Stormwater Management Plan (Concept Stage)

2CRU & Muirhead North, Lee Point Road, Lee Point

DC1603/R4

Prepared for

Defence Housing Australia

22 December 2019

Cardno

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Document Information

Prepared for	Defence Housing Australia
Project Name	2CRU & Muirhead North, Lee Point Road, Lee Point
File Reference	R4V1_SMP_2CRU and Muirhead Nth.docx
Job Reference	DC1603/R4
Date	22 December 2019
Version Number	1

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Effective Date 20/12/2018

Approved By:

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Date Approved 22/12/2019

Document History

Version	Effective Date	Description of Revision	Prepared by	Reviewed by
1	22/12/2019	Issued	Ram Gurung	Cara van Megchelen

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1 Introduction

This concept stage SMP has been prepared for two sites, 2CRU and Muirhead North. Previously, Cardno prepared a preliminary stage SMP for the two sites, 2CRU and Muirhead North, to support the Development Application (DA) for each site. Muirhead North development is proposed to be located near the intersection of Aldenham Road and Lee Point Road on parcel 9370, Lee Point, as shown in Figure 1-1. The 2CRU development is proposed to be located west of Lee Point Road on parcel 4873, Figure 1-1.

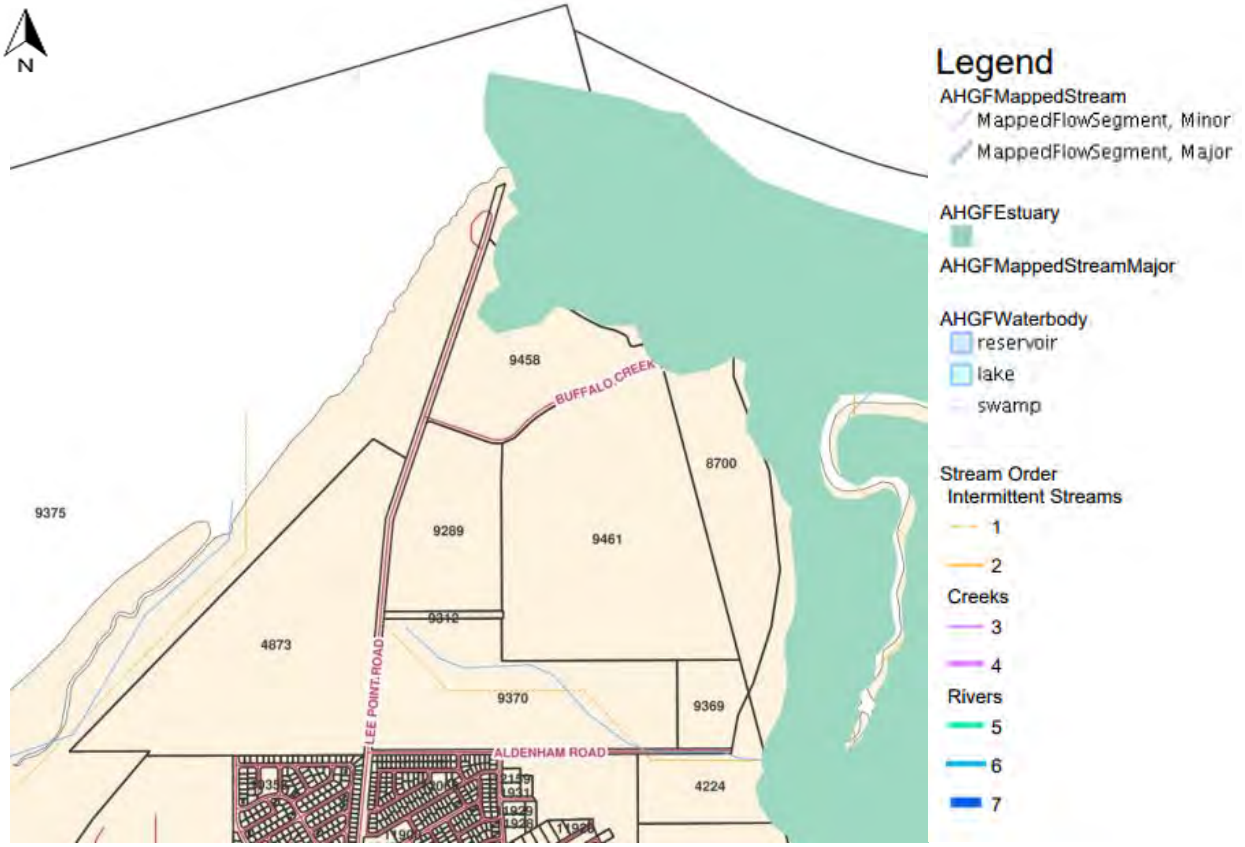

Figure 1-1 Muirhead North site location relative to surface water drainage (NR Maps, 2018)

The 2CRU and Muirhead North sites are to be developed by Defence Housing Australia (DHA) and shall consist predominantly of residential lots with smaller sections dedicated to commercial purposes and a school within Muirhead North. The development layout details are provided in Appendix A for both 2CRU and Muirhead North.

The Muirhead North site shall be developed in conjunction with '2CRU', a development to the west of the site, as described in the Cardno report *2CRU – Lee Point Road, Lee Point – Stormwater Management Plan'* dated 29 November 2017 (ref: DC1603/R1/V4). Muirhead North preliminary stormwater management is outlined in the Cardno 'Muirhead North – Lee Point Road, Lee Point – Stormwater Management Plan' dated 20 December 2018 (ref: DC1603/R3/V4).

Previously, the separate SMPs were prepared for 2CRU and Muirhead North. However, the SMPs have been combined into one since stormwater run-off flows from the 2CRU site through the Muirhead North site. This report details the concept stormwater management requirements for the two developments.

1.1 Site Description

1.1.1 Existing Conditions

Both of the sites are currently undeveloped and predominately consists of open woodland.

1.1.1.1 2CRU

The 2CRU site is located to the west of Lee Point Road. The site is currently unoccupied and previously was used for a Royal Australian Air Force (RAAF) transmission facility situated in the northern half of the site. This facility previously included buildings, sealed roads and car parking together with cleared unsealed areas. The buildings and car parking areas have since been removed with only some sealed roads remaining. A number of unsealed tracks also traverse the site. The vegetation on the 2CRU site is predominantly casuarina forest and open woodland with densities increasing along the western boundary where the land drops off sharply towards Sandy Creek and Beagle Gulf. The existing catchment characteristics are shown on Figure 2.

1.1.1.2 Muirhead North

A number of unsealed tracks traverse the site and a rural dam exists immediately to the north. There is an environmentally significant rainforest area within the site that will be retained, location illustrated on Figure 2 in Appendix B. Flows are conveyed across Lee Point Road from the 2CRU site.

1.1.2 Proposed Development

DHA propose to develop the Muirhead North site for residential and mixed-use land uses including commercial areas. The majority of the development will comprise standard residential lots and will also include lots for commercial use. The proposed development layout is provided in Appendix A.

2 Guidance and Management Practices Summary

A review of current guidance and management practices for stormwater quality and quantity management for urban developments in the Darwin region was undertaken. This stormwater management has been prepared in accordance with the following relevant policies and guidelines:

- Subdivision and Development Guidelines, Darwin City Council [COD, 2005];
- Australian Rainfall and Runoff - A Guide to Flood Estimation:
  - Volume 1 [IEAust, 2003]; and
  - Volume 2 [IEAust, 1987].
- Water Quality Objectives for the Darwin Harbour Region, [Department of Natural Resources, Environment, The Arts and Sport, 2010]
- Water Sensitive Urban Design:
  - Water Sensitive Urban Design - Modelling Guide, Northern Territory Department of Planning and Infrastructure [NTDPI1, 2009];
  - Water Sensitive Urban Design - Technical Design Guideline, Northern Territory Department of Planning and Infrastructure [NTDPI2, 2009];
  - Water Sensitive Urban Design - Vegetation Selection Guide, Northern Territory Department of Planning and Infrastructure [NTDPI3, 2009];
  - Water Sensitive Urban Design - Operation and Maintenance Guidelines, Northern Territory Department of Planning and Infrastructure [NTDPI4, 2009];
  - Water Sensitive Urban Design - Water Quality Monitoring Strategy, Northern Territory Department of Planning and Infrastructure [NTDPI5, 2009]; and
  - Water Sensitive Urban Design - Construction, Asset Handover, Maintenance Guideline, Northern Territory Department of Planning and Infrastructure [NTDPI6, 2009].

3 Site Specific Considerations

3.1 Water Sensitive Urban Design

An alternative stormwater treatment approach has been adopted and presented in this study that excludes bio-retention basins. This approach is based on the observed practical performance of bio-retention basins in the Darwin region and as they are not desired by the City of Darwin for the reasons outlined in Section 5. Therefore, alternative WQO's have been proposed due to the limitations regarding which stormwater treatment devices can be practically incorporated and maintained; these are outlined in Table 5-1.

3.2 Attenuation of Post-Development Peak Flow

The post-development flow presented in this study considers peak flow attenuation basins, but with reduced volume than previously reported (Cardno, 19 October 2018).

3.3 Muirhead North

3.3.1 Peak Flow Attenuation

A recent Assessment Report 88 by the Northern Territory Environment Protection Authority (NTEPA) highlighted the importance of retaining the native vegetation where a 16,000m^3 basin was previously proposed to be located. This basin was referred to as 'Basin 7' in Cardno's Stormwater Management Plan (Preliminary Stage), Muirhead North - Lee Point Road, Lee Point, dated 19 October 2018. The recommendation (Assessment Report 88) relating to 'Basin 7' within the Muirhead development is provided below:

> **Recommendation 15**
>
> **That approvals for Muirhead North should provide adequate protection for the monsoon rainforest patch and habitat for the black-footed tree-rat. In particular, it is recommended that any approval require:**
>
> - **a vegetated buffer of at least 25 m around the monsoon rainforest patch in Muirhead North**
> - **the retention of native vegetation in the 'Drainage/Conservation Area' (Figure 4), excluding the 1.85 ha 'Detention Storage'**
> - **rezoning the retained area of native vegetation as CN conservation under the NT Planning Scheme.**
>
> Where works are required within the 'detention/conservation area' that have not been considered in this report, the Proponent would need to consult with the NT EPA about whether further consideration under the EA Act is required.
>
> The NT EPA considers that the Proposal is likely to result in a significant residual impact to black-footed tree-rat and that, while this is not sufficiently large or certain to make the project unacceptable, it is appropriate that an offset be developed that directly contributes to the conservation security of the species and that meets the minimum requirements of the Australian Government's Offset Policy.

Based on the above outlined recommendation, flow attenuation basins shall not be located within the area shaded dark green in Figure 3-1 ("open space / drainage reserve area"). Consequently, the space available for flow attenuation basins has been greatly reduced. An additional design constraint to consider is that the depth of water in flow attenuation basins should not exceed 1.2m during the 20 year ARI event. Therefore, both area and depth are important considerations for the design of flow attenuation basins.

Figure 3-1 Muirhead North location of “open space/drainage area”

Alternative methods to attenuate peak flows without ‘Basin 7’ were investigated. Previously the mitigated post-development 100 year ARI peak flow was similar to the pre-developed peak flow. With reduced basin storage there is an increase in peak flow during the 100 year ARI event, results presented in Section 4.3. In addition, as a result of retaining vegetation in the area described above, peak flow from the majority of the rural blocks (location 3 in Figure 3-1), will not have peak flow attenuation. As these are the rural blocks (4,000m^2 and larger) the impact of peak flows from this area will be lower than the smaller blocks in the remainder of the development, which are typically 450 to 800m^2 blocks, as the larger blocks have a lower relative impervious area.

3.3.2 Monsoon Rainforest

The environmentally significant rainforest area, referred to as the ‘Monsoon Rainforest’ shall be retained and maintained. The location is illustrated on Figure 2 in Appendix B. During the master planning stage, SMEC completed a *Hydrological review of Muirhead North rainforest patch* (SMEC 2015). In summary, SMEC *addressed the intention and outlined proposed treatments to preserve the natural environment of the rainforest*. Following on from this study, the post-development catchment contributing flow to the rainforest area was sized to realise similar flow quantity to the existing conditions. Discussion about water quantity relative to the Monsoon rainforest is provided in Section 4.3.2.2 and discussion about the developments water quality management is provided in Section 5.

