Stormwater Management Plan (Preliminary Stage)

Muirhead North - Lee Point Road, Lee Point

DC1603/R3

Prepared for

Defence Housing Australia

20 December 2018

Cardno

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1 Introduction

This preliminary stage Stormwater Management Plan (SMP) has been prepared by Cardno in order to support a Development Application (DA) for Muirhead North. 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.

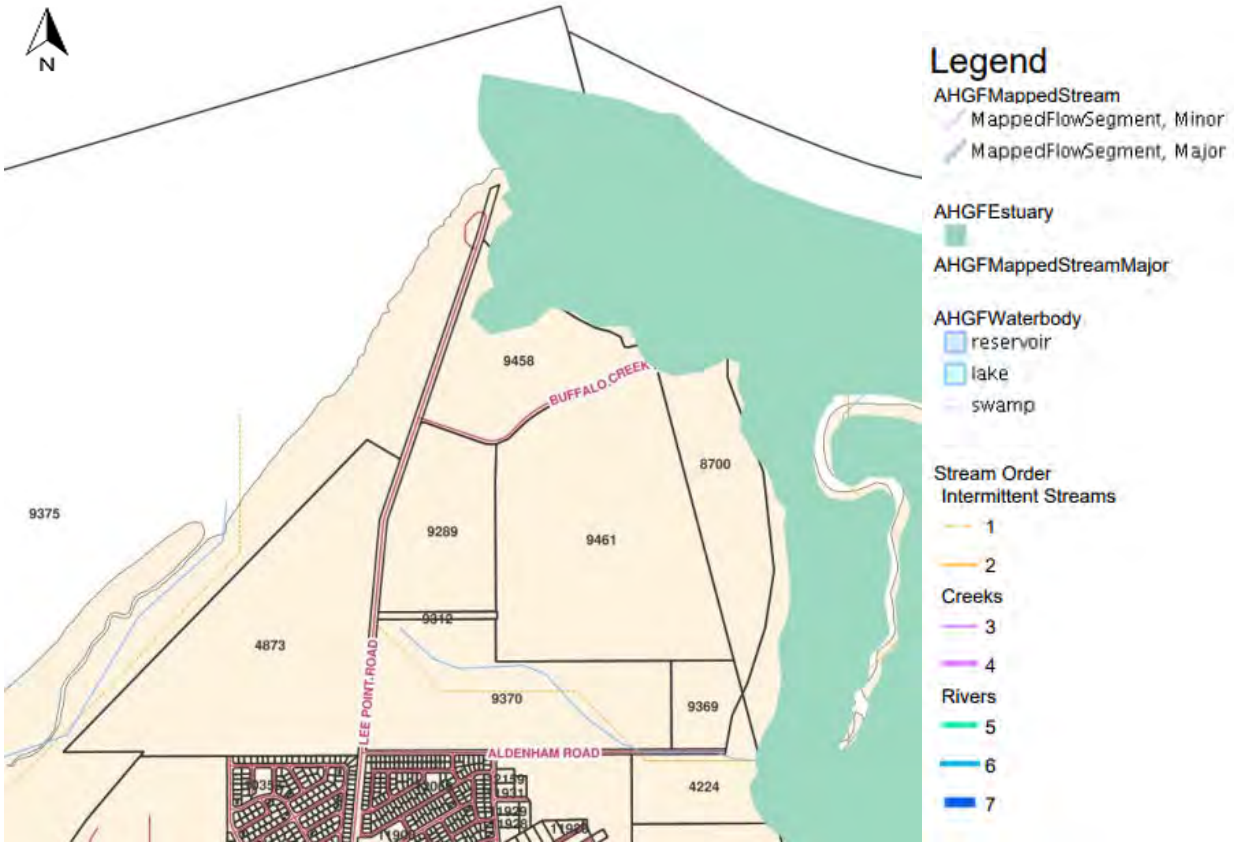


Figure 1-1 Muirhead North site location relative to surface water drainage (NR Maps, 2018)

The Muirhead North site is 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. The development layout details are provided in Appendix A.

The site has the potential to 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). This report details the preliminary stormwater management requirements for the development.

1.1 Site Description

1.1.1 Existing Conditions

The site is currently undeveloped and predominately consists of open woodland. 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.

Topography across the site ranges from approximately 5 to 25 m AHD, 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 2. These include naturally occurring gullies within the centre of the site.

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 convey flow collected within the road side drain to the east. The second culvert crossing is shown in Figure 1-3. A proportion of the 2CRU existing catchment discharges flow to the proposed Muirhead North site via the two culverts, illustrated in Figure 2, Appendix B. The existing catchment delineation and general direction of runoff across the Muirhead North site and surrounding areas are shown on Figure 2, Appendix B.

Figure 1-2 Culvert Crossing of Lee Point Road 115m South of the Lee Point Resort (Ref: Nearmap 2016)

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 Peak Flow Attenuation

A recent report, 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.

