# Berrimah North Drainage Study

City of Darwin

August 2014

## Document Verification

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## Approval for Issue

| Name | Signature | Date |
|---|---|---|
| Michael Van Itallie |  | 19.08.2014 |
| Natasha Bertinazzi |  | 19.08.2014 |

# Contents

# Tables

# Figures



# Appendices

# EXECUTIVE SUMMARY

This report provides the City of Darwin with information of the impact of development in conjunction with the Draft Area Plan for Berrimah North on stormwater drainage.

This Drainage Study investigates the flood behaviour of the area in its existing condition and ensures that the proposed development will not cause any worsening of peak stormwater runoff on downstream receiving environments. The receiving environments in particular are the Marrara Swamp, Rapid Creek, Ironstone and Knuckey Lagoons.

All of the design elements in this report are preliminary and are based on LiDAR survey data and it is recommended that further detailed survey will be required during the detailed design phase.

This report identified that the topography in this area is very flat and as such standard pipe drainage is not feasible in all parts the Berrimah North Area. In these areas open channels are recommended to convey the minor and major stormwater flows.

It was also identified that the existing culverts beneath Amy Johnson Avenue near the Boulter Road – Amy Johnson Avenue intersection did not have a free flowing discharge during the wet season and this was encompassed in the 2d hydraulic model.

It was identified that the most effective stormwater drainage design, given the site constraints, was a combination of pipe drainage and open channels. 7 detention basins are proposed to detain the increased stormwater runoff to ensure that the downstream peak flow rate is not worsened. These recommendations can be used as guidelines to achieve non-worsening during the detail design phase.

Through the use of open channels there is the potential to provide stormwater treatment to this area. This will help maintain the environmental health of the receiving environments.

The overall findings show that there is no worsening of the peak discharge to Rapid Creek and Ironstone and Knuckey Lagoons from pre to post-development with the proposed stormwater infrastructure design. There is also no increase in overall stormwater discharge volumes to Ironstone and Knuckey Lagoons. However there is an overall increase in the discharge volumes to Rapid Creek which has been identified to not cause any worsening at Yankee Weir (Refer to the Berrimah North Stage 2 report prepared by ADG Engineers).

# 1 INTRODUCTION

ADG Engineers Pty Ltd (Aust) has been engaged by The City of Darwin to undertake an assessment of the required stormwater infrastructure to facilitate the Draft Berrimah North Concept Plan (November 2013) located in Berrimah, Darwin, Northern Territory.

This report was compiled using information from the following sources:

- Site Investigations
- Northern Territory Government Data
- Liaison with the City of Darwin
- Department of Infrastructure
- As constructed Drawings
- Road Network Division
- Land Surface Data from Department of Land and Environment (DLPE) Land Services
- SKM Rapid Creek Flood Study Report and Addendum (December 2013)

## 1.1 PURPOSE OF REPORT

The purpose of the report is to provide the City of Darwin with a proposed solution that addresses the stormwater drainage infrastructure required to service the Berrimah North Area without worsening the downstream stormwater systems (Marrara Swamp, Rapid Creek and Ironstone and Knuckey Lagoons) and receiving environments.

The following report comprises of:

- Minor storm event analysis (Q2 and Q5), to determine the drainage system required to service the estimated absolute potential development allowed for under the proposed land uses;
- Major storm analysis (Q100) to determine the major system required to ensure stormwater doesn't impact on properties and downstream catchments.

## 1.2 AREA DETAIL

The proposed developable area is located in the bounds of Amy Johnson Avenue, Stuart Highway, Vanderlin Drive and McMillans Road, Berrimah North within the City of Darwin local government area, herein described as the subject site. The total site area is 307ha. The existing land titles and details are given in Table 1 below.

**Table 1– Property Detail**

| | |
|---|---|
| Title | 2439 on S 74/012, 5873, 5874 and 5875 on L2006/113, 4106 on S 85/355, 5693, 5694 and 5695 on L2003/067, 5602 on L2002/084B, 5787 on S2002/195, 5628 and 5627 on L2003/051, 2167 on S 75/041, 1908 on S 74/022, 5959 on S2007/216, 4568 on S 95/260, 3391 on S 91/242, 4440 on S 93/196, 4885, 4886, 4887 and 4888 on S 97/180, 4280, 4279, 4278, 4277 and 4303 on LTO 91/074, 3915 on S 85/127, 3071 on S 84/211, 4882 on S |

| | |
|---|---|
| | 96/349B, 2237 on S 79/080, 6467 on LTO 2012/070, 2845 on S 83/179, 6599 on LTO 2012/098A, 4262 S 911035 |
| Street Address | 74-110 Amy Johnson Avenue, 564 - 798 Vanderlin Drive, 1-113 Boulter Road, 4-10 Crerar Road, 16- 42 Bowerlee Road, 621 Stuart Highway, BERRIMAH. |
| Site Area | 307ha |

A locality map is given below in Figure 1.