4 Stormwater Quantity Assessment

The development of the site has the potential to increase local site runoff due to the increase in impervious areas. This potential increase in site runoff can result in downstream increases of peak flood levels, waterway erosion and affect bank stability. To prevent adverse impacts external to the site, appropriate mitigation measures are necessary to limit post-developed runoff to similar to the pre-developed conditions. A concept hydraulic model was also developed for the post-development case. The hydraulic model developed considered the impact of the proposed diversion of high flows along Lee Point Road.

This section details the stormwater quantity assessment that was undertaken for the 2CRU and Muirhead North development, with supporting figures (summarised below). Stormwater quantity related figures provided in Appendix B include:

- Figure 1 Site Location
- Figure 2 Catchment Characteristics
- Figure 3 XPRAFTS Pre-Development Model Layout
- Figure 4 XPRAFTS Post-Developed Model Layout

Stormwater runoff from the proposed development west of Lee Point Road (2CRU) was incorporated into this assessment as the Muirhead North development receives runoff from 2CRU. Stormwater management details for 2CRU are provided in the report '2CRU – Lee Point Road, Lee Point – Stormwater Management Plan' dated 29 November 2017 (ref: DC1603/R1/V4).

In addition to mitigating downstream adverse impacts, the impact of the development on the existing environmentally significant rainforest area has been considered. The primary risk to the rainforest area is the reduction in low (base) flows from the upstream catchment. The concept stage assessment undertaken has focused on maintaining the quantity of flow to the rainforest area to similar to the existing (pre-development) flow.

4.1 Model Setup

Modelling has been conducted using XPRAFTS (Version 2018) based on the models developed as part of the preliminary SMPs:

- '2CRU – Lee Point Road, Lee Point – Stormwater Management Plan' dated 29 November 2017 (ref: DC1603/R1/V4)
- 'Muirhead North – Lee Point Road, Lee Point – Stormwater Management Plan' dated 20 December 2018 (ref: DC1603/R3/V4).

XPRAFTS is an event based hydrologic model that calculates flood hydrographs from storm rainfall hyetographs. It also has the ability to model basic hydraulic structures such as detention basins.

4.1.1 Land Use

The adopted fraction imperviousness for each land use for the pre and post-development site is listed in Table 4-1.

Table 4-1 Adopted impervious fraction

Land use	Fraction Impervious (%)
Residential Medium Density	60
Rural Residential	20
Open Space/Park/Sports Oval	0
Commercial	90
School	65
Road	100

4.1.2 Catchment

4.1.2.1 Pre-Development Case

Delineation of the existing sub-catchments illustrated on Figure 3 (Appendix B) were based on site ground survey and Aerial Laser Survey (ALS) of the area.

Topography across the 2CRU site ranges from approximately 33mAHD, at the highest point of the ridge which traverses the middle of the site in a roughly south to north alignment, down to the lowest point of 4.5mAHD in the south west corner. The lowest point along the Lee Point Road eastern frontage is approximately 22.5mAHD located 200m to the south of the Lee Point Resort southern boundary. Gradients across the site are generally less than 3% with steeper slopes adjacent to the western boundary within the proposed conservation area and within the south western corner where runoff from the local site catchment conveys flows to Sandy Creek.

While the majority of surface runoff across the site is conveyed as relatively shallow sheet flow and surface flow, there are some minor gullies where surface runoff is concentrated in defined gullies and excavated drains. These include natural gullies within the south west corner and also open drains located along the sealed road entrance to the former RAAF facility. The drain along the former RAAF facility entry road conveys flows to Lee Point Road via twin box culverts and a lined opened drain as shown in Figure 1-2 below courtesy of NearMap 2016.

Figure 4-1 Former RAAF Facility Entry Road (Ref: Nearmap 2016)

Flows are conveyed across Lee Point Road via 2 x 1200W x 450H RCBCs into an unlined drain that runs along the Lee Point Resort southern boundary before discharging into a large rural dam. A second culvert crossing of Lee Point Road is located 115m further south and consists of 5 x 750 RCPs that conveys flows collected within the road side drain to the east. The second culvert crossing is shown in Figure 1-3.

Figure 4-2 Culvert Crossing of Lee Point Road 115m South of the Lee Point Resort (Ref: Nearmap 2016)

The local catchment conveying flows to the south west corner via local gullies discharges into Sandy Creek which runs parallel to the coast in a north-easterly direction before joining the Beagle Gulf. There is also a relatively small catchment in the northwest corner of the site which conveys local runoff via the Casuarina Coastal Reserve and beach frontage to Beagle Gulf. It appears that this flow is conveyed as relatively shallow sheet flow down the escarpment.

There are no identifiable external catchments contributing to flows through the site with the Royal Darwin Hospital and Lyons Estate, adjacent to the southern boundary, effectively forming a catchment divide with flows from the site being conveyed via open drains along this boundary to both Sandy Creek and Lee Point Road. The overall catchment delineation and general direction of runoff across the 2CRU site and surrounding areas are shown on Figure 2.

Topography across the Muirhead North site ranges from approximately 5 to 25 mAHD, generally grading from the west to east prior to discharging into the estuarine Buffalo Creek. Surface runoff from the site is mainly conveyed via sheet flow and surface flow with a few areas where runoff is concentrated in defined gullies, as illustrated in Figure 4-3. These include naturally occurring gullies within the centre of the site.

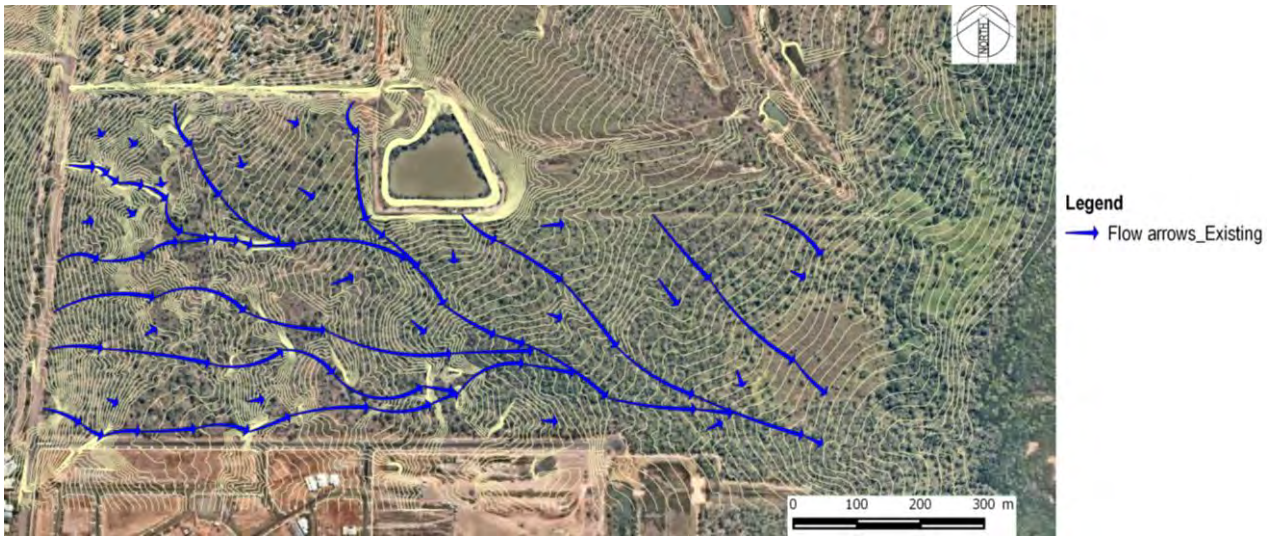

Figure 4-3 Muirhead North existing general surface water runoff direction

4.1.2.2 Post-Development Case

The catchments for the post-development scenario were based on the site layout plan design surface, provided in Appendix A (15 October 2018).

4.1.2.3 Summary

The pre and post development sub-catchment properties incorporated into the XPRAFTS model are provided in Table 4-2 and Table 4-3.

Table 4-2 Sub-catchment details – pre development (EX05)

Sub-catchment ID	Area (ha)	Impervious (%)
WA	2.1	0
WB	5.2	0
WC	3.8	0
WD	5.6	0
WE	1.3	0
WF	1.2	0
WG	13.7	0
WH	2.2	0
EA	9.8	0
EB	9.8	0
EC	12.1	0
ED	12.2	0
EE	16.3	0
EF	10.7	0
EG	7.0	0
EH	5.0	0
EI	6.0	0
EJ	12.6	0
Total	**136.7**	**0**

Table 4-3 Sub-catchment details –post development (DD03)

Sub-catchment ID	Area (ha)	Impervious (%)
2C01	3.9	31
2C02	13.8	49
2C03	8.3	54
2C04	7.4	52
2C05	1.8	12
2C06A	4.1	52
2C06B	0.5	34
2C07	3.5	0
2C08	9.4	51
2C09	6.4	50
2C10	3.1	0
2C11	1.3	0
2C12	2.2	0
2C13	1.2	0
MU01A	2.3	5
MU01B	2.0	36
MU02	4.6	59
MU03	4.7	50
MU04	3.5	53
MU05	1.4	55
MU06	7.6	52
MU07A	1.3	57
MU07B	1.6	54
MU08	3.4	9
MU09	2.6	0
MU10	9.7	22
MU11	8.6	6
MU12a	0.8	39
MU12b	1.6	0
MU13	4.3	0
MU14	5.7	0
MU15	3.9	0
Total	**136.7**	**32**

4.1.3 Storm Durations

The XPRAFTs model was used to determine the peak flows discharging from the site for a full range of Average Recurrence Intervals (ARIs) (1 to 100 years) for all standard storm durations between 15 minutes and 180 minutes. Model results were validated to the Rational Method as detailed in the previous SMPs developed for each site.

4.1.4 Design rainfall intensities

Design rainfall intensities for the area were calculated using AusIFD Version 2.0, summarised below.

- 2 year, 1 hour rainfall intensity = 62.64 mm/h
- 2 year, 12 hour rainfall intensity = 9.78 mm/h
- 2 year, 72 hour rainfall intensity = 3.02 mm/h
- 50 year, 1 hour rainfall intensity = 100.0 mm/h
- 50 year, 12 hour rainfall intensity = 16.13 mm/h
- 50 year, 72 hour rainfall intensity = 6.04 mm/h

4.1.5 Losses and Model Parameters

An initial loss of 0 mm and a continuing loss rate of 0 mm/h were used for all storm events in line with the *Subdivision and Development Guidelines* (COD, 2005), which recommends that all catchments are to be considered to be saturated.

The below parameters were adopted for the area, as prescribed by *ARR* (IEAust, 1987).

- Skew (G) = 0.37
- Geographical Factor (F2) = 4.39
- Geographical Factor (F50) = 18.50

4.1.6 Basin Design Criteria

This concept SMP incorporated the following flow attenuation basin design criteria:

- 1 in 6 batters to facilitate maintenance of turfed batters; and
- Maximum depth of 1.2m for the 20 year ARI event for public safety.
  - Noting: this may be increased in the future with appropriate signage, fencing and approval from Council.

4.2 Model Scenarios

The following scenarios have been considered for the assessment:

- **Pre-Development Case**: This case models the site in its current existing condition, illustrated on Figure 3.
- **Post-Development Case - Residential Development:** This case is based on the pre-development case but models the site with the proposed development in place. The post-development model layout is the same as the pre-development case, illustrated on Figure 4.

4.2.1 Mitigation

It is proposed to mitigate the increases in flows (Table 4-6) via flow attenuation basins. Four flow attenuation basins are proposed. One flow attenuation basin is proposed adjacent to the monsoon rainforest patch within Muirhead North. Three basins are proposed to be located within the 2CRU site, one to the south-west corner and two located along the west of Lee Point road. It is proposed to further optimise these storages during detailed design phase.

Assessment Report 88 highlighted the importance of retaining the native vegetation where a 16,000m^3 basin was previously proposed to be located in the Muirhead North site, to the far east of the site. Based on this recommendation it is proposed to avoid locating flow attenuation basins within the area shaded dark green in Figure 3-1 (“open space / drainage reserve area”). Alternative methods to attenuate peak flows without ‘Basin 7’/’Basin MU08’ being located in the native vegetation areas were investigated and reported (5 December 2018). The alternative peak flow attenuation approach proposed incorporates flow attenuation in the Active Recreation Reserve ‘ARR’ and a relocated basin, located just west of the rainforest patch (hatched in red in Figure 3-1). A consequence of reduced storage is a higher impact on peak flows in the order of 8-10%, while previously the mitigated post-development peak flows were similar to or lower than the pre-developed peak flow.