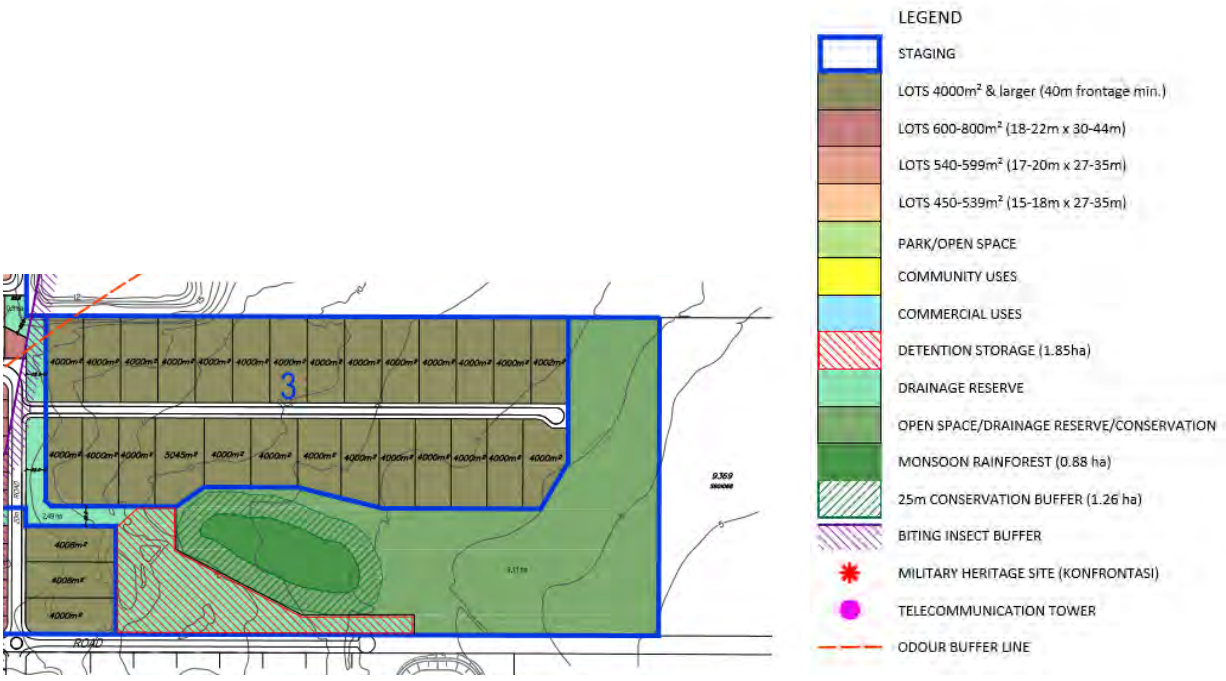


Figure 3-1 Muirhead North location of "open space/drainage area"

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 volume there is an 8% increase in peak flow during the 100 year ARI event. 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) it is anticipated that 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.

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

3.2 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.

3.3 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.

4 Stormwater Quantity Assessment

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. 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.

This section details the stormwater quantity assessment that was undertaken for the 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) has also been 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 preliminary 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 2013 SP1) based on the models developed as part of the Cardno (2017) report. 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

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. The catchments for the post-development scenario were based on the site layout plan, provided in Appendix A (15 October 2018). The pre and post development sub-catchment properties incorporated into the XPRAFTS model are provided in Table 4-2.

Table 4-2 Sub-catchment details – pre and post development

Sub-catchment ID	Pre- development (EX03)		Post-development (M18)	
	Area (ha)	Impervious (%)	Area (ha)	Impervious (%)
ED	12.1	0	9.5	69
EE	16.2	0	17.9	70
EF	10.7	0	7.1	0
EG	7.0	0	12.1	56
EH	4.4	0	4.4	0
EI	6.0	0	6.0	N/A
EJ	12.5	0	14.7	0
ED (Active Recreation Reserve)	N/A	N/A	3.5	0

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 Cardno (2017) report.

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 preliminary 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 a detention basin (Basin No. 7) and additional storage within the 'Active Recreation Reserve'. The post-development hydraulic model developed also considered the impact of the proposed diversion of high flows along Lee Point Road.

Assessment Report 88 highlighted the importance of retaining the native vegetation where a 16,000m^3 basin was previously proposed to be located. 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' 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 No. 7, 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.

In summary, in order to retain more native vegetation, the proposed post-development flow attenuation incorporates storages, but with reduced volume than previously reported (Cardno, 19 October 2018).

4.2.1.1 Active Recreation Reserve Storage

Three of the sporting grounds within the 'Active Recreation Reserve' to the west of the school are proposed to delay flow discharging from the adjacent 2CRU development. For the purposes of this assessment it was assumed that the sporting grounds will progressively fill by 300mm depth at each stage / sporting field. The ARR Stage Vs. Storage relationship modelled in XPRAFTs and the Stage Vs. Area relationship are provided in Figure 4-1 and Table 4-3.

The modelled ARR outlet arrangement is summarised below:

- 2 x RCBC (0.45 m W x 0.3 m H)
- 50 m wide weir at 0.6m depth

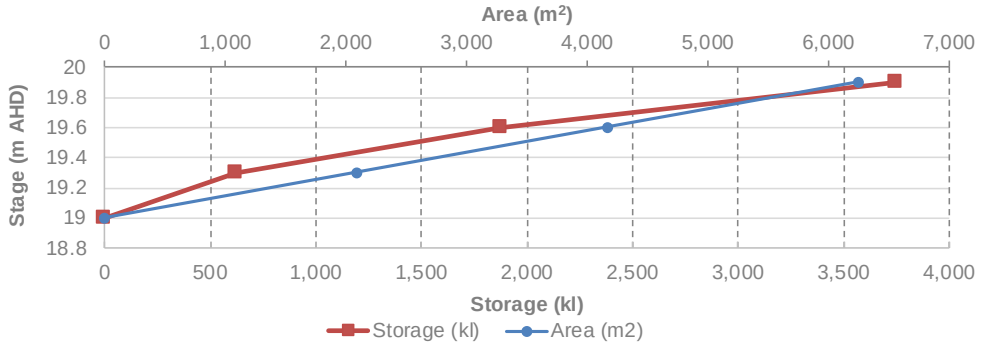


Figure 4-1 ARR Detention Stage-Storage-Area Relationship

Table 4-3 ARR stage – storage – area relationship

Depth (m)	Storage (kl)	Area (m^2)
0	0	0
0.3	625	2,083
0.6	1,875	4,167
0.9	3,750	6,250

4.2.1.2 Basin 7

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 Basin 7 has reduced from the previously reported SMP due to being relocated southwest of the rainforest path. The revised Basin 7 Stage Vs. Storage relationship modelled in XPRAFTs and the Stage Vs. Area relationship are presented in Figure 4-2 in Table 4-4.

The modelled outlet arrangement is summarised below:

- 6 x RCBC (1.5 m W x 0.6 m H)
- 7.5 m wide weir at RL 0.95 m AHD

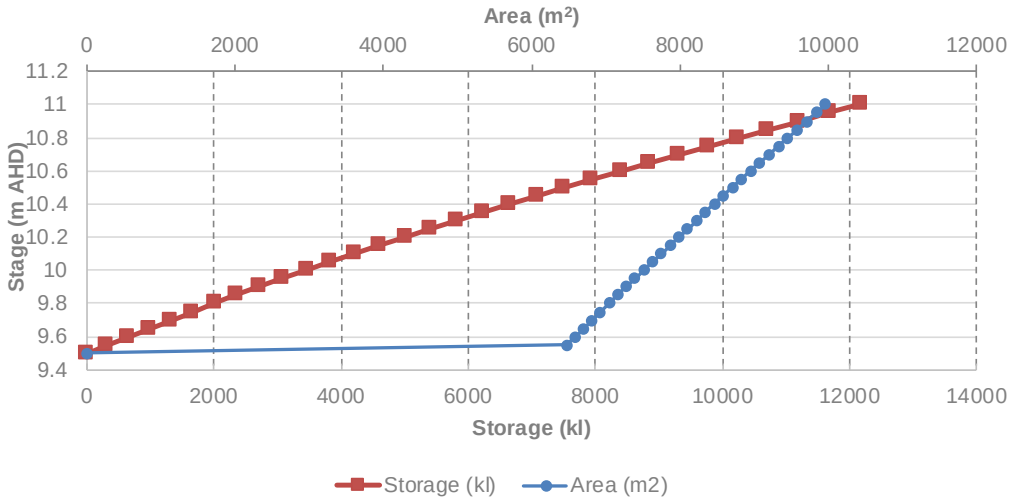


Figure 4-2 Preliminary Detention Basin Stage-Storage-Area Relationship

Table 4-4 Basin 7 stage – storage – area relationship

Depth (m)	Storage (kl)	Area (m²)
0	0	0
0.2	1,316	6,812
0.4	2,724	7,272
0.6	4,225	7,741
0.8	5,821	8,219
1.0	7,514	8,706
1.2	9,304	9,202
1.4	11,195	9,707
1.5	12,179	9,963