**Figure 1 – Locality Map (As accessed from Google maps 10.03.2014)**

## 1.3 EXISTING SITE FEATURES

The subject site is predominately undeveloped with areas that are developed consisting of a mix of rural residential, commercial community facilities and utilities. The ground coverage of subject site varies from highly vegetated to bare soil. The existing accesses to the developed lots are via sealed and unsealed rural type roads which connect to Amy Johnson Avenue, Stuart Highway, Vanderlin Drive and McMillian Road. The subject site is relatively flat with an average slope below 1 per cent. There are existing restricted development areas within the site area. These restricted development areas are shown in a green outline in the figure below. The existing site condition of the overall area is presented in Figure 2 below.

Further specific information in terms of existing stormwater drainage features, discharge points and catchment site conditions is explained in sections 1.3.1 – 1.3.12 below. Refer to **Appendix D** for the overall SK02 and SK03- Pre Development Catchment Plan. The existing site condition has

been interpreted using google maps, provided as constructed information and imagery received from Land Information Services.


**Figure 2 – Existing Site Condition**

### 1.3.1 Catchment 1

Catchment 1 has existing buildings occupying approximately 15 per cent of the catchment area (refer to the figure on the right). The remainder of the catchment is covered by medium dense bush. There are also rural sealed roads which provide access to the existing buildings. This catchment currently falls to McMillans Road. It has been assumed that the current point of discharge for this catchment is to the drainage swale and Road Network Division (RND) road drainage infrastructure on McMillans Road, shown in green in Figure 3 which ultimately discharges to Rapid Creek.

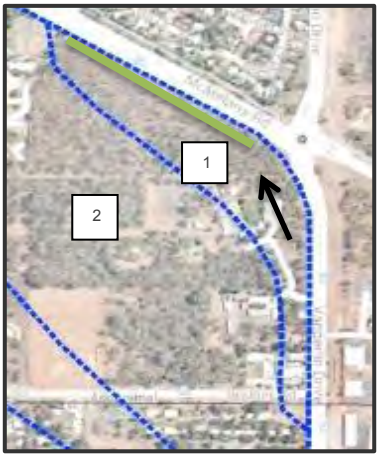



**Figure 3 - Catchment 1 Existing Site Condition**

### 1.3.2 Catchment 2

Catchment 2 currently has impervious cover of approximately 20 per cent. These impervious areas are a combination of commercial, Marrara Christian College and rural residential facilities. The remainder of the catchment comprises of predominately medium dense bush with areas of bare soil. This catchment also comprises of a part of Boulter Road which is a sealed rural road. The Catchment currently slopes towards Amy Johnson Avenue and discharges to an existing swale adjacent to Amy Johnson Avenue, ultimately discharging to Rapid Creek. Refer to Figure 4.


**Figure 4 – Catchment 2 Existing Site Condition**

### 1.3.3 Catchment 3

Catchment 3 consists of approximately 20 per cent impervious areas, with the remainder of the site comprising of medium dense bush and bare soil areas. This catchment also includes portion of Boulter Road. A restricted development area is located in this catchment and is shown by the green outline in Figure 5. This catchment currently discharges to the existing culverts beneath Amy Johnson Avenue (shown by the red symbol) adjacent to the restricted development area. This culvert drains directly to the Marrara Swamp Area which ultimately discharges to Rapid Creek. A site inspection confirmed that in the restricted development area the culverts are subjected to significant ponding of water during the wet season. Refer to the Site inspection photos 14 and 15 in **Appendix B** which show that the water surface elevation is at obvert level of the culverts. Sketches SK02 and SK03, Pre Development Catchments in **Appendix D** outline the location of the existing drainage easements which form part of this catchment.