Previously, it was proposed to attenuate flow within the ‘Active Recreational Reserve’ (ARR). Flow was proposed to empty from the ARR within 12hrs. However, due to concerns about public health, flow attenuation within the ARR was abandoned. As a consequence, an increase in peak flow is presented in this report in comparison with the previous preliminary SMP for Muirhead North. Within the 2CRU site, there is a very small residential area located to the north-west corner that discharges towards the north. The area of this residential portion is 3.9ha and is identified as sub-catchment 2C01. It is considered appropriate to allow flow from this small residential area to discharge from site without flow attenuation. This consideration is based on the modified flow regime from the site, the post-development estimated peak flow is lower than pre-development peak flow, as shown in Table 4-8.

In summary, in order to retain more native vegetation, the proposed post-development flow attenuation incorporates storages, but with reduced volume than previously reported in the preliminary SMPs. The detention basin outlets are detailed in Table 4-4 with the stage-storage relationships shown in Table 4-5.

Table 4-4 Detention Basin Details

Basin ID	Outlet Pipes	Outlet Weir	20 Year Depth in Basin (m)	100 Year Depth in Basin (m)	Volume at 20 Year Level (m^3)	Volume at 100 Year Level (m^3)
MU08 (previously Basin 7)	6 / 1500 W x 600 H RCBC	7.5m width RL 10.6mAHD	1.18	1.45	7,126	8,744
2C10	4 / 1200 W x 300 H RCBC	5m width RL 21.15mAHD	1.19	1.46	3,291	4,123
EA	4 / 1200 W x 300 H RCBC	5m width RL 25.65 mAHD	1.17	1.44	1,146	1,467
2C05	4 / 1200 W x 300 H RCBC	5m width RL 23.4mAHD	1.12	1.42	3,380	4,404

Table 4-5 Proposed Concept Detention Basin Stage-Storage Relationships

Stage (m)	MU08 (previously Basin 7)	2C10	EA	2C05
1.5	9,157	4,281	1,565	4,735
1.45	8,771	4,085	1,485	4,519
1.4	8,390	3,894	1,407	4,307
1.35	8,015	3,706	1,332	4,099
1.3	7,646	3,522	1,258	3,896
1.25	7,283	3,342	1,187	3,697
1.2	6,926	3,166	1,118	3,502
1.15	6,574	2,993	1,050	3,311
1.1	6,228	2,824	985	3,124
1.05	5,888	2,659	922	2,941
1	5,553	2,498	861	2,763
0.95	5,224	2,340	801	2,588
0.9	4,900	2,186	744	2,418
0.85	4,582	2,035	688	2,251
0.8	4,270	1,888	634	2,088
0.75	3,963	1,745	582	1,930
0.7	3,661	1,605	532	1,775
0.65	3,365	1,469	484	1,624
0.6	3,075	1,336	437	1,477
0.55	2,790	1,206	392	1,333
0.5	2,510	1,080	349	1,194
0.45	2,235	957	307	1,058
0.4	1,966	838	267	926
0.35	1,702	722	228	797
0.3	1,443	609	191	673
0.25	1,190	500	156	552
0.2	941	393	122	434

Stage (m)	MU08 (previously Basin 7)	2C10	EA	2C05
0.15	698	290	89	320
0.1	460	190	58	210
0.05	227	93	28	103
0	-	-	-	-

Previously, the mitigated post-development peak flow was similar to the pre-developed peak flow. However, in order to retain more native vegetation, the area available to construct flow attenuation basins has been reduced. Therefore, the area and subsequently the volume of flow attenuation basins within Muirhead North were reduced due to being relocated southwest of the rainforest path. The Basin Stage Vs. Storage relationship modelled in XPRAFTs are presented in Figure 4-4 in Table 4-5.