4.3 Results

4.3.1 Post-Development Case

The resultant peak 100 year ARI flood discharge for both scenarios is shown in Table 4-5. 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.

Table 4-5 Unmitigated Peak Discharge at Outlet (RP5)

ARI (years)	Peak Flow (m^3/s)		Difference (m^3/s)	Impact (%)
	Pre-development	Post-development		
100	27.6	35.5	7.88	29%
50	24.5	31.2	6.69	27%
20	21.0	27.8	6.82	32%
10	18.0	24.3	6.34	35%
5	16.1	22.1	5.97	37%
2	13.0	17.8	4.77	37%

4.3.2 Mitigated Post-Development Case

The resulting mitigated peak flows at the downstream catchment extent for all design events are presented in Table 4-6. The preliminary mitigated development arrangement is presented in Figure 4. These results demonstrate that significant peak flood flow reductions are still achieved with reduced storage, when comparing the impact presented in Table 4-5 with the impact presented in Table 4-6. While there is an 8 – 12 % impact on peak flows discharging from the site, this equates to an increase in the order of 1.4 to 2.2m^3/s in addition to the pre-development peak flow range of 13 to 27.6m^3/s. The peak flow impact is therefore considered acceptable, taking into consideration the peak flow difference and that flows discharging from Basin 7 will be via a grass lined channel that will be designed to slow velocities, prior to discharging to Buffalo Creek.

Table 4-6 Mitigated Peak Discharge at Outlet (RP5)

ARI (years)	Peak Flow (m^3/s)		Difference (m^3/s)	Impact (%)
	Pre-development	Post-development		
100	27.6	29.8	2.2	8%
50	24.5	26.5	2.0	8%
20	21.0	23.0	2.0	10%
10	18.0	20.0	2.0	11%
5	16.1	18.0	1.9	12%
2	13.0	14.4	1.4	11%

The flow attenuation storages proposed for the site achieved the depths, volumes and peak outflows detailed in Table 4-7. 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 4-7 Peak flow mitigation details

ARI (years)	Basin No. 7			ARR Storage		
	Water level (m AHD)	Volume (m^3)*	Peak outflow^ (m^3/s)	Water level (m AHD)	Volume (m^3)*	Peak outflow^ (m^3/s)
100	1.4	11,219	19.2	0.8	3,123	8.1
50	1.3	10,265	17.1	0.8	3,028	7.3
20	1.2	9,304	15.0	0.8	2,920	6.3
10	1.1	8,445	13.2	0.8	2,816	5.5
5	1.1	7,848	11.9	0.7	2,748	4.9
2	0.9	6,480	9.5	0.7	2,629	4.1

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.

4.3.2.2 Managing Discharge to Buffalo Creek

In the existing conditions, the majority of flow from the site concentrates to the south east corner of the site via naturally occurring gullies where it then discharges to Buffalo Creek, as illustrated in Figure 4-3.

The majority of stormwater runoff from the developed site is proposed to discharge into Basin 7, where flows will be attenuated, as outlined in Table 4-6. Flow from Basin 7 shall discharge into an open channel north of Aldenham Road, a 430m long grassed lined swale or bio-swale. The grassed swale will be designed to prevent erosion of the receiving environment. The development flow regime has been designed to align similar to the existing, with the majority of the developments flow being conveyed along the southern boundary of the site via Aldenham Road swale, discharging into the estuarine Buffalo Creek.

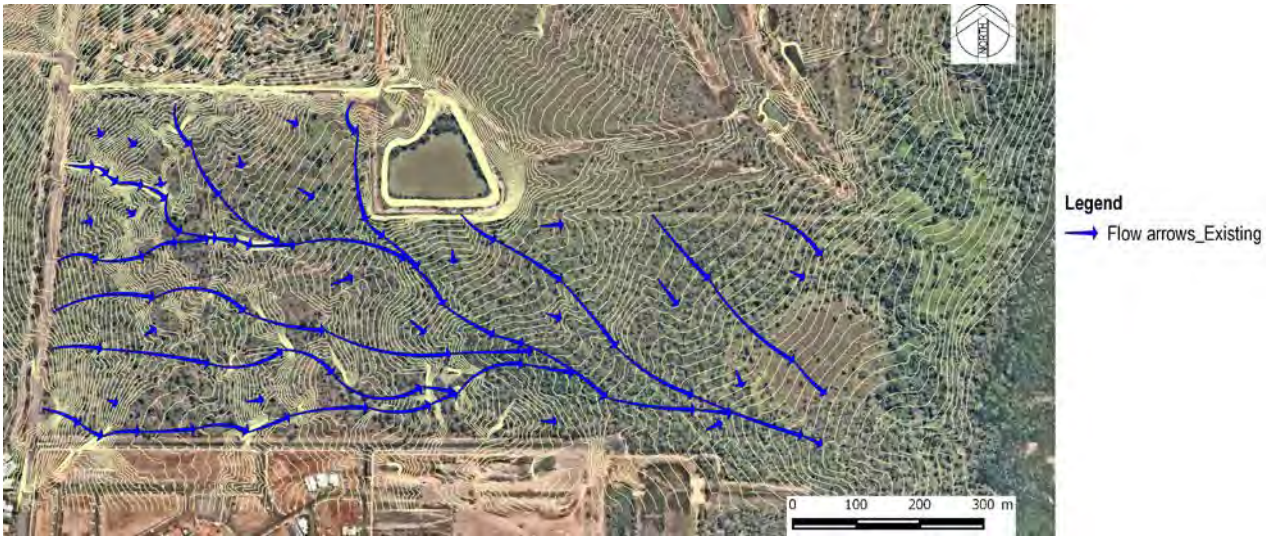


Figure 4-3 Muirhead North existing general surface water runoff direction

The velocity discharging from Aldenham Road swale (without flow dissipation incorporated into the model) was estimated to range from 1.4m/s for the 2 year ARI up to 1.8m/s for the 100 year ARI, based on preliminary analysis. During detailed design, the design will be refined to further reduce the flow velocity in Aldenham Road swale. Velocity is an important consideration when assessing the potential for erosion. For this reason, it was preferred to discharge flow from the site via a grass lined channel rather than via a pipeline, which generally have higher velocity impacts.