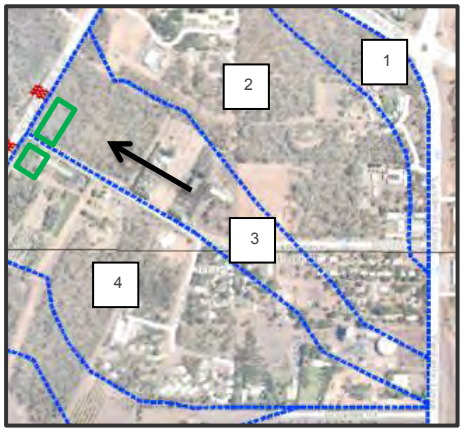



**Figure 5 – Catchment 3 Existing Site Condition**

### 1.3.4 Catchment 4

The impervious areas of catchment 4 contribute to approximately 20 per cent of the total catchment area. The remainder of the site is made up of medium dense bush, average grassed lawns, cropping/farming areas and bare soil. The catchment also includes road areas including Boulter Road, Crerar Road, Nara Place and other small road accesses. There is also a restricted development area as part of this catchment shown in the Figure 6. There are currently existing drainage easements in this catchment. Refer to sketches SK02 and SK03 Pre Development Catchments in **Appendix D** for drainage easement locations**.** The discharge for this catchment is to the existing culverts beneath Amy Johnson Avenue (shown by the red symbol) which discharge directly to the Marrara Swamp and ultimately discharges to Rapid Creek. These culverts also have a water surface elevation at obvert during the wet season, refer to **Appendix B** for the site photos12 and 13.


**Figure 6 – Catchment 4 Existing Site Condition**

### 1.3.5 Catchment 5

Catchment 5 is predominately pervious with only 2 small roof areas contributing to the impervious area. The pervious areas comprise of medium dense bush, bare soil, poorly grassed areas and light tree planting. There is one 10m (approx.) wide easement in this catchment which extends off Bowerlee Road to towards Amy Johnson Avenue. Refer to **Appendix D** for the existing easement locations. The site slopes to the west at approximately 0.4 per cent. The discharge point for the catchment is to the existing culvert beneath Amy Johnson Avenue, shown by the red symbol in Figure 7 which ultimately discharges to Rapid Creek.

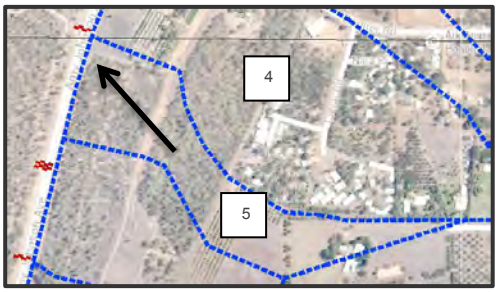



**Figure 7 – Catchment 5 Existing Site Condition**

### 1.3.6 Catchment 6

There are no impervious areas in catchment 6. The area is made up of medium/ light dense bush and bare soil. The site currently grades to the west on a slope of 0.4 per cent. The discharge point for the catchment is the existing culverts beneath Amy Johnson Avenue and ultimately Rapid Creek.

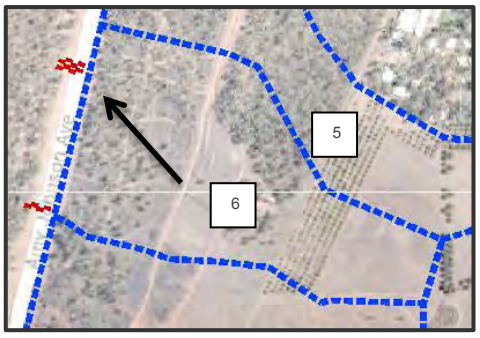



**Figure 8 – Catchment 6 Existing site Condition**

### 1.3.7 Catchment 7

Catchment 7 also has no impervious areas. The pervious areas comprise of bare soil and very light bush cover in a small proportion of the area. The site currently falls to the west at a slope of 0.3 per cent. The discharge point for this catchment is to the existing culvert beneath Amy Johnson Avenue and ultimately Rapid Creek. The catchment also has an area which has been identified as a restricted development area, shown in Figure 9 by the green outline.