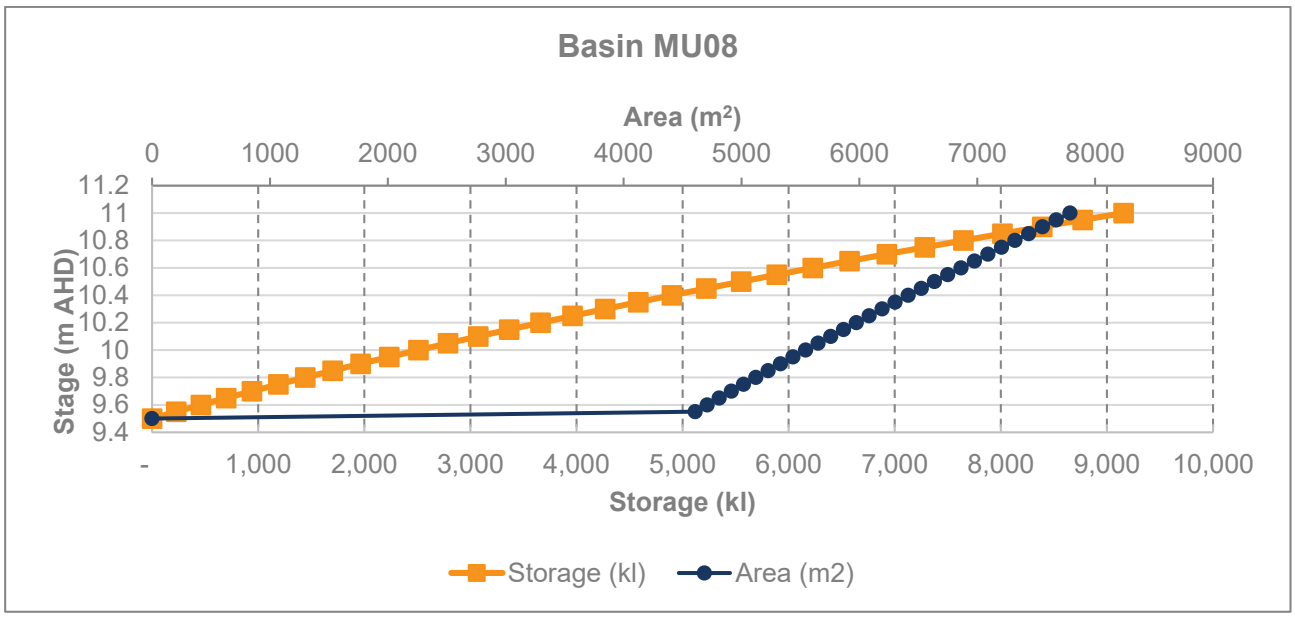

Figure 4-4 MU08 Detention Basin Stage-Storage-Area Relationship

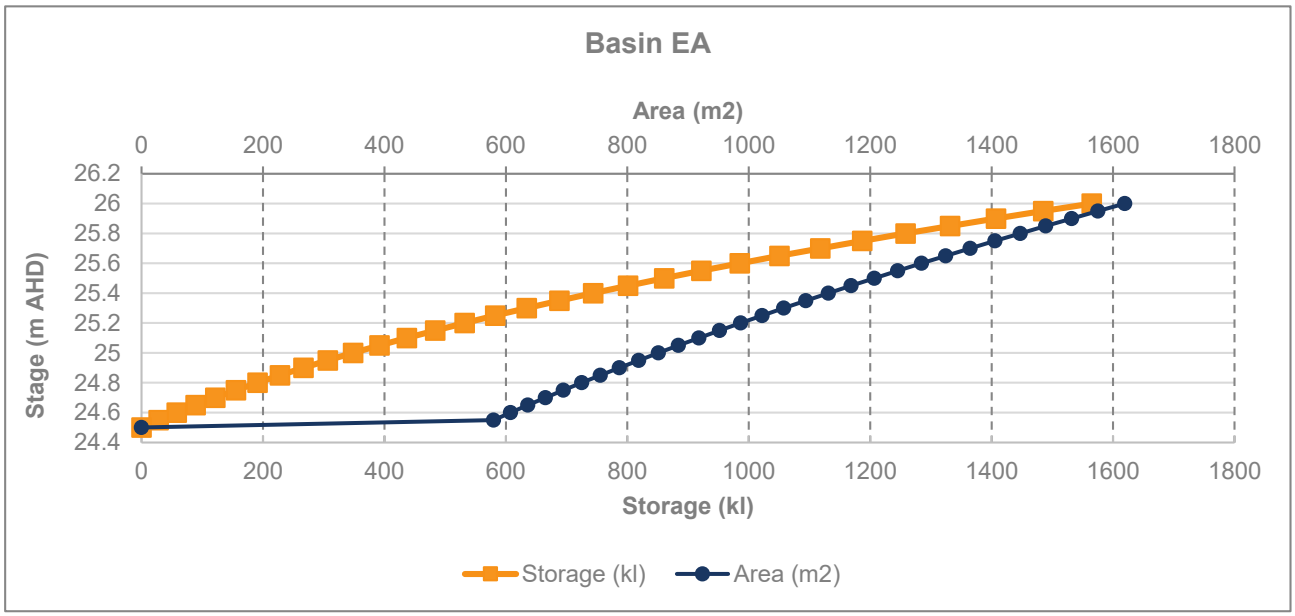

Figure 4-5 EA Detention Stage-Storage-Area Relationship

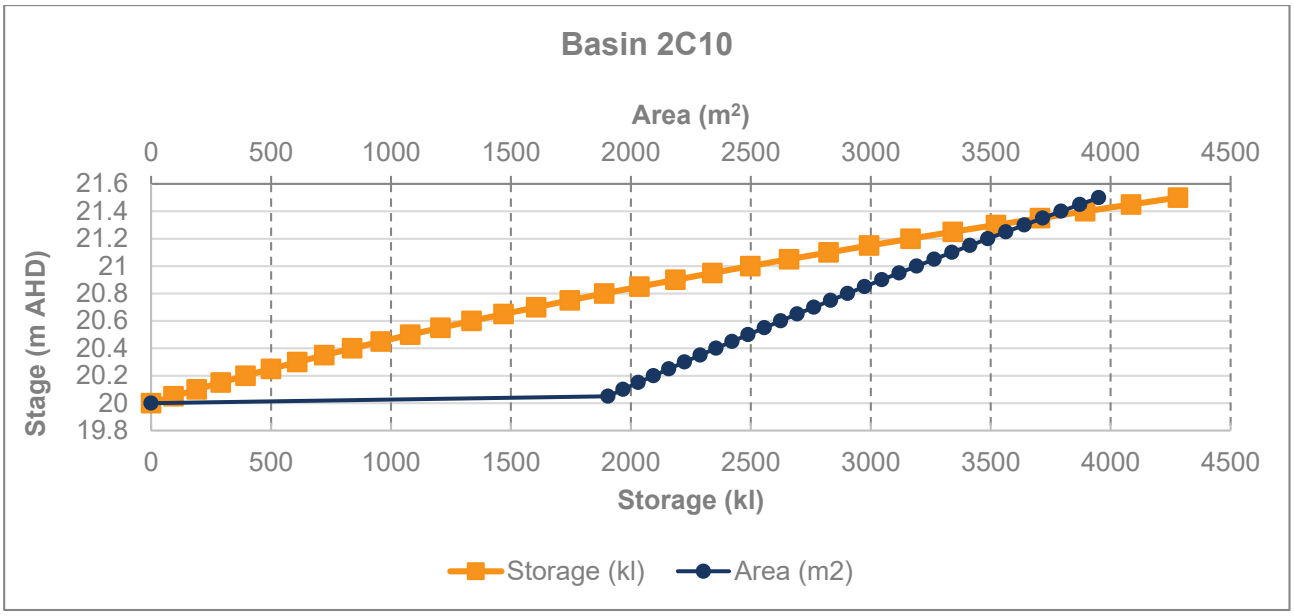

Figure 4-6 2C10 Detention Stage-Storage-Area Relationship

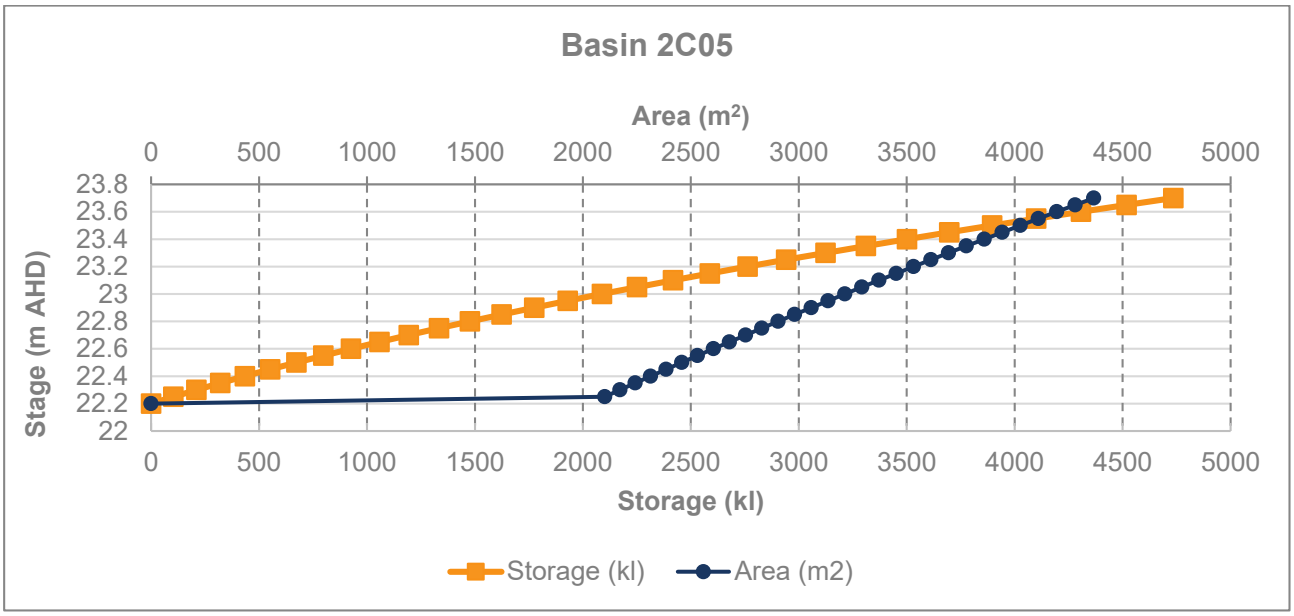

Figure 4-7 2C10 Detention Stage-Storage-Area Relationship

4.3 Results

4.3.1 Post-Development Case

The resultant peak flood discharge for both scenarios is shown in Table 4-6.

Table 4-6 Unmitigated Peak Discharge at Outlet (Node4)

ARI (years)	Pre-Developed			Post-Developed Unmitigated			Flow Difference	
	Flow (m^3/s)	Critical Duration (min)	Time to Peak (min)	Flow (m^3/s)	Critical Duration (min)	Time to Peak (min)	(m^3/s)	(%)
100	40.7	60	56.0	58.9	60	25.0	18.2	45%
50	36.2	60	56.0	52.5	60	25.0	16.3	45%
20	30.9	60	56.0	46.8	60	25.0	15.9	52%
10	26.7	60	57.0	40.8	60	25.0	14.1	53%
5	23.8	60	57.0	36.7	60	25.0	12.8	54%
2	19.2	60	57.0	29.8	60	25.0	10.6	55%

The proposed development is predicted to increase peak discharges at the site outlet. Consequently, mitigation of the increased peak discharge is needed, detailed in Section 4.3.2.

4.3.2 Mitigated Post-Development Case

The resulting mitigated peak flows for the overall 2CRU and Muirhead for all design events are presented in Table 4-7. These results demonstrate the peak flood flow reductions achieved with reduced storage in order to retain more native vegetation. The concept mitigated development arrangement is presented in Figure 4.

Table 4-7 Mitigated Peak Discharge for total site (Node4)

ARI (years)	Pre-Developed			Post-Developed Mitigated			Flow Difference	
	Flow (m^3/s)	Critical Duration (min)	Time to Peak (min)	Flow (m^3/s)	Critical Duration (min)	Time to Peak (min)	(m^3/s)	(%)
100	40.7	60	56.0	49.0	60	36.0	8.4	21%
50	36.2	60	56.0	43.2	60	36.0	7.1	20%
20	30.9	60	56.0	37.8	60	35.0	6.9	22%
10	26.7	60	57.0	33.1	60	36.0	6.4	24%
5	23.8	60	57.0	30.1	60	36.0	6.2	26%
2	19.2	60	57.0	24.8	60	36.0	5.6	29%

Mitigated peak flows for the total site as well as the four main discharge points are provided in Table 4-8. overall 2CRU and Muirhead North for all design events are presented in Table 4-7. Since the flow regime of the existing catchment has been modified, there is a variation in catchments extents contributing to the discharge points as well as mitigation of the peak flows. Post-development peak flow discharge from RP01 was lower than pre-development without attenuation of peak flows. This demonstrates that it is reasonable not to attenuate flow from catchment 2C01. The highest percentage increase in peak flow was report at RP06. This is because there is limited space for attenuation of peak flow from catchment 2C02. Peak flow discharge to the south-west corner of the 2CRU site was adequately attenuated with only a slight increase in peak flow during the 2 year ARI.

Table 4-8 Mitigated Peak Discharge at various locations for the 100 and 2 year ARI events

ID	Description	100 year ARI				2 year ARI			
		Peak Q (m^3/s)		Difference		Peak Q (m^3/s)		Difference	
		Pre-Dev	Post-Dev	(m^3/s)	(%)	Pre-Dev	Post-Dev	(m^3/s)	(%)
Node4	Total site (2CRU & Muirhead Nth)	40.7	49.0	+8.4	+21 %	19.2	24.8	+5.6	+29 %
RP01	2CRU 3.9ha catchment discharging towards the north	2.3	1.6	-0.7	-30 %	1.1	0.8	-0.2	-21 %
RP5	Discharge east of Muirhead North site	27.8	32.3	+4.5	+16 %	13.0	16.1	+3.2	+24 %
RP04	2CRU south-west discharge point	9.9	9.5	-0.4	-4 %	4.7	4.9	+0.2	+3 %
RP06	2CRU catchment discharging from basin EA to the existing dam	4.1	6.2	+2.0	+49 %	1.9	3.2	+1.3	+66 %

The flow attenuation storages proposed for the site achieved the depths, volumes and peak outflows detailed in Table 4-9. As this stage is concept design, depending on the final outfall arrangement and the method of flow interception, these volumes may differ. The volumes of the proposed system will be finalised during the detailed design phase.

Table 4-9 Peak flow mitigation details

Basin ID	ARI	Duration	Peak Inflow (m^3/s)	Peak Outflow (m^3/s) ^	Peak Flow Difference (%)	Peak Basin Volume * (m^3)	Peak Basin Stage (m AHD)
EA_Basin	2	60	4.0	3.2	-20%	604	25.3
EA_Basin	5	60	4.8	3.7	-23%	799	25.4
EA_Basin	10	60	5.3	4.0	-25%	935	25.6
EA_Basin	20	60	6.1	4.5	-26%	1,146	25.7
EA_Basin	50	60	6.7	5.3	-22%	1,305	25.8
EA_Basin	100	60	7.5	6.2	-18%	1,467	25.9
MU08_Basin	2	60	11.6	9.6	-17%	4,878	10.4
MU08_Basin	5	60	14.0	11.4	-18%	5,815	10.5
MU08_Basin	10	60	15.4	12.4	-19%	6,385	10.6
MU08_Basin	20	60	17.3	14.0	-19%	7,126	10.7
MU08_Basin	50	60	19.0	16.0	-16%	7,919	10.8
MU08_Basin	100	60	21.1	18.1	-14%	8,744	10.9
2C10_Basin	2	60	4.4	3.2	-27%	1,831	20.8
2C10_Basin	5	60	5.4	3.7	-30%	2,377	21.0
2C10_Basin	10	60	6.0	4.0	-32%	2,749	21.1
2C10_Basin	20	60	6.9	4.6	-33%	3,291	21.2
2C10_Basin	50	60	7.7	5.5	-28%	3,738	21.4
2C10_Basin	100	60	8.6	6.4	-26%	4,123	21.5
2C05_Basin	2	60	5.1	3.1	-40%	1,861	22.9
2C05_Basin	5	60	6.2	3.6	-42%	2,404	23.1
2C05_Basin	10	60	6.8	3.9	-44%	2,780	23.2
2C05_Basin	20	60	7.8	4.3	-46%	3,379	23.4

Basin ID	ARI	Duration	Peak Inflow (m^3/s)	Peak Outflow (m^3/s) ^	Peak Flow Difference (%)	Peak Basin Volume * (m^3)	Peak Basin Stage (m AHD)
2C05_Basin	50	60	8.6	5.0	-42%	3,978	23.5
2C05_Basin	100	60	9.6	5.7	41%	4,404	23.6

Notes:

* These volumes were determined from XPRAFTs.

^ The outlet design proposed is concept in nature and may require refinement at detailed design once ultimate finished surface levels and landscape design has been established.

4.3.3 Managing Discharge to Buffalo Creek from Muirhead North

The majority of stormwater runoff from the site is proposed to discharge into Basin MU08. Flow from Basin MU08 shall discharge into an open channel north of Aldenham Road, which will discharge into Buffalo Creek. Preliminary hydraulic analysis was undertaken to assist conceptual design considerations. Noting that further modelling and assessment is required and the detailed design flow may vary depending on the final arrangement selected. Based on the concept stage hydraulic model, the velocity in Aldenham Road swale was estimated to be in the range 0.8m/s for the 2 year ARI up to 1.2m/s for the 100 year ARI. Velocity is an important consideration when evaluating the erosion potential of a site.

Further design consideration of how flow from Aldenham Road swale will discharge and transition into Buffalo Creek shall be undertaken during detailed design. Potential outlet arrangements can be identified via further modelling and analysis to ensure that erosion is not exacerbated by the stormwater discharge. It is preferable to use a design that ties in with the existing topography and environmental features, such as vegetated lined channels potentially with coir logs and native grasses. Alternatively, where modelling indicates the need for more structured stormwater management concrete lined channels may be proposed.

In summary, further modelling and assessment of the site hydrology is needed to accurately size the channels and to design the lining type. The outlet arrangement from the Aldenham Road swale to the downstream environment shall be designed by a suitably qualified engineer and shall ensure erosion post-development is minimised.

4.3.3.1 Monsoon Rainforest

The concept mitigation arrangement presented is intended to reduce the hydrologic impact of the proposed Muirhead development on the rainforest area to be retained. Table 4-8 summarises the estimated existing peak flows determined from the XPRAFTs model to the rainforest area. The peak flows to the rainforest area under developed (mitigated) conditions will be managed to prevent flows in exceedance of the existing flows discharging to the area. Noting that it is proposed to divert most of the peak flows into detention Basin 7, detailed in Section 4.2.1. The arrangement of flow diversion will be determined during detailed design.

Table 4-10 Existing Peak Flows to Rainforest (XPRAFTs reporting point EF)

ARI (year)	Pre-developed (EX05)
100	20.0
50	17.7
20	15.1
10	12.9
5	11.5
2	9.2

4.4 Mosquito Breeding Considerations

To minimise the potential for mosquito breeding and to reduce the frequency of inundation, a low flow channel will be provided to bypass the 1 year ARI flow around the proposed detention (oval). Based on the modelling undertaken, the ARR reduces to 0.02 m depth with 5 hrs for all ARI events. The proposed main basin MU08 (Basin 7) reduces to below 0.08 m after 5 hrs for all rainfall events. The basins will fully drain to empty within 48 hrs.

4.5 Summary

The reported modelling results are based on a concept design stage. The modelling results presented the peak flood flow reductions achieved with reduced impact on native vegetation, based on the modelled detention basin arrangement and sizing, Figure 4. Since this is a concept design stage, the design may be subject to change and thus there could be some variation to the reduction achieved.

It is proposed to discharge flow from the development area along the southern border (Aldenham Road) via a 430m long and 20m wide grassed lined swale or bio-swale. The grassed swale would be designed to prevent erosion of the receiving environment. During detailed design stage some variation to the overall size of the basins may occur. However, the intent of the basin is to be maintained. Any redesign will necessitate re-analysis of the system to ensure that the developed peak flow discharging from the site are managed to prevent erosion of the downstream environment.

5 Stormwater Quality Assessment

Urban development has the potential to negatively impact the downstream environment due to increased turbidity, pollutant loads and / or release of contaminants during construction and operation. Potential water quality impacts from this development shall be managed with effective implementation of the measures outlined in the following section to meet specific Water Quality Objectives (WQO's).