The outlet from Aldenham Road swale to Buffalo Creek will incorporate flow dissipation to further slow the flows entering Buffalo Creek. Potential outlet arrangements can be identified via further modelling and

analysis to ensure that erosion is not caused by the stormwater discharge from the site. For example, 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. Further design consideration of how flow from Aldenham Road swale will discharge and transition into Buffalo Creek shall be undertaken during detailed design to ensure erosion is mitigated.

In summary, further hydraulic modelling and assessment of the site will be undertaken during detailed design 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 to ensure erosion post-development is minimised. This 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.

4.3.2.3 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 storage reduces to 0.02 m depth within 5 hrs for all ARI events and 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.

4.3.2.4 Monsoon Rainforest

The preliminary 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 4-8 Existing Peak Flows to Rainforest (XPRAFTs reporting point EF)

ARI (year)	Pre-developed (E03)
100	19.9
50	17.6
20	15.1
10	12.9
5	11.5
2	9.2

4.4 Summary

The reported modelling results are based on a preliminary 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 preliminary design stage, the design may be subject to change and thus there could be some variation to the reduction achieved. 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 Muirhead development were initially adopted from *Darwin, Water Sensitive Urban Design (WSUD) Planning Guide (2009).* Initially (26 July 2017) the treatment measures proposed for the Muirhead development 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 4-1 outlines the WQO's proposed for the 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 4-1. 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 SQID's are suitable for the Darwin Harbour region. Consideration was made to incorporate larger bio-retention basins in the Muirhaead 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 SQID's 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 preliminary SMP.

Proposed preliminary locations for the Stormwater Quality Improvement Devices (SQID's) are illustrated in Figure 5, Appendix B. For the purpose of this preliminary water quality treatment assessment the below listed SQID's were incorporated into the MUSIC model:

- Gross pollutant traps (GPTs);
- Grassed swales; and
- Dry sedimentation basins.

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, identified by SQID 7B, 8 and 10 in Figure 5 of Appendix B. 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 long swale (SQID 10) will convey stormwater downstream from the development site. This 430m 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 a pipeline along Aldenham Road was undertaken to minimise the potential for erosion and water quality impacts on downstream waterways.

5.2.3 Pollutant Impact Assessment

An initial assessment (MUSIC model) of the Muirhead development undertaken found the WQO's outlined in Table 4-1 could be achieved with the SQID's listed in Section 5.2.2. Further modelling will be undertaken during the detailed design phases to ensure compliance with WQO's outlined in Table 5-1.

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.

5.2.4 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

In summary, the conceptual water quality assessment (MUSIC model) of the Muirhead North development undertaken found the WQO's listed in Table 5-1 could be achieved. Further MUISC modelling and the design of the SQID's 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.

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. Noting that inundation across the site from local catchment runoff, resulting in shallow sheet flow and concentrated gully flows, has not 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.

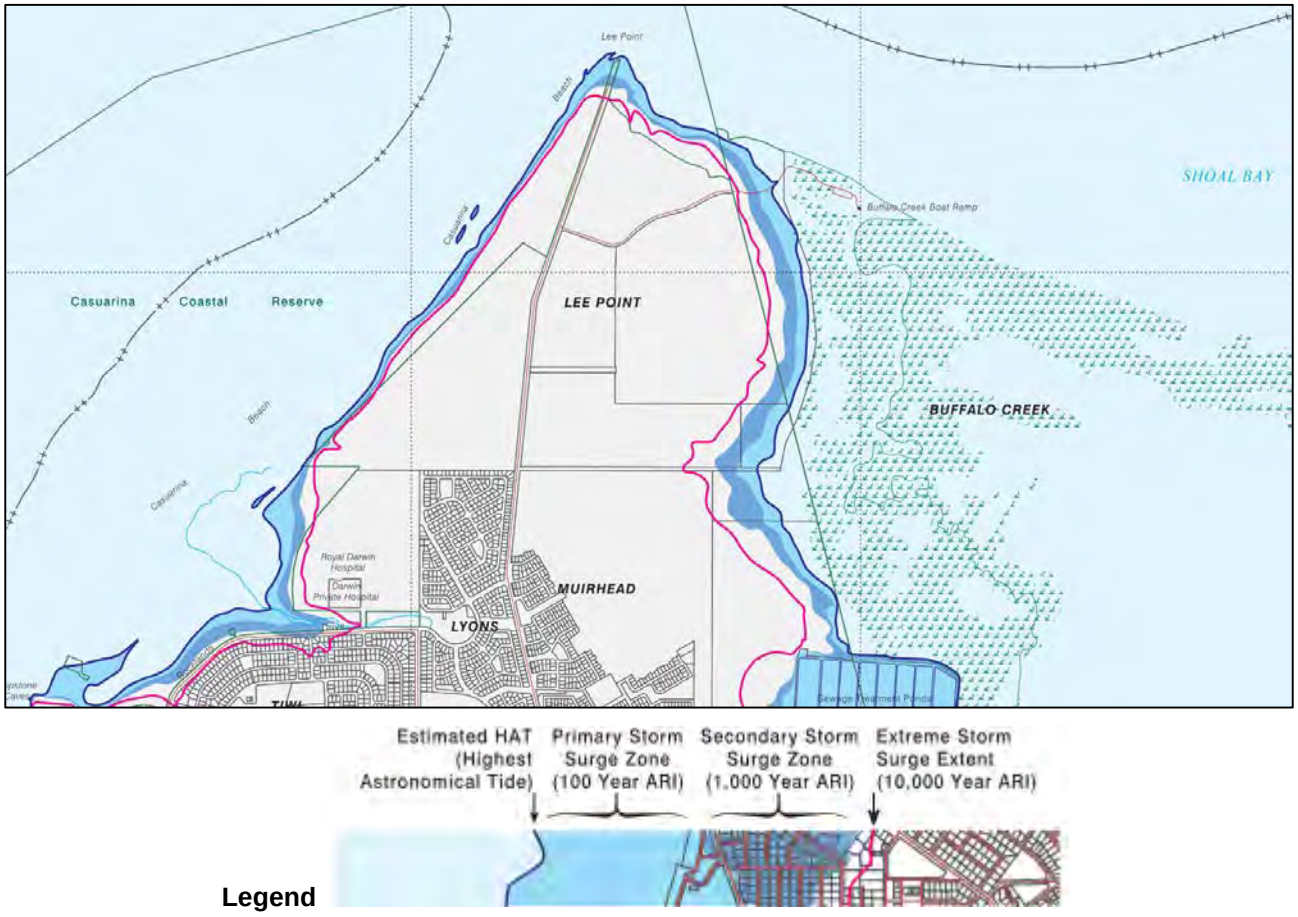


Figure 6-2 Darwin Area Storm Surge Inundation for 2100 Extract (GHD, 2014)

7 Conclusions

This SMP has been prepared by Cardno to support the application for the proposed Muirhead North development. This study has investigated the water quantity and quality for the site and provides preliminary 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 SQID's.

