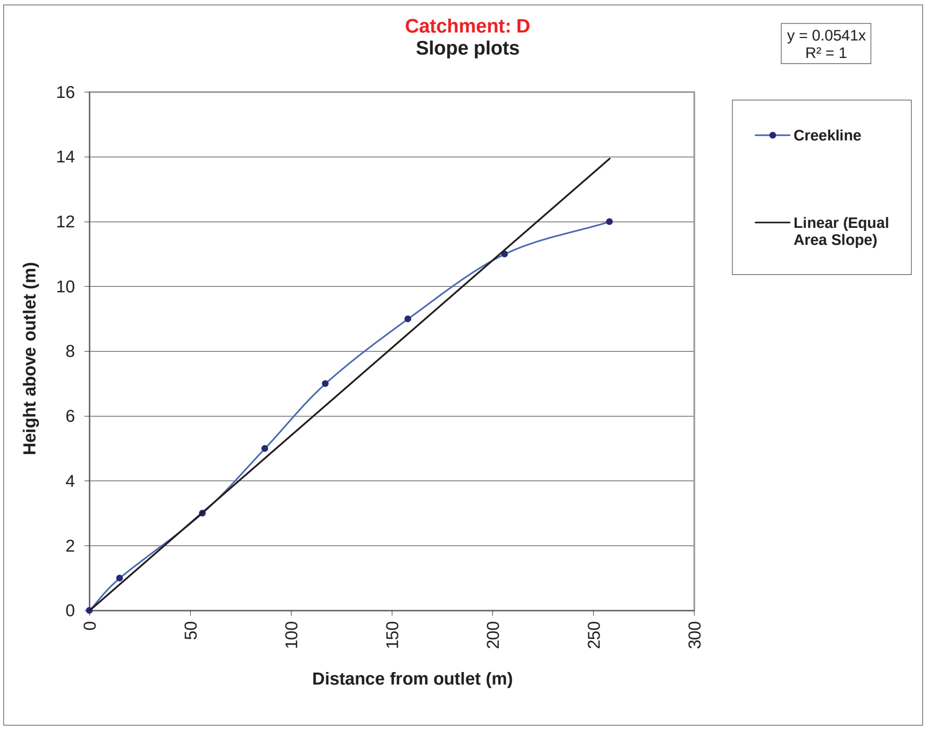
| Distance from outlet (m) | Height above outlet (m) | Trapezoid areas (CREEKLINE) |
|---|---|---|
| 0 | 0 | 8 |
| 15 | 1 | 82 |
| 56 | 3 | 124 |
| 87 | 5 | 180 |
| 117 | 7 | 328 |
| 158 | 9 | 480 |
| 206 | 11 | 598 |
| 258 | 12 | **1,800** |

| | | |
|---|---|---|
| ∆ L | 0.258 | km |

| | | |
|---|---|---|
| Area | 50,187 | $m^2$ |

| | | |
|---|---|---|
| Se (EQUAL AREA SLOPE) | 54.07 | m/km |
| | 5.4% | % |

| Equal Area Ordinates | |
|---|---|
| 0 | 0 |
| 258 | 14 |



# APPENDIX D: Hydrology & Drainage Design Data

**Hydrological Assessment of Subject Site - Lots 4, 5 & 10 Francisco Rd., Bonniefield, WA.**

| | |
|---|---|
| 1-hour 10-year ARI Intensity, ${}^{10}I_1$ (mm/hr) | 29.40 |
| Pervious Area Runoff Coefficient for 1 in 10 yrs ARI, $C^1_{10}$ | 0.16 |