5.1 Construction Phase

During the construction phase, the potential exists for increases in the amount of pollutants, particularly sediment, exported from the site. During this period a suitable Erosion and Sediment Control (ESC) plan will be required as part of the construction phase Environmental Management Plan (EMP). This ESC plan will limit construction phase water quality impacts to a minimum, if it is developed and operated in accordance to current best practice guidelines.

5.2 Operational Phase

5.2.1 Water Quality Objectives

The WQO's for the 2CRU and Muirhead North developments were initially adopted from *Darwin, Water Sensitive Urban Design (WSUD) Planning Guide (2009).* Initially (26 July 2017) the treatment measures proposed for the two sites included Ecosol 'Net Guards' and bio-retention basins. However, while modelling indicates that bio-retention basins achieve good reductions, in practice, in the Darwin region the performance of bio-retention basins has been lower than that anticipated.

A research paper submitted from the Queensland University of Technology assessed the effectiveness of water quality control systems in southeast Queensland. The title of the research paper was *'Assessing the Effectiveness of Water Sensitive Urban Design in Southeast Queensland'* (Parker, 2010). A research outcome was the limitation over time of bio-retention systems. Specifically, the issues identified were clogging, degradation and general issues of proper maintenance. The typical design life of a bio-retention system before desilting is required is 20 years. The research paper concluded it was unlikely for existing bio-retention systems to function effectively throughout their design life, taking into consideration the current quality of the maintenance conditions (Parker, 2010).

In summary, an alternative stormwater treatment approach has been adopted that excludes bio-retention basins. This approach is based on the observed practical performance of bio-retention basins in the Darwin region and as they are not desired by the City of Darwin for the reasons outlined above. Consequently, alternative WQO's are proposed for the development, outlined in Table 5-1. Alternative WQO's have been proposed due to the limitations regarding which stormwater treatment devices can be practically incorporated and maintained, detailed in Section 5.2.2.

Table 5-1 outlines the WQO's proposed for the 2CRU and Muirhead North development.

Table 5-1 Muirhead North proposed Water Quality Objectives

Parameter	Muirhead Proposed WQO
Suspended Solids (TSS)	80% reduction
Total Phosphorus (TP)	50% reduction
Total Nitrogen (TN)	20% reduction
Gross Pollutants (GP)	90% reduction

The stormwater treatment system shall be designed during the detailed design stage and shall realise WQO's outlined in Table 5-1. In order to enable the development of a suitable treatment train, stormwater pollution modelling methodology shall be adopted from the *Darwin, Water Sensitive Urban Design Planning Guide (2009)*. This guide provides a method of quantifying reductions within a computer model (MUSIC Model).

5.2.2 Proposed Treatment Train

As described in Section 5.2.1, limitations exist regarding which SQIDs are suitable for the Darwin Harbour region. Consideration was made to incorporate larger bio-retention basins in the Muirhead development. However, previous investigations found in practice the performance of bio-retention basins was lower than

predicted. Additionally, the incorporation of large scale retention basins in the Darwin region has been observed to increase the risk of mosquito breeding potential.

A review of previously successful SQIDs implemented within the Darwin Harbour region will guide the final WSUD approach for Muirhead North. For example, it will be determined during detailed design phase of the project if opportunities exist to utilise small scale bio-retention systems, such as tree pits and raingardens. It is noted in the Darwin Harbour WSUD *'Rainwater Tank Discussion Paper'* (2009) that the use of rainwater tanks for re-use of rainwater could also reduce the stormwater pollutant loads generated within the site while also reducing the demand on town water supply. The discussion paper advises:

> *Despite the high seasonality of rainfall in the Darwin region significant volumes of rainwater can still be harvested during the wet season. Rainwater tanks are effective in Darwin when connected to high volume indoor uses such as washing machines and hot water services.*
>
> *The high volumes and high reliability of rainfall during the wet season means that rainwater tanks will supply almost all of the internal non-potable end-use demands during the wet season. This high reliability for up to six months of the year compensates for the lack of rainfall during the three to four months during the dry season when no demands are being supplied by rainfall.*
>
> *For the Darwin region and its particular climate and end use demands:*
>
> - *the most efficient tank size that balances yield with roof size, climate and demand scenario is almost consistently a 1 to 2 kL tank.*
> - *Rainwater tanks to be effective need to be connected to high volume indoor uses such as washing machines and/or hot water services.*
>
> *Furthermore, TDS of the Darwin water supply is similar to that expected in rainwater tanks and is thus unlikely to cause issues with corrosion in hot water systems.*

The feasibility of implementing rainwater tanks shall be determined during detailed design. Therefore, a requirement for rainwater tanks has not been included as part of this concept SMP.

Proposed concept locations for the Stormwater Quality Improvement Devices (SQIDs) are illustrated in Appendix C. For the purpose of this preliminary water quality treatment assessment the below listed SQIDs were incorporated into the MUSIC model:

- Gross pollutant traps (GPTs); and
- Grassed swales;

Noting, it is necessary to ensure that the system employed provides adequate stormwater quality and flow regime (both via surface and groundwater) to maintain ecosystem health to the Monsoon rainforest area.

5.2.2.1 Gross Pollutant Traps

To minimise the size and quantity of SQIDs it is proposed to incorporate pre-treatment devices such as Rocla 'CleansAll' (or similar). The recommended pollutant removal efficiencies for these devices have been provided by the manufacturer (November 2018) and are listed below.

- 65 % reduction in Suspended Solids;
- 25 % reduction in Total Phosphorus;
- 0 % reduction in Total Nitrogen; and
- 95 % reduction in gross pollutants.

Cardno (25 September 2018) sought further clarification from Rocla about the CleansAll treatment performance for 'Free Oils' and 'Total Petroleum Hydrocarbons'. Rocla provided the below advice:

> *CleansAll units typically remove 100% of 'free' oils, at flows less than the maximum treatment flow. If flows exceed the maximum treatment flow, there is potential for oils to bypass the collection chamber by overtopping the weir.*

5.2.2.2 Swales

Swales utilise overland flow and mild slopes to slow down water velocities and remove pollutants from stormwater. Three grass lined swales are proposed to be incorporated into the development. The interaction between the vegetation and stormwater flow facilitates velocity reduction and maintains the slowed flow conditions. Additionally, the vegetation encourages pollutant settlement and retention.

The conceptually proposed Aldenham Road swale will convey water downstream from the development site. This swale will be either a grass lined swale or a bio-swale, both capable of slowing water and removing pollutants. Selection of a swale rather than pipes along Aldenham Road was to minimise the potential for erosion and water quality impacts on downstream waterways.

5.2.3 Catchment Breakdown

The two sites were assessed based on the XPRAFTS catchments, presented in Section 4. The proposed development layout, catchments and treatment device locations are summarised in Table 5-2.

Table 5-2 2CRU and Muirhead North MUSIC Catchment Details

Source Node ID	Total Area (ha)	Medium density residential (ha)	Low density residential (ha)	Open space / parkland (ha)	SQID Description
2C01	3.9	2.2	-	1.7	ROCLA CleansAll 750
2C02	13.8	10.8	-	3.0	ROCLA CleansAll 750
2C03 & 2C05	10.2	8.9	-	1.3	ROCLA CleansAll 1200, Swale N-S, Swale E-W & Swale Aldenham Rd
2C04	7.4	7.1	-	0.3	ROCLA CleansAll 750, Swale N-S, Swale E-W & Swale Aldenham Rd
2C06A	4.1	4.1	-		ROCLA CleansAll 750, Swale N-S, Swale E-W & Swale Aldenham Rd
2C06B	0.5	0.5	-		ROCLA CleansAll 750, Swale N-S, Swale E-W & Swale Aldenham Rd
2C07	3.5			3.5	-
2C08 & 2C09	15.8	15.5	-	0.3	ROCLA CleansAll 1200
2C10	3.1			3.1	-
2C11 & 2C12	3.6			3.5	-
2C13	1.2			1.2	-
MU01A, MU01B & MU02	8.9	4.6	-	4.3	Swale N-S & Swale E-W
MU03 & MU05	6.1	6.1	-	-	ROCLA CleansAll 1200, Swale N-S, Swale E-W & Swale Aldenham Rd
MU04 & MU06	11.1	10.5		0.6	ROCLA CleansAll 1200, Swale E-W-B, Swale E-W & Swale Aldenham Rd
MU07A & MU07B	2.9	2.9		-	Treatment within 'The Breezes'
MU08	3.4		1.6	1.8	Swale E-W & Swale Aldenham Rd
MU10	9.7		9.7	-	ROCLA CleansAll 750
MU11-Urban	2.4		2.4	-	-
MU11-Forest	6.2	-		6.2	-
MU12A	0.8			-	Treatment within 'The Breezes'
MU09,MU13, MU14&MU15	16.4			16.4	-

Urban source nodes were adopted for the residential development areas. Catchments were broken down into source node types as follows:

- *Urban Residential* – representing the typical medium density residential lots including ground and roof area.
- *Urban Low Density* – representing the proposed lots with lower density than the typical lots.

> *Open Space* – representing proposed open space and parkland areas.

Rainfall runoff, pollutant export parameters and impervious area proportions were applied as appropriate to each source node based on the provided lot layout. Details of source nodes for each sub-catchment are provided in Table 5-3.

Table 5-3 MUSIC Model Adopted Fraction Imperviousness

Land use	Fraction Impervious (%)
Residential Medium Density	60
Rural Residential	20
Open Space/Park/Sports Oval	0

5.2.4 Pollutant Impact Assessment

Results of the pollutant export analysis were extracted from MUSIC and are summarised in Table 5-4 for the total combined site and Table 5-5 for the 2CRU site and Table 5-6 for the Muirhead North site. As detailed, the results indicate that the proposed stormwater treatment measures do not achieve the WQOs outlined in the previously approved Muirhead North preliminary SMP (Table 5-1), except for gross pollutants.

These results demonstrate that the SQIDs listed in Section 5.2.2 can achieve a reasonable level of treatment for suspended solids, total phosphorous and gross pollutants. However, treatment of total nitrogen was very low, especially for the 2CRU site which includes CleansAll treatment devices and does not include biological treatment devices, such as grassed lined swales. The SQIDs selected are those approved by City of Darwin. Further modelling will be undertaken during the detailed design phase to maximise treatment with the approved treatment devices.

Table 5-4 Total combined MUSIC Model Results Vs. Targets

Pollutant	Proposed unmitigated (kg/yr)	Proposed with mitigation (kg/yr)	Load Reduction (%)	*WQO Target Reduction (%)*
Total Suspended Solids	251,000	87,300	65.3	*80*
Total Phosphorous	509	310	39.1	*50*
Total Nitrogen	3,780	3,410	10.0	*20*
Gross Pollutants	27,100	1,970	92.7	*90*

Table 5-5 2CRU MUSIC Model Results Vs. Targets

Pollutant	Proposed unmitigated (kg/yr)	Proposed with mitigation (kg/yr)	Load Reduction (%)	*WQO Target Reduction (%)*
Total Suspended Solids	46,400	20,000	56.8	*80*
Total Phosphorous	91	70	22.7	*50*
Total Nitrogen	687	687	0	*20*
Gross Pollutants	4,770	263	94.5	*90*

Table 5-6 Muirhead North MUSIC Model Results Vs. Targets

Pollutant	Proposed unmitigated (kg/yr)	Proposed with mitigation (kg/yr)	Load Reduction (%)	*WQO Target Reduction (%)*
Total Suspended Solids	196,000	58,200	70.3	*80*
Total Phosphorous	400	222	45	*50*
Total Nitrogen	2,960	2,590	13	*20*
Gross Pollutants	21,300	722	97	*90*

5.2.5 Monitoring and Maintenance Stage

Water quality monitoring is proposed for the site post development and will be used to confirm or highlight the treatment systems effectiveness. Ecosystem monitoring of the rainforest area is proposed, with water quality monitoring to be undertaken within the downstream channel. The primary risk to the rainforest area is the reduction in low (base) flows from the upstream catchment. If during the monitoring phase it is identified

the rainforest area is suffering due to the development, re-evaluation of the water quality treatment measures upstream may be required.

As part of the ongoing water quality monitoring proposed for the site, the effectiveness of the proposed treatment systems relative WQO's will be assessed. This assessment should be undertaken utilising the risk based approach set out within the document. If during this process the site runoff is found to be posing a high risk to the ecosystem, management intervention to mitigate this risk will be required. Intervention may involve the addition of extra water quality treatment devices or a review of the design and effectiveness of the treatment measures constructed onsite.