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 were managed by incorporating detention basins to attenuate post-developed discharges similar to the pre-developed levels. Noting that an impact assessment of the local flood conditions should 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 will be completed during the detailed design phase of the DA.

This SMP also sought to balance the land area designated for mitigating increases in peak flows as a result of the development with the area of existing vegetation retained. In summary, to retain more vegetation there is less space to construct flow attenuation basins and therefore there is a manageable impact of the post-developed peak flows of 8-12% compared to the pre-developed peak flows. 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). Noting that the Aldenham Road swale shall be designed during detailed design stage to prevent erosion of the receiving waterways.

The type and preliminary locations of SQID's have been provided in this SMP. During detailed design stage SQID's shall be designed to ensure stormwater quality discharging from the development site meets the WQO's outlined in this report.

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.

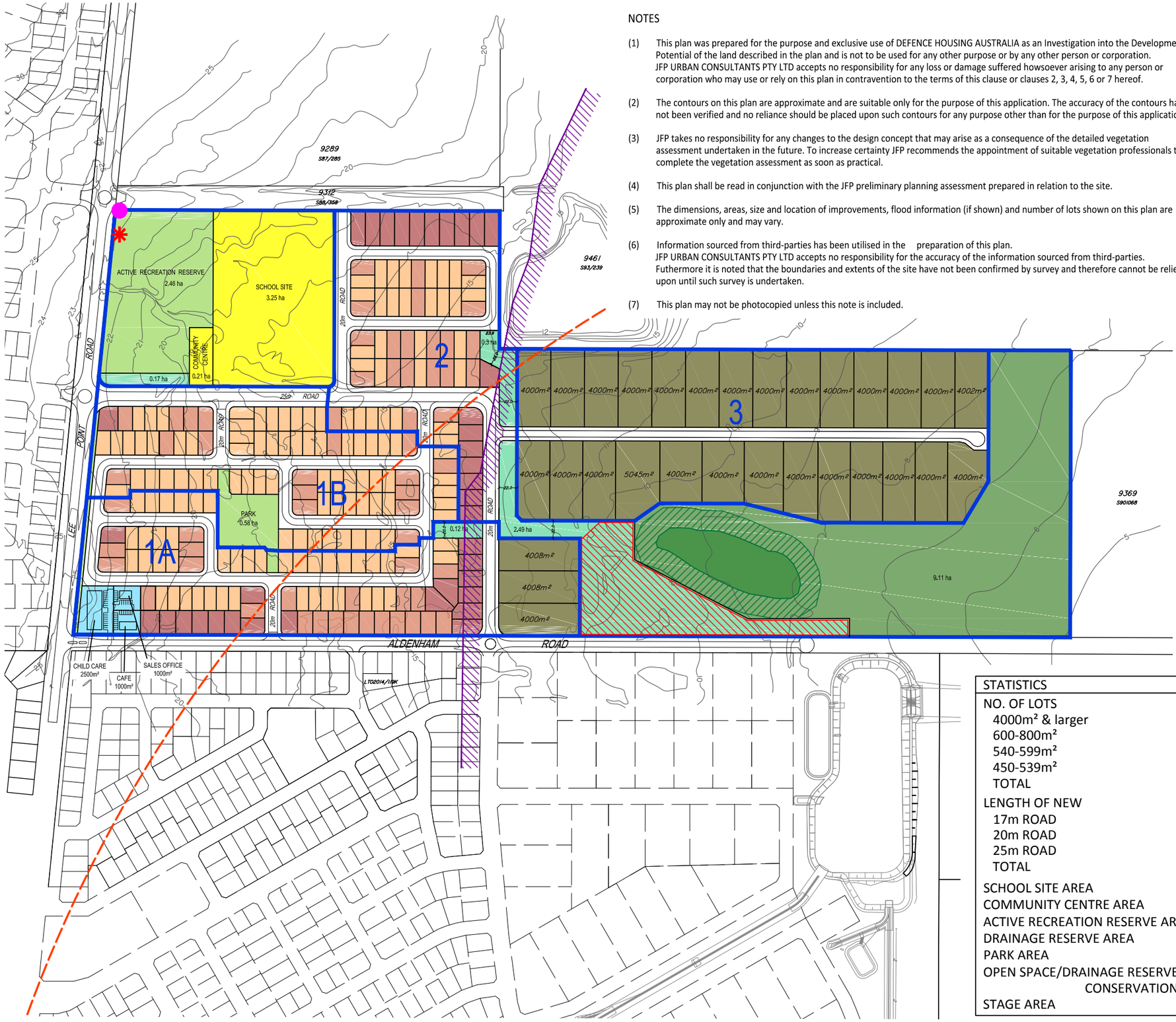
While Cardno's report accurately assesses peak flows from design storms, it is an ungauged catchment and consequently future observed flows may vary from that predicted.