**Input Values: COLUMNS IN RED**

| Catchment Descriptions | Catchment Area ($m^2$) | Catchment Area ($km^2$) | Catchment Area (ha) | Mainstream Description | Mainstream Length (km) *from Equal Area Slope Plot* | Mainstrem Average Slope (m/km) *from Equal Area Slope Plot* | Time of Concentration (Bransby-Williams) $t_c$ (mins) | Rainfall Intensity - Bransby-Williams (mm/hr) | | | | | | Imperv. Fraction | Runoff Coeff. 1 in 10 yrs | Rational Method Runoff Coefficients ($C_y$) (Bransby-Williams) using $C_y = F_y \bullet C_{10}$ | | | | | | Peak Stormwater Flow (Q) Rational Method (Bransby-Williams) using $C_y = F_y \bullet C_{10}$ (AR&R *urban* method) ($m^3/s$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $I_2$ | $I_5$ | $I_{10}$ | $I_{20}$ | $I_{50}$ | $I_{100}$ | *f* | $C_{10}$ | $C_2$ | $C_5$ | $C_{10}$ | $C_{20}$ | $C_{50}$ | $C_{100}$ | ARI = 2 yrs | ARI = 5 yrs | ARI = 10 yrs | ARI = 20 yrs | ARI = 50 yrs | ARI = 100 yrs |
| **PRE-DEVELOPMENT** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Catchment A** | 317,134 | 0.32 | 32 | Overland | 0.710 | 17 | 26 | 34.3 | 43.6 | 49.5 | 57.6 | 68.8 | 77.8 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.514 | 0.73 | 0.872 | 1.066 | 1.394 | 1.645 |
| **Catchment B** | 85,582 | 0.09 | 9 | Overland | 0.260 | 50 | 9 | 59.1 | 75.9 | 86.7 | 101.5 | 122 | 138.6 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.239 | 0.343 | 0.412 | 0.507 | 0.667 | 0.791 |
| **Catchment C** | 171,838 | 0.17 | 17 | Overland | 0.548 | 18 | 21 | 38.7 | 49.2 | 56 | 65.2 | 78.1 | 88.4 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.314 | 0.446 | 0.535 | 0.654 | 0.857 | 1.013 |
| **Catchment D** | 50,187 | 0.05 | 5 | Overland | 0.258 | 54 | 9 | 59.1 | 75.9 | 86.7 | 101.5 | 122 | 138.6 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.14 | 0.201 | 0.242 | 0.297 | 0.391 | 0.464 |
| **POST-DEVELOPMENT** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Catchment $A_1$** | 239,113 | 0.24 | 24 | Overland | 0.710 | 17 | 27 | 33.6 | 42.6 | 48.4 | 56.3 | 67.3 | 76.1 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.379 | 0.538 | 0.643 | 0.785 | 1.028 | 1.213 |
| **Catchment $B_1$** | 81,700 | 0.08 | 8 | Overland | 0.260 | 50 | 9 | 59.1 | 75.9 | 86.7 | 101.5 | 122 | 138.6 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.228 | 0.327 | 0.394 | 0.484 | 0.637 | 0.755 |
| **Catchment $C_1$** | 136,703 | 0.14 | 14 | Overland | 0.548 | 18 | 22 | 37.7 | 48 | 54.5 | 63.5 | 76 | 86 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.243 | 0.346 | 0.414 | 0.506 | 0.664 | 0.784 |
| **Catchment $D_1$** | 34,746 | 0.03 | 3 | Overland | 0.258 | 54 | 9 | 59.1 | 75.9 | 86.7 | 101.5 | 122 | 138.6 | 0.05 | 0.2 | 0.17 | 0.19 | 0.2 | 0.21 | 0.23 | 0.24 | 0.097 | 0.139 | 0.167 | 0.206 | 0.271 | 0.321 |
| **Catchment 1** | 13,384 | 0.01 | 1 | Along internal rd | 0.544 | 29 | 24 | 35.9 | 45.7 | 51.9 | 60.4 | 72.2 | 81.7 | 0.8 | 0.75 | 0.64 | 0.71 | 0.75 | 0.79 | 0.86 | 0.9 | 0.085 | 0.121 | 0.145 | 0.177 | 0.231 | 0.273 |
| **Catchment 2** | 40,191 | 0.04 | 4 | Along internal rd | 0.762 | 10 | 38 | 27.4 | 34.7 | 39.3 | 45.7 | 54.5 | 61.5 | 0.8 | 0.75 | 0.64 | 0.71 | 0.75 | 0.79 | 0.86 | 0.9 | 0.196 | 0.275 | 0.329 | 0.403 | 0.523 | 0.618 |
| **Catchment 3** | 6,019 | 0.01 | 1 | Along internal rd | 0.425 | 24 | 22 | 37.7 | 48 | 54.5 | 63.5 | 76 | 86 | 0.8 | 0.75 | 0.64 | 0.71 | 0.75 | 0.79 | 0.86 | 0.9 | 0.04 | 0.057 | 0.068 | 0.084 | 0.109 | 0.129 |
| **Catchment 4** | 17,350 | 0.02 | 2 | Along internal rd | 0.700 | 14 | 35 | 28.8 | 36.5 | 41.4 | 48.1 | 57.4 | 64.8 | 0.8 | 0.75 | 0.64 | 0.71 | 0.75 | 0.79 | 0.86 | 0.9 | 0.089 | 0.125 | 0.15 | 0.183 | 0.238 | 0.281 |
| **Catchment 5** | 18,051 | 0.02 | 2 | Along internal rd | 0.785 | 20 | 37 | 27.8 | 35.3 | 40 | 46.5 | 55.4 | 62.6 | 0.8 | 0.75 | 0.64 | 0.71 | 0.75 | 0.79 | 0.86 | 0.9 | 0.089 | 0.126 | 0.15 | 0.184 | 0.239 | 0.282 |