5.3 Summary

The conceptual water quality assessment (MUSIC model) of the 2CRU and Muirhead North development found the WQO's listed in Table 5-1 could not be achieved with the approved stormwater treatment devices. Further MUISC modelling and the design of the SQIDs shall be undertaken during the detailed design stage. Water quality monitoring is proposed to be undertaken after construction of the development to determine the realised stormwater treatment.

Based on our understanding of the site, the primary ecosystem at risk within the site extent is the existing rainforest area. During the detailed design stage the stormwater system will be designed to ensure the existing hydrologic regime is maintained as much as feasible.

6 Regional Flood Assessment

Given the proximity of the proposed development site to Beagle Gulf, a review of the sites potential for storm tide inundation was undertaken. The storm tide levels for Lee Point are provided in the *High Resolution Storm Tide and Climate Change Impacts Study – 2010* (SEA, 2010), summarised in Table 6-1. Inundation across the site from local catchment runoff, resulting in shallow sheet flow and concentrated gully flows, has not been quantified in this report.

Table 6-1 Total Storm Tide Levels (mAHD) at Lee Point

Year	Estimated Return Period of Total Storm Tide Level (year)				
	50	100	500	1,000	10,000
2010	4.5	4.7	5.2	5.4	5.8
2050	4.9	5.1	5.6	5.8	7.1
2100	5.4	5.6	6.1	6.5	7.4

The storm tide levels for 2100 event (Table 5-1) have been mapped as part of the *Northern Territory Storm Surge Mapping* (GHD, 2014). Figure 6-2 presents the storm tide inundation extent relative to the proposed development location. As can be observed, the majority of the development extent is outside both the 100 year and 1,000 year ARI storm tide level for 2100.

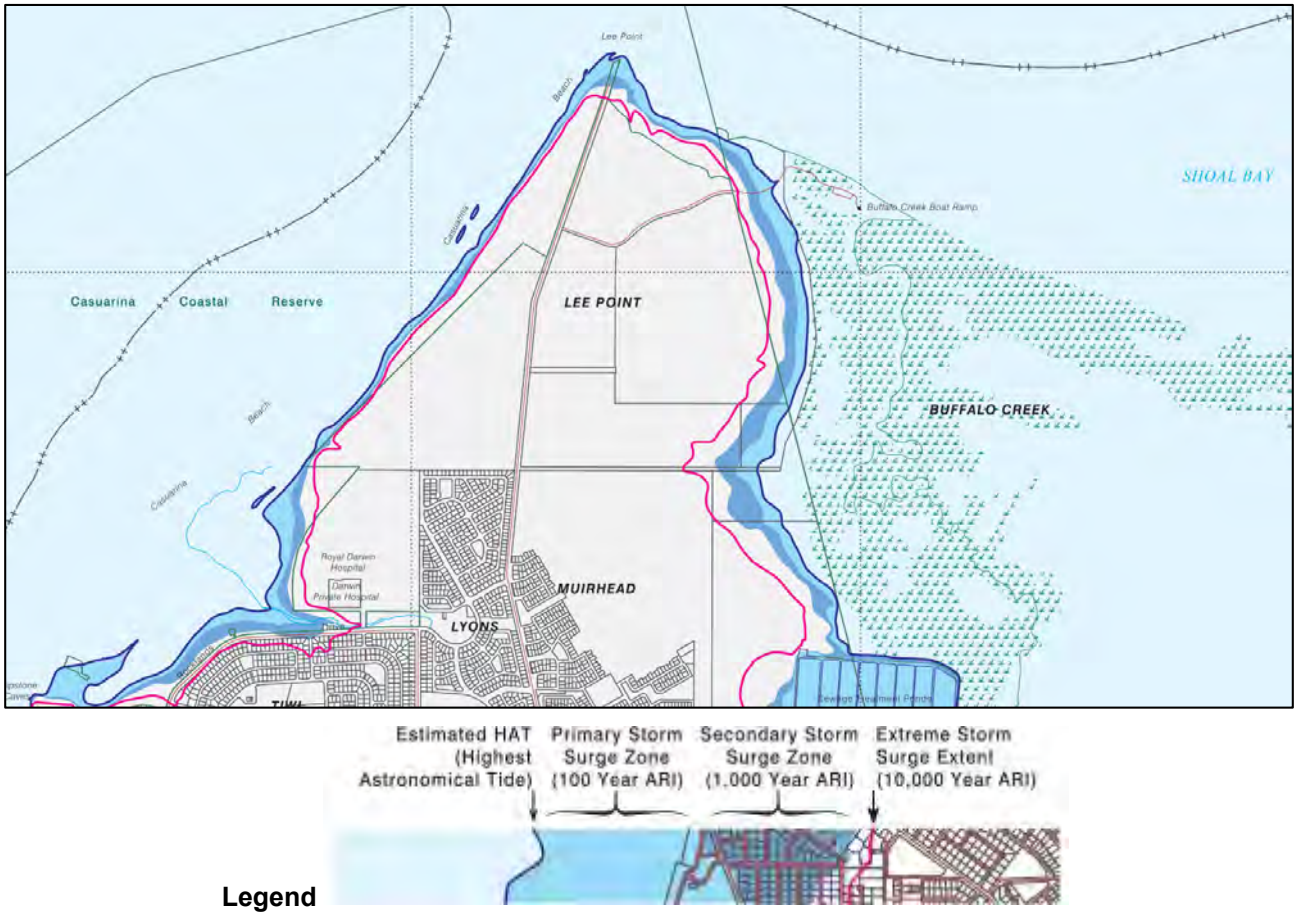

Figure 6-2 Darwin Area Storm Surge Inundation for 2100 Extract (GHD, 2014)

7 Conclusions

This concept SMP has been prepared by Cardno for the proposed 2CRU and Muirhead North developments. This study has investigated the water quantity and quality for the site and provides concept stage evidence the applicable development codes can be adhered to.

In preparation of this report the following assessments were completed:

- A review of relevant policies and guidelines;
- A hydrologic assessment;
- A review of regional flooding; and
- Assessment to determine locations and WQO's for SQIDs.

The hydrologic assessment was undertaken to determine the impact on existing peak flows from the development. The outcomes of the hydrologic model were used to determine the peak flow mitigation requirements, such as locating and sizing storage basins. Local hydrologic modelling determined the predicted peak flow discharge from the development. Peak flows from the site shall be managed by incorporating detention basins to attenuate post-developed discharges as much as practicable, given site specific considerations. Noting that an impact assessment of the local flood conditions shall be conducted for the environmentally significant rainforest area to prevent adverse impacts on the vegetation health. This is outside the scope of the conceptual SMP and should be completed during the detailed design phase of the DA.

This concept SMP also sought to balance the area designated for mitigating increases in peak flows as a result of the development with the area of existing vegetation retained. With reduced basin capacity, the impact of the post-developed peak flows would be 20-29% compared to the pre-developed peak flows, which is a reduction from 45-55% impact for the unmitigated case. The benefit of reduced basin capacity is that a larger area of forest can be retained, in line with Assessment Report 88 Recommendation 15 (described in Section 3.1). The Aldenham Road swale shall be designed during detailed design stage to prevent erosion of the discharging environment, Buffalo Creek and likewise for the 2CRU site discharge to Sandy Creek.

The type and concept locations for SQIDs have been provided in this SMP. During detailed design stage, SQIDs shall be designed to ensure adequate stormwater quality discharging from the development site.

8 Qualifications

This report has been prepared by Cardno for Defence Housing Australia (DHA) and specifically to provide stormwater management advice for the Muirhead North development. Our analysis and overall approach has been catered to the specific requirements of DHA, and may not be applicable beyond this scope. For this reason, any other third parties other than Council are not authorised to utilise this report without further input and advice.

Cardno has relied on the following information provided by others:

- Site survey undertaken by Bennett & Bennett;
- ALS data of the site and immediate surrounding catchment was sourced from the Department of Lands, Planning and the Environment (DLPE) to derive contours; and
- Aerial imagery, sourced from Nearmap and Google Earth; and
- Rainfall data supplied by the Bureau of Meteorology.

The accuracy of the report is dependent upon the accuracy of this information.

While Cardno's report accurately assesses peak flows from design storms, it is an ungauged catchment and consequently future observed flows may vary from that predicted.

9 References

- Australian Rainfall and Runoff (ARR) [IEAust, 1987];
- Cardno report '2CRU – Lee Point Road, Lee Point – Stormwater Management Plan' dated 25 May 2017 (ref: DC1603/R1/V2);
- Cardno report 'Muirhead North – Lee Point Road, Lee Point – Stormwater Management Plan' dated 20 December 2018 (ref: DC1603/R3/V4).
- City of Darwin (Council) - Subdivision and Development Guidelines, [COD, 2005];
- Queensland Urban Drainage Manual (QUDM) [DEWS, 2013];
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- Department of Environment and Natural Resources, 2018, NR Maps, Northern Territory Government, [NR Maps, 2018];
- Parker, N. (2010). Assessing the Effectiveness of Water Sensitive Urban Design in Southeast Queensland. Brisbane: Queensland University of Technology. Retrieved February 19, 2018, from https://eprints.qut.edu.au/34119/1/Nathaniel_Parker_Thesis.pdf; and
- Water Sensitive Urban Design (WSUD) [DPI, 2009].

APPENDIX A

DEVELOPMENT LAYOUT FIGURE

NOTES

(1) This plan was prepared for the purpose and exclusive use of DEFENCE HOUSING AUSTRALIA as an Investigation into the Development Potential of the land described in the plan and is not to be used for any other purpose or by any other person or corporation. JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this plan in contravention to the terms of this clause or clauses 2, 3, 4, 5, 6 or 7 hereof.

(2) The contours on this plan are approximate and are suitable only for the purpose of this application. The accuracy of the contours has not been verified and no reliance should be placed upon such contours for any purpose other than for the purpose of this application.

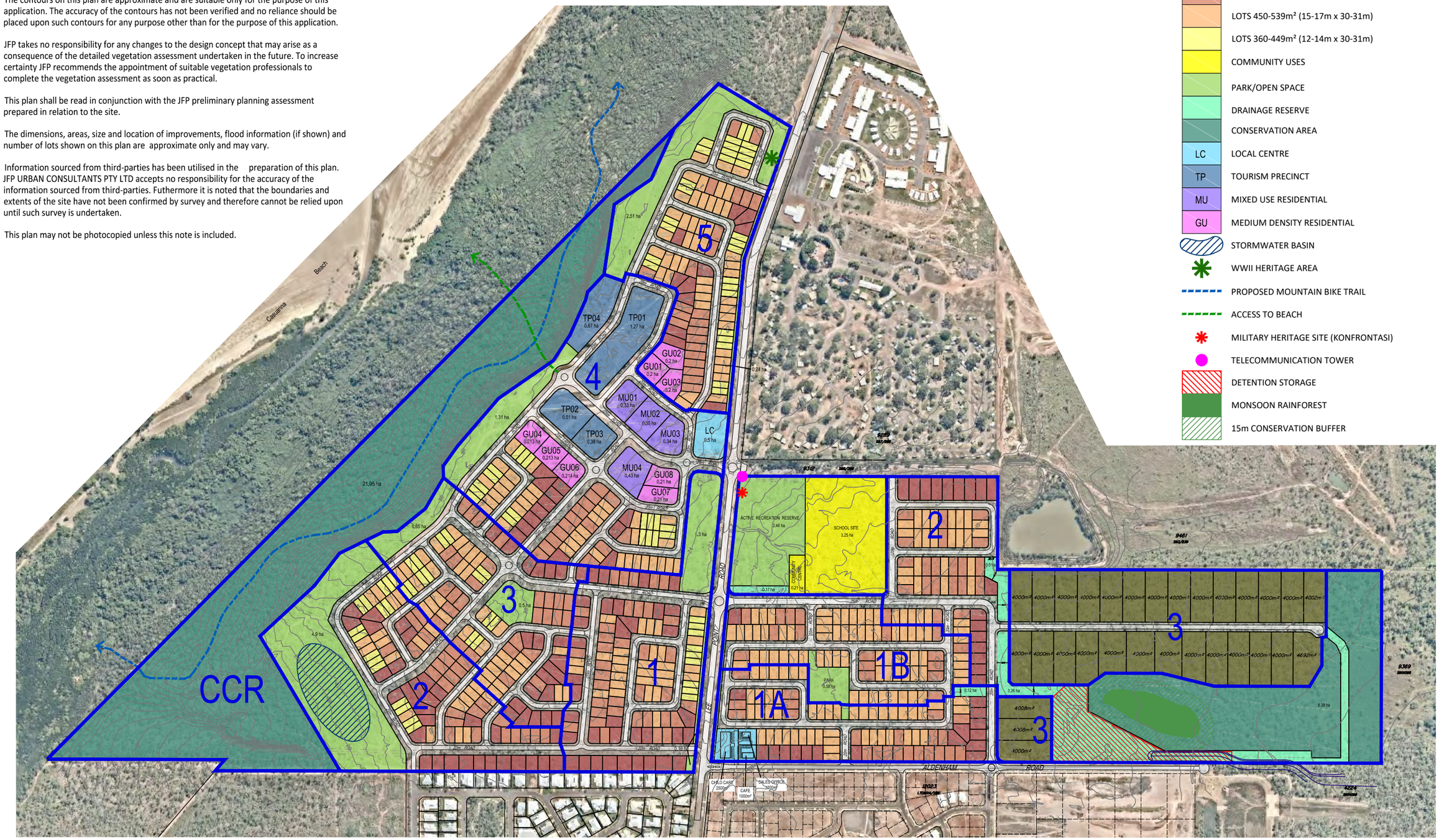
(3) JFP takes no responsibility for any changes to the design concept that may arise as a consequence of the detailed vegetation assessment undertaken in the future. To increase certainty JFP recommends the appointment of suitable vegetation professionals to complete the vegetation assessment as soon as practical.