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);
- City of Darwin (Council) - Subdivision and Development Guidelines, [COD, 2005];
- Queensland Urban Drainage Manual (QUDM) [DEWS, 2013];
- City of Darwin (Council) - Subdivision and Development Guidelines, [COD, 2005];
- 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. Brsbane: 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 (40m frontage min.)
- LOTS 600-800m² (18-22m x 30-44m)
- LOTS 540-599m² (17-20m x 27-35m)
- LOTS 450-539m² (15-18m x 27-35m)
- PARK/OPEN SPACE
- COMMUNITY USES
- COMMERCIAL USES
- DETENTION STORAGE (1.85ha)
- DRAINAGE RESERVE
- OPEN SPACE/DRAINAGE RESERVE/CONSERVATION
- MONSOON RAINFOREST (0.88 ha)
- 25m CONSERVATION BUFFER (1.26 ha)
- BITING INSECT BUFFER
- MILITARY HERITAGE SITE (KONFRONTASI)
- TELECOMMUNICATION TOWER
- ODOUR BUFFER LINE

PROPERTY DESCRIPTION
LOT 9370 ON S901068
TOTAL AREA 51.17 ha

STATISTICS	STAGE 1A	STAGE 1B	STAGE 2	STAGE 3	BALANCE	TOTAL
NO. OF LOTS						
4000m² & larger	3	0	0	27	0	30 (11%)
600-800m²	18	1	18	0	0	37 (14%)
540-599m²	24	17	21	0	0	62 (23%)
450-539m²	43	67	31	0	0	141 (52%)
TOTAL	88	85	70	27	0	270 (100%)
LENGTH OF NEW						
17m ROAD	750m	750m	495m	580m	0	2575m
20m ROAD	200m	75m	360m	0	0	635m
25m ROAD	0	285m	210m	0	0	495m
TOTAL	950m	1110m	1065m	580m	0	3705m
SCHOOL SITE AREA	0	0	0	0	3.25ha	3.25ha
COMMUNITY CENTRE AREA	0	0	0	0	0.21ha	0.21ha
ACTIVE RECREATION RESERVE AREA	0	0	0	0	2.46ha	2.46ha
DRAINAGE RESERVE AREA	0.12ha	0	2.79ha	0	0.17ha	3.08ha
PARK AREA	0.04ha	0.54ha	0	0	0	0.58ha
OPEN SPACE/DRAINAGE RESERVE/ CONSERVATION	0	0	9.11ha	0	0	9.11ha
STAGE AREA	8.15ha	6.89ha	18.1ha	11.92ha	6.11ha	51.17ha

Note: Average residential lot size is 533m²; Average rural lot size is 4001m²

JFP URBAN CONSULTANTS
PLANNERS
URBAN DESIGNERS
SURVEYORS
ENGINEERS
LANDSCAPE ARCHITECTS

MN OVERALL PROPOSAL PLAN V

544 LEE POINT ROAD, LEE POINT, DARWIN
DEFENCE HOUSING AUSTRALIA

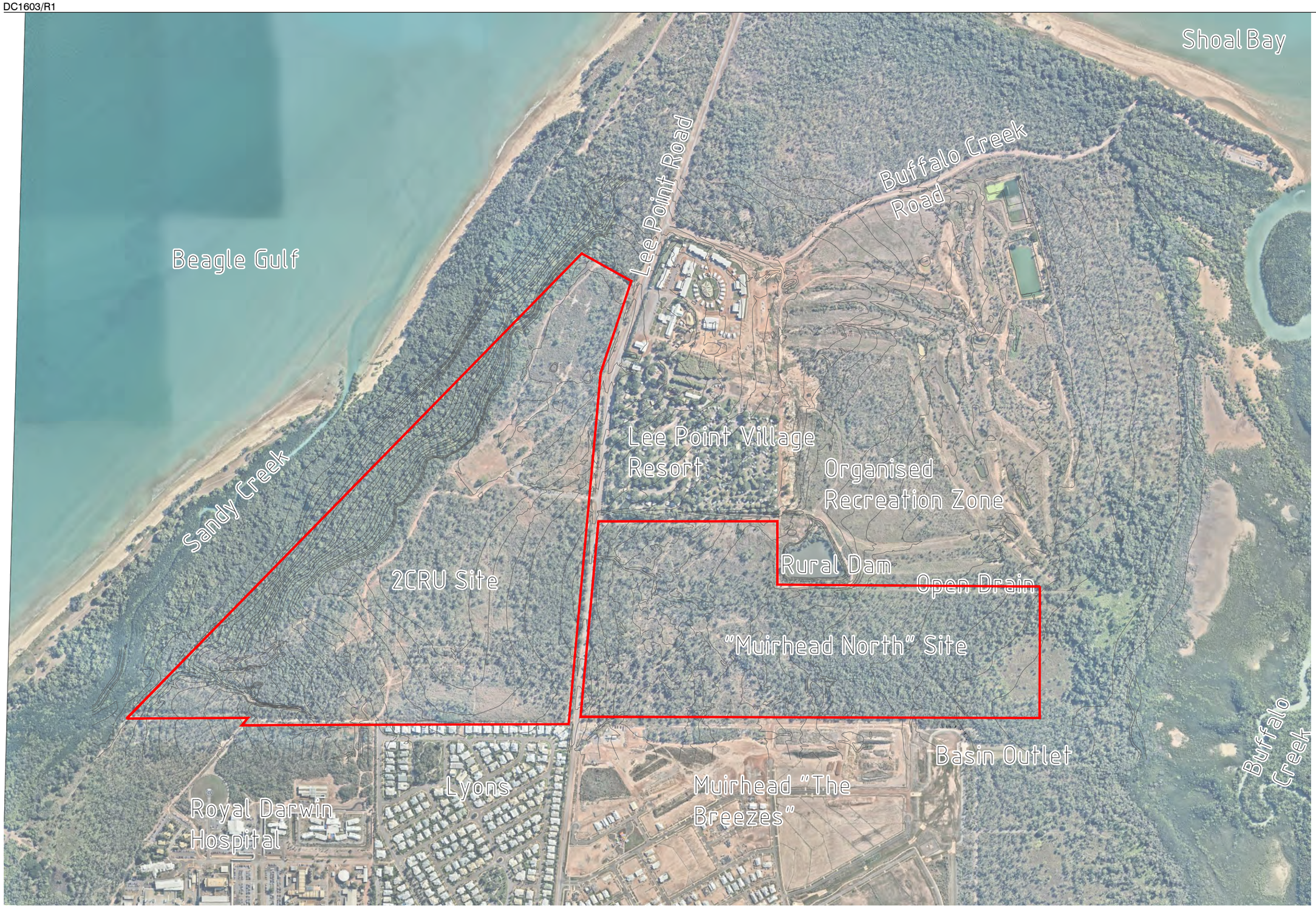
JOB NUMBER: M2737P MN_Overall Proposal V
ISSUE: NORTH:
SCALE: 1:5000 @ A3
DATE: 6th December 2018