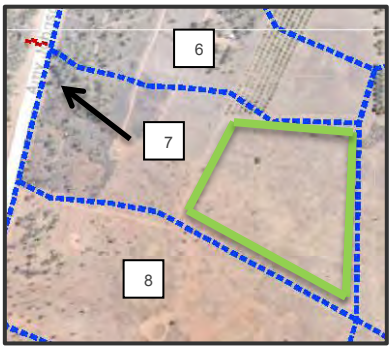



**Figure 9 – Catchment 7 Existing Site Condition**

### 1.3.8 Catchment 8

Almost the entirety of this catchment is deemed to be a restricted development area (shown by the green outline in Figure 10). The small proportion of the site which is not part of the restricted development area is currently being used as a stockpiling area for the newly constructed Berrimah Business Park. The overall catchment is predominately bare soil with a very light cover of trees to the west. The catchment slopes to the west at approximately 0.3 per cent. The discharge is to the existing culverts beneath Amy Johnson Avenue, shown by the red symbol and ultimately discharges to Rapid Creek.

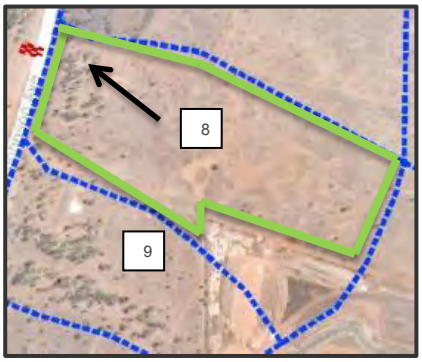



**Figure 10– Catchment 8 Existing site Condition**

### 1.3.9 Catchment 9

The majority of this catchment is also deemed to be restricted development area. The remainder of the site is being used as the stockpiling area for the newly constructed Berrimah Business Park. The catchment slopes to the west at 0.7 per cent with a very light cover of trees and bare soils making up the pervious characteristics. The existing discharge point is to the culverts beneath Amy Johnson Avenue and ultimately to Rapid Creek.

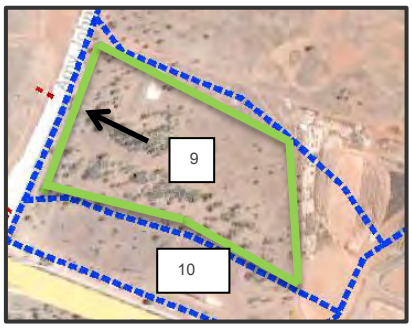



**Figure 11 – Catchment 9 Existing Site Condition**

### 1.3.10 Catchment 10

The entirety of the site is deemed to be restricted development area. The catchment is predominately covered with bare soil and slopes to the west at 0.7 per cent. The existing discharge point is to the culverts beneath Amy Johnson Avenue and then drains to the south underneath the Stuart Highway.

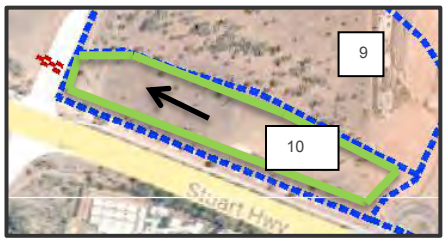



**Figure 12 – Catchment 10 Existing Site Condition**

### 1.3.11 Catchment 11

Catchment 11 is the largest catchment within the total investigation area. The area is predominately covered by bare soil with areas of light tree coverage. The imperious areas for this catchment contribute to approximately 20 per cent of the total catchment area. The impervious areas include the Power Water Corporation (PWC) Utilities Area and a small mini golf and driving range facility just east of the tank farm. It slopes to the east at 0.3 per cent to the existing culverts beneath Vanderlin Drive into an existing swale which ultimately discharges to Ironstone and Knuckey Lagoons.

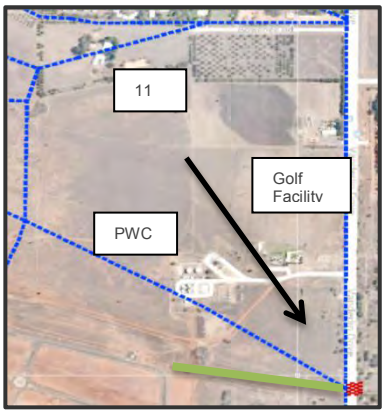



**Figure 13 – Catchment 11 Existing Site Condition**

### 1.3.12 Catchment 12

Catchment 12's impervious areas contribute to approximately 40 per cent of the overall area. These impervious areas include roof areas from existing building, road areas and carparking areas. The pervious areas comprise of bare soil and light tree coverage. The site slopes to the east at 0.3 per cent and discharges to the culverts beneath Vanderlin Drive which ultimately discharges to Ironstone and Knuckey Lagoons. The newly constructed Berrimah Business Park (BBP) is within this catchment and includes a swale and culvert design to discharge its stormwater to the Vanderlin Drive culverts. The BBP culvert's intended purpose is to provide a controlled outflow for the BBP development allowing stormwater runoff to be detained in a constructed swale upstream of the culvert. The Berrimah Business Park occupies approximately 50 per cent of the overall catchment.