(4) This plan shall be read in conjunction with the JFP preliminary planning assessment prepared in relation to the site.

(5) The dimensions, areas, size and location of improvements, flood information (if shown) and number of lots shown on this plan are approximate only and may vary.

(6) Information sourced from third-parties has been utilised in the preparation of this plan. JFP URBAN CONSULTANTS PTY LTD accepts no responsibility for the accuracy of the information sourced from third-parties. Futhermore it is noted that the boundaries and extents of the site have not been confirmed by survey and therefore cannot be relied upon until such survey is undertaken.

(7) This plan may not be photocopied unless this note is included.



LEGEND

- STAGING
- LOTS 4000m² & larger (45m frontage min.)
- LOTS 600-750m² (20m x 30-31m)
- LOTS 540-599m² (18-19m x 30-31m)
- LOTS 450-539m² (15-17m x 30-31m)
- LOTS 360-449m² (12-14m x 30-31m)
- COMMUNITY USES
- PARK/OPEN SPACE
- DRAINAGE RESERVE
- CONSERVATION AREA
- LC — LOCAL CENTRE
- TP — TOURISM PRECINCT
- MU — MIXED USE RESIDENTIAL
- GU — MEDIUM DENSITY RESIDENTIAL
- STORMWATER BASIN
- WWII HERITAGE AREA
- PROPOSED MOUNTAIN BIKE TRAIL
- ACCESS TO BEACH
- MILITARY HERITAGE SITE (KONFRONTASI)
- TELECOMMUNICATION TOWER
- DETENTION STORAGE
- MONSOON RAINFOREST
- 15m CONSERVATION BUFFER

JFP URBAN CONSULTANTS

PLANNERS
URBAN DESIGNERS
SURVEYORS
ENGINEERS
LANDSCAPE ARCHITECTS

OVERALL CONCEPT PLAN F

LEE POINT ROAD, LEE POINT, DARWIN
DEFENCE HOUSING AUSTRALIA

JOB NUMBER: M2737P_Overall Concept F
ISSUE: F
NORTH:
SCALE: 1:7000 @ A3
DATE: 9th April 2019

APPENDIX

B

STORMWATER MANAGEMENT PLAN FIGURES

Cardno

N

Aerial imagery courtesy of Nearmap, 2016

100 0 100 200 300 400 500m
1:10,000

Legend

Site boundary

Scale 1:10,000 (A3)

FIGURE 1
SITE TOPOGRAPHY

December 2019

Project No.: DC1603

PRINT DATE: 22 December, 2019 - 8:30pm

Defence Housing Australia

CAD FILE: O:\004__JOBS\00__WE19\DC1603_DDPhase_2CRU_MuirheadNth\3_Data\2_Analysis\AutoCad\Figures_R4V_Muirhead_CVM_2013.dwg
XREF's: Stormwater Drainage Updated Outfall_1; X-StormWater; Concept_Stormwater; M2737P_Overall Concept F

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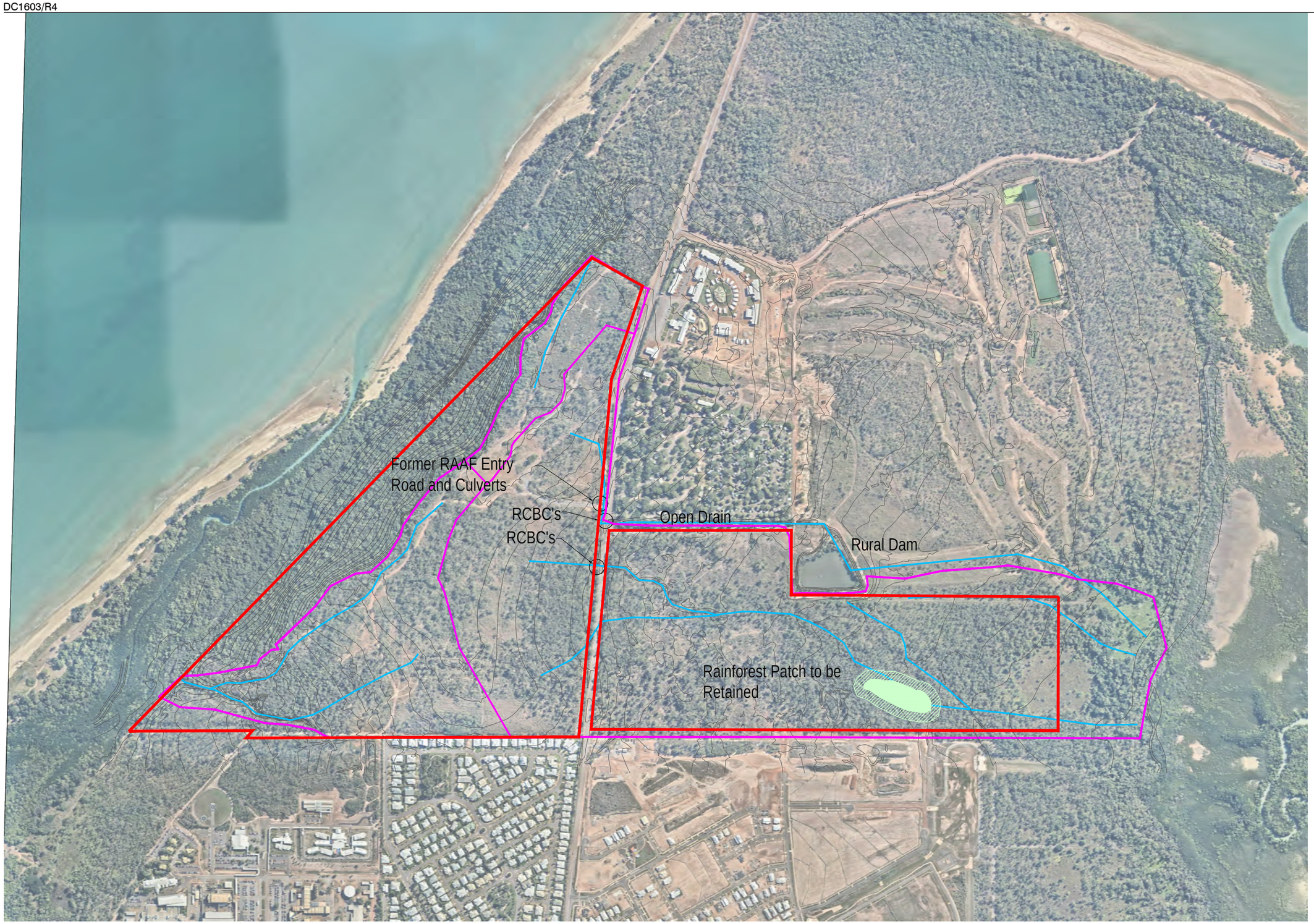

N

Legend

- Sub-catchments
- Flow path
- Site boundary
- Culvert location
- Monsoon rainforest (0.88ha)
- Rainforest patch buffer

Aerial imagery courtesy of Nearmap, 2016

100 0 100 200 300 400 500m
1:10,000

Scale 1:10,000 (A3)

FIGURE 2
CATCHMENT CHARACTERISTICS

December 2019

Project No.: DC1603

Defence Housing Australia

CAD FILE: O:\004__JOBS\00__WE19\DC1603_DDPhase_2CRU_MuirheadNth\3_Data\2_Analysis\AutoCad\Figures_R4V_Muirhead_CVM_2013.dwg
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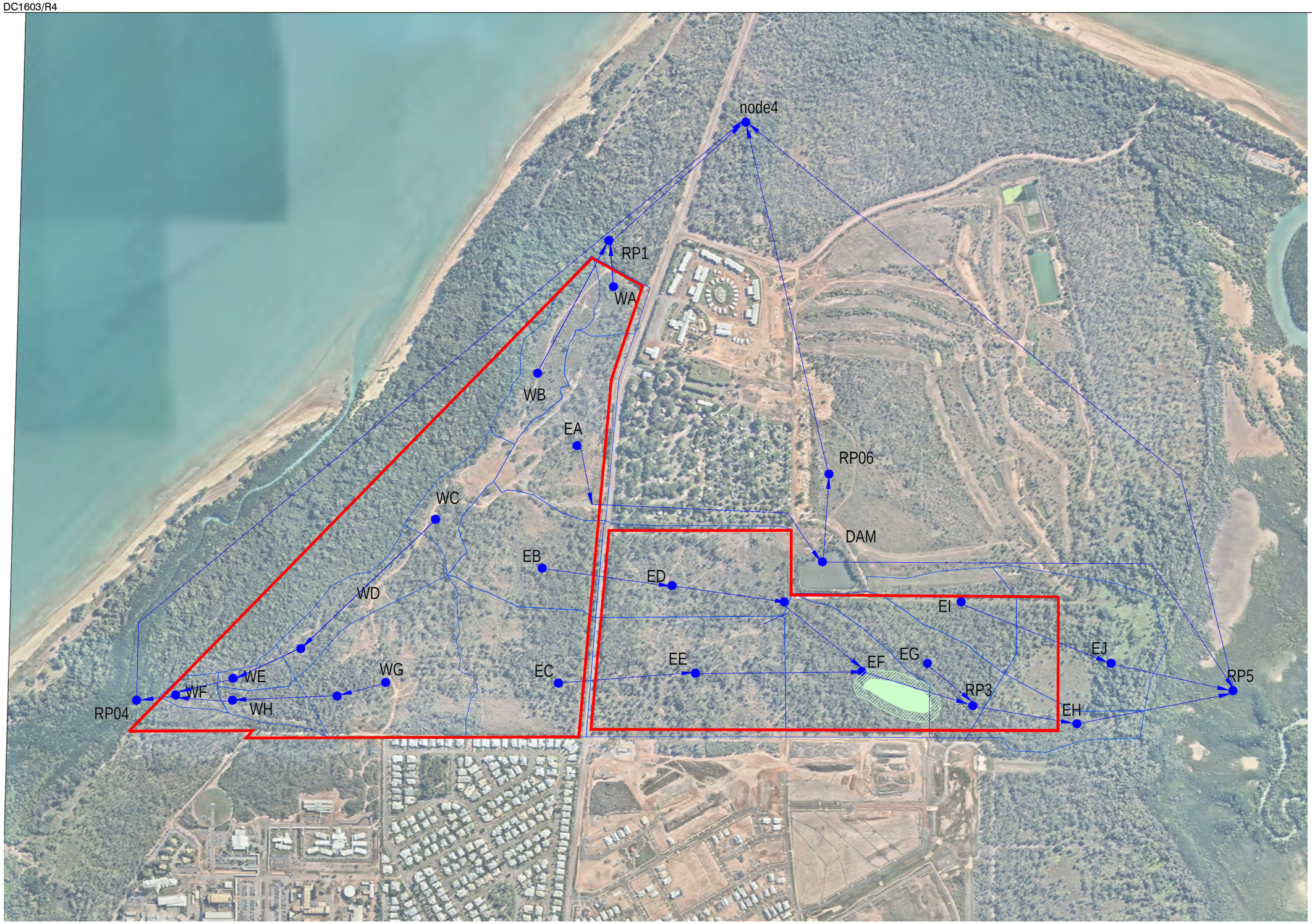
PRINT DATE: 22 December, 2019 - 8:31pm