APPENDIX

B

STORMWATER MANAGEMENT PLAN FIGURES

Cardno



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 2018

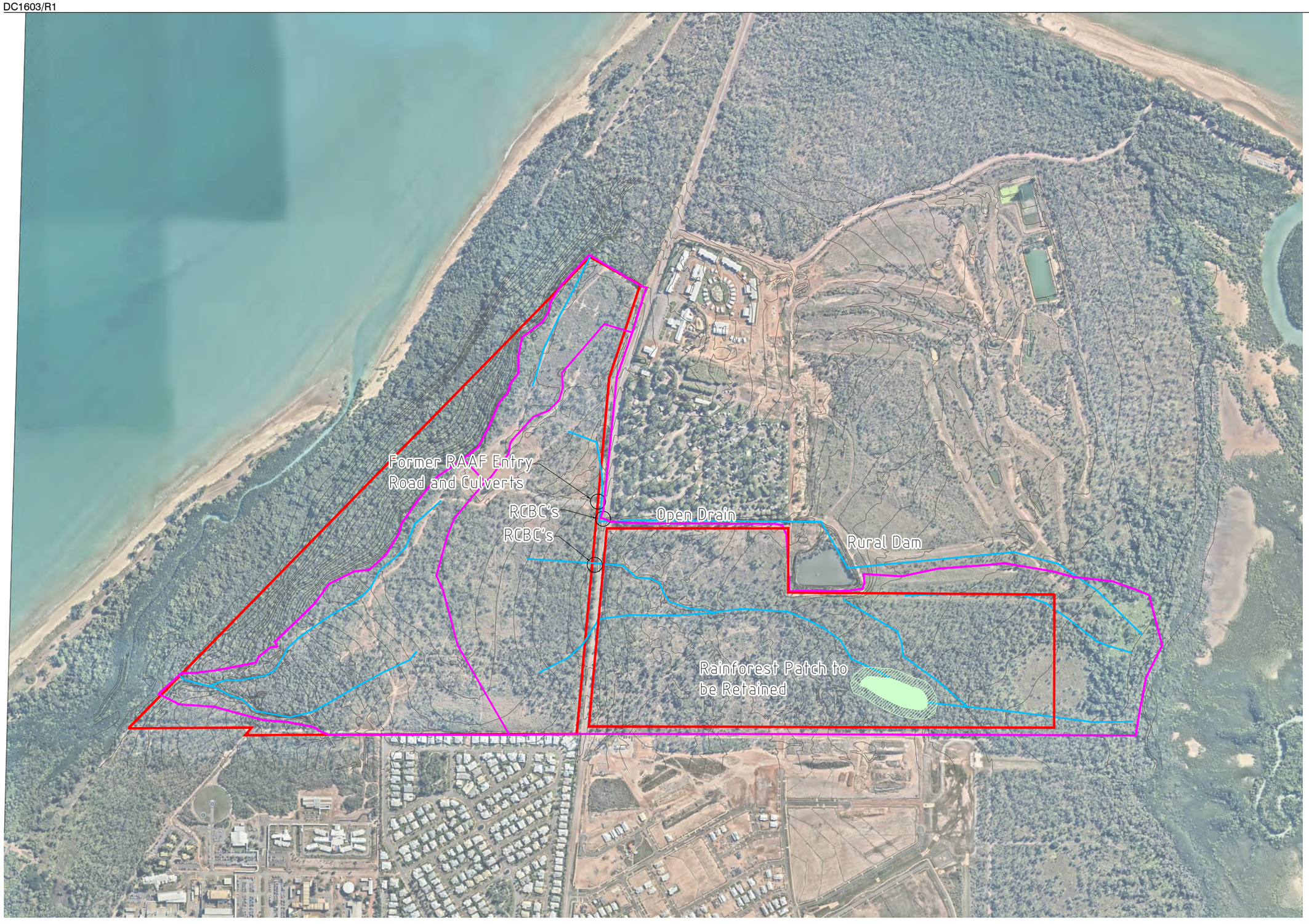
Project No.: DC1603

Defence Housing Australia

CAD FILE: C:\Temp_Cad\AcPublish_24508\Figures_R4\V4_Muirhead_CVM.dwg
XREF's: Stormwater Drainage Updated Outfall_1; X-StormWater; Extract of M2737P MN_Overall Proposal V

PRINT DATE: 20 December, 2018 - 6:50pm

Cardno



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 2018

Project No.: DC1603

PRINT DATE: 20 December, 2018 - 6:50pm

Defence Housing Australia

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XREF's: Stormwater Drainage Updated Outfall_1; X-StormWater; Extract of M27137P MN_Overall Proposal V

Legend

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

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

Scale 1:10,000 (A3)

FIGURE 3
XPRAFTS EXISTING CATCHMENTS

December 2018

Project No.: DC1603

Defence Housing Australia

CAD FILE: C:\Temp_Cad\AcPublish_24508\Figures_R4\V4_Muirhead_CVM.dwg
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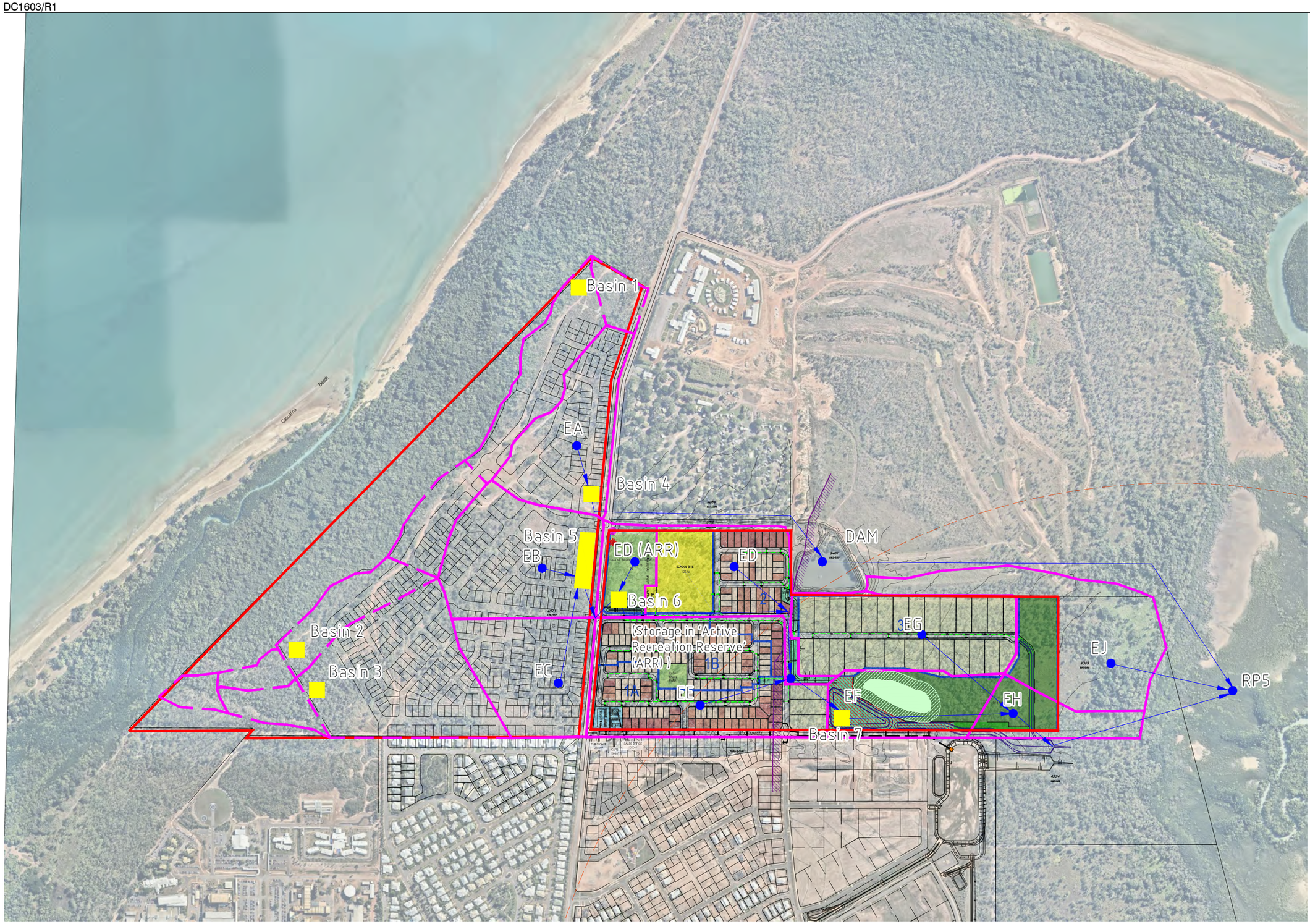