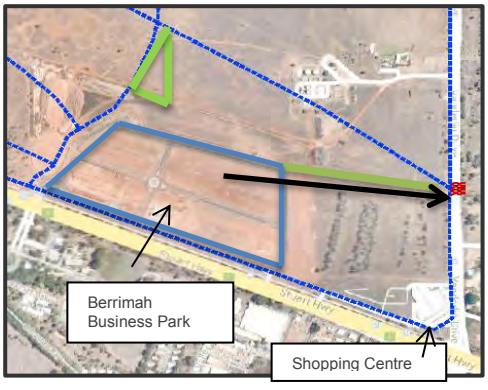



**Figure 14 – Catchment 12 Existing Site Condition**

## 1.4 SURROUNDING LAND USE

The surrounding land use comprises of an array of different uses. The existing land use north of McMillan Road is the Karama urban residential subdivision. East of Vanderlin Drive the existing land use is made up of commercial, rural residential and natural drainage features (Knuckey and Ironstone Lagoons). To the south of Stuart Highway, Coonawarra, the land use is a mix of commercial and urban residential. The RAAF base and Darwin International Airport are located to the west of Amy Johnson Avenue. The majority of the defence area is unused and heavily vegetated with a small percentage of the land used for defence purposes. Also located to the west of Amy Johnson Avenue is the Marrara Swamp.

# 2 PROPOSED DEVELOPMENT

The Department of Lands, Planning and Environment has prepared a Draft Area Plan for the Berrimah North Area. The intent of this area plan is to distinguish types of zoning for development areas, identify critical infrastructure locations and to provide connectivity to commercial, industrial and residential areas. This plan will facilitate the future development of the Berrimah North Area. The Area Plan has 2 parts. Part 1 identifies the site constraints and strategic infrastructure, Part 2 presents the proposed zoning (refer to **Appendix A**). Section 2.1 below describes the particular areas of the Draft Area Plan for Berrimah North.

## 2.1 LAND USE PLANNING

Part 1, also shown in **Appendix A** identifies the key site constraints and strategic infrastructure. Below is a summary of the identified site constraints and strategic infrastructure;

- Australian noise exposure forecast
- Defence regulations – no structures and no structure above 7.5m and 15m
- Overall area catchments and sub catchments
- Discharges to control structure
- Darwin Airport approach splay/public safety area
- Access from arterial road (Boulter Road).

Part 2 of the Draft Berrimah North Area is shown in the **Appendix A.** It can be seen that the proposed land uses are:

- Urban Residential
- Commercial Purpose
- Rural Residential
- Open Space incorporating drainage features
- Restricted Development (Airport restriction zone)
- Light industry
- Utility
- Commercial/mix use

The plan also incorporates the following features and services:

- Pedestrian/cycleway

- Compact neighbourhood which maximises the number of dwellings within a 400m walk from the neighbourhood centre and a bus stop in this particular area will enable easy access for residents to the public transport corridor proposed for Vanderlin Drive.
- Public transport corridor including bus stops
- Access roads

## 2.2 OPTIONS, REQUIREMENTS AND OPPORTUNITIES

The Draft Area Plan for Berrimah North allows flexibility for changes to the plan due to drainage restrictions. The topography of the land encompassed in the Berrimah North Area Plan has a slope of approximately 0.3 per cent on average. This very flat slope makes the existing site very difficult to provide a discharge with the current landform. Earthworks design will enable a possible solution to providing the site with stormwater drainage. It is a requirement that the post-development scenario does not adversely affect any of the proposed developable areas or worsen the downstream flood conditions and environmental values. To meet this requirement, changes to the area plan layout are investigated in this report. These changes include using proposed road areas for the location of stormwater drainage infrastructure, using the restricted development areas as detention areas, creating a