Legend
- Sub-catchments
- Site boundary
- Link
- EI Catchment node
- Monsoon rainforest (0.88ha)
- Rainforest patch buffer

Aerial imagery courtesy of Nearmap, 2016

100 0 100 200 300 400 500m
1:10,000

Scale 1:10,000 (A3)

FIGURE 3
XPRAFTS EXISTING CATCHMENTS

December 2019

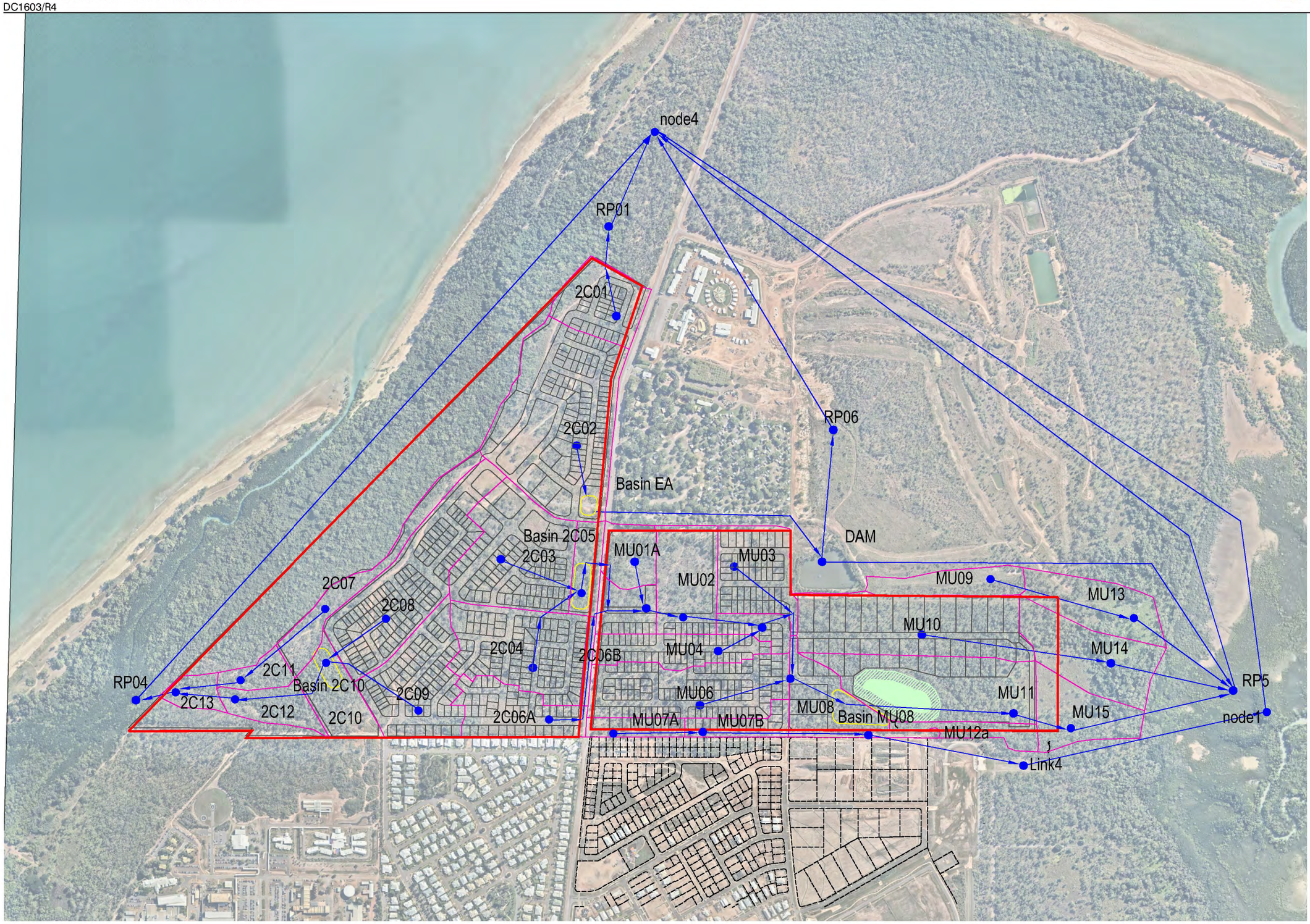
Project No.: DC1603

Defence Housing Australia

CAD FILE: O:\004_JOBS\00_WE19\DC1603_DDPhase_2CRU_MuirheadNth\3_Data\2_Analysis\AutoCad\Figures_R4V_Muirhead_CVM_2013.dwg
XREF's: Stormwater Drainage Updated Outfall_1; X-StormWater; Concept_Stormwater; M2737P_Overall Concept F

PRINT DATE: 22 December, 2019 - 8:32pm

Cardno



Legend

- Sub-catchments
- Site boundary
- Flow Path
- Detention basin
- EI Catchment node
- Monsoon rainforest (0.88ha)
- Rainforest patch buffer

Aerial imagery courtesy of Nearmap, 2016

100 0 100 200 300 400 500m
1:10,000

Scale 1:10,000 (A3)

FIGURE 4

CONCEPT XPRAFTS DEVELOPED CATCHMENTS

December 2019

Project No.: DC1603

Defence Housing Australia

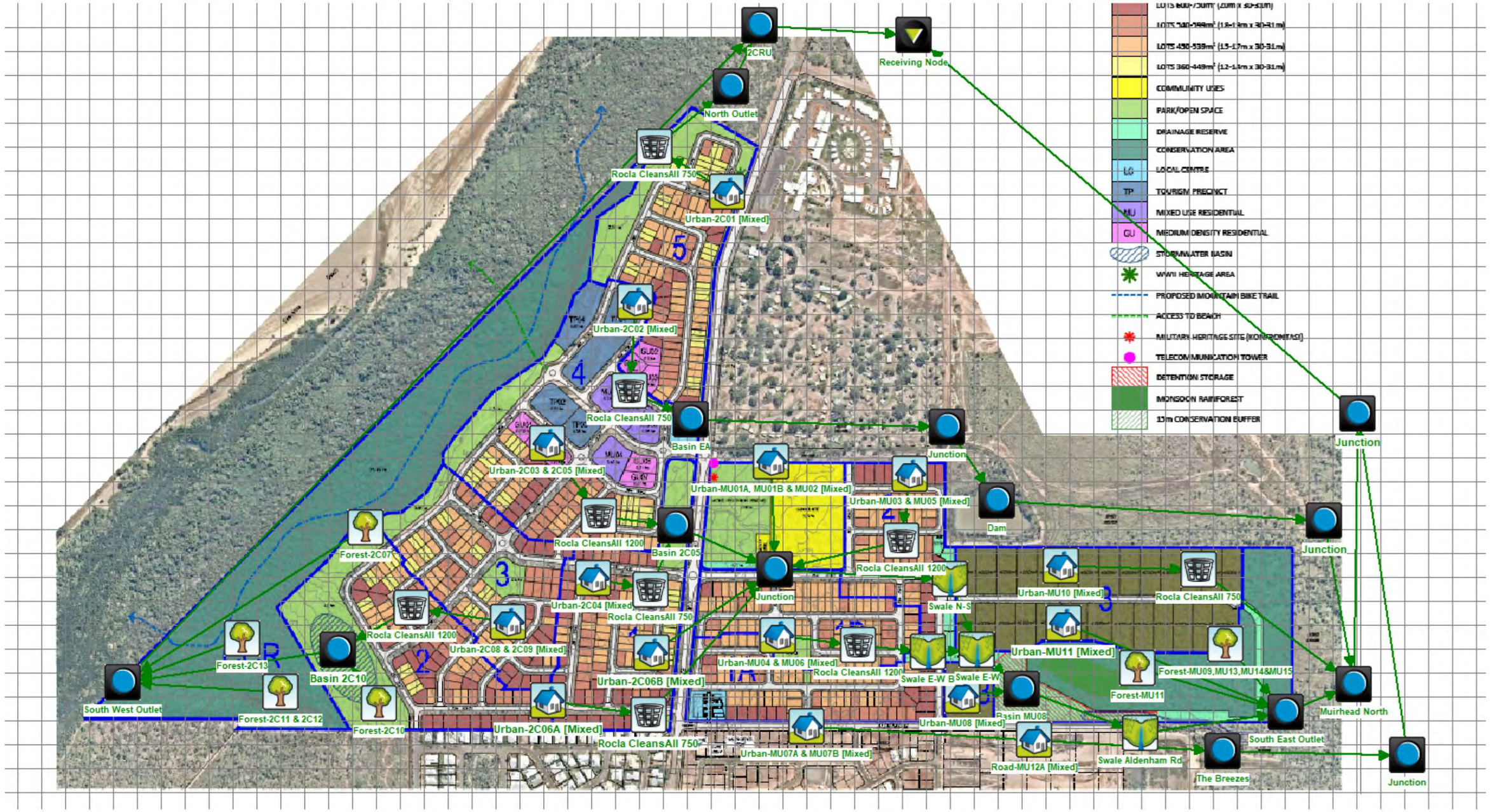
CAD FILE: O:\844__JOBS\88_WE19\DC1603_DDPhase_2CRU_MuirheadNth\3_Data\2_Analysis\AutoCad\Figures_R4V_Muirhead_CVM_2013.dwg
XREF's: Stormwater Drainage Updated Outfall_1; X-StormWater; Concept_Stormwater; M2737P_Overall Concept F

PRINT DATE: 22 December, 2019 - 8:36pm

APPENDIX

C

MUSIC MODEL LAYOUT


2CRU
Receiving Node
North Outlet
Rocla CleansAll 750
Urban-2C01 [Mixed]
Urban-2C02 [Mixed]
Rocla CleansAll 750
Basin EA
Junction
Urban-2C03 & 2C05 [Mixed]
Urban-MU01A, MU01B & MU02 [Mixed]
Urban-MU03 & MU05 [Mixed]
Dam
Junction
Forest-2C07
Rocla CleansAll 1200
Basin 2C05
Junction
Rocla CleansAll 1200
Urban-MU10 [Mixed]
Rocla CleansAll 750
Urban-2C04 [Mixed]
Rocla CleansAll 750
Swale N-S
Rocla CleansAll 1200
Forest-2C13
Basin 2C10
Urban-2C08 & 2C09 [Mixed]
Urban-MU04 & MU06 [Mixed]
Rocla CleansAll 1200
Swale E-W B
Swale E-W
Urban-MU11 [Mixed]
Forest-MU09,MU13,MU14&MU15
Forest-MU11
South West Outlet
Forest-2C11 & 2C12
Forest-2C10
Urban-2C06B [Mixed]
Urban-2C06A [Mixed]
Rocla CleansAll 750
Urban-MU08 [Mixed]
Basin MU08
Muirhead North
Urban-MU07A & MU07B [Mixed]
Road-MU12A [Mixed]
Swale Aldenham Rd
South East Outlet
The Breezes
Junction
LOTS 600+/UNIT (20m x 30-50m)
LOTS 540-599m² (18-19m x 30-31m)
LOTS 450-539m² (15-17m x 30-31m)
LOTS 360-449m² (12-14m x 30-31m)
COMMUNITY USES
PARK/OPEN SPACE
DRAINAGE RESERVE
CONSERVATION AREA
LC LOCAL CENTRE
TP TOURISM PRECINCT
MU MIXED USE RESIDENTIAL
CU MEDIUM DENSITY RESIDENTIAL
STORMWATER BASIN
WWII HERITAGE AREA
PROPOSED MOUNTAIN BIKE TRAIL
ACCESS TO BEACH
MILITARY HERITAGE SITE (NON-PRIMITAS)
TELECOMMUNICATION TOWER
DETENTION STORAGE
MONSOON RAINFOREST
15m CONSERVATION BUFFER

About Cardno

Cardno is a professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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