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1:10,000

Scale 1:10,000 (A3)

FIGURE 4
CONCEPT XPRAFTS DEVELOPED CATCHMENTS

December 2018

Project No.: DC1603

Defence Housing Australia

CAD FILE: C:\Temp_Cad\AcPublish_24508\Figures_R4V4_Muirhead_CVM.dwg
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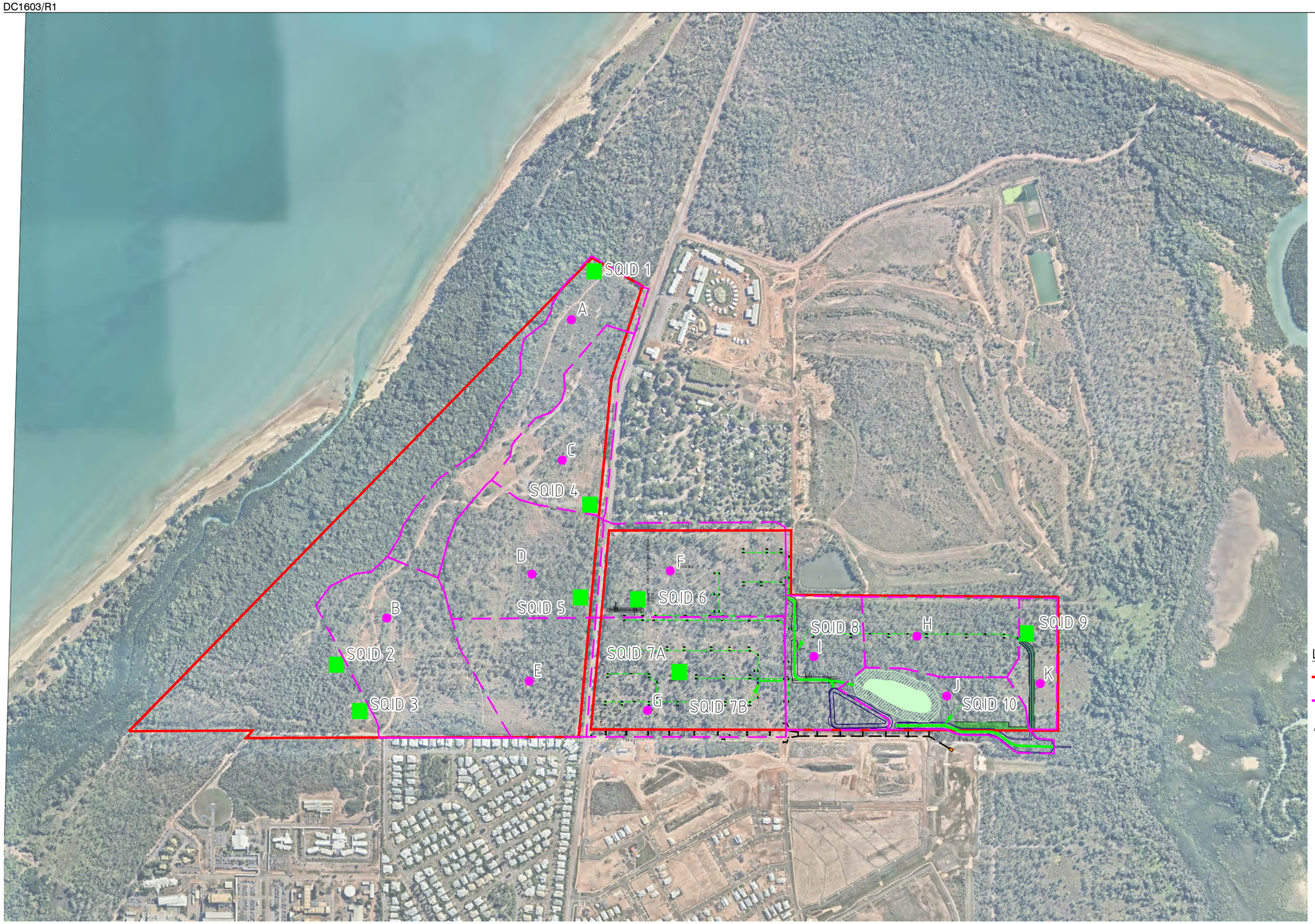

N

Legend

- Site boundary
- MUSIC Sub-catchments
- A MUSIC Catchment ID
- Indicative location of SQID's *(Stormwater Quality Improvement Devices)*
- Monsoon rainforest
- 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 5

CONCEPT STORMWATER TREATMENT MEASURES

December 2018

Project No.: DC1603

Defence Housing Australia

CAD FILE: C:\Temp_Cad\AcPublish_24508\Figures_R4V4_Muirhead_CVM.dwg
XREF's: Stormwater Drainage Updated Outfall_1; X-StormWater; Extract of MZ737P MN_Overall Proposal V

PRINT DATE: 20 December, 2018 - 6:50pm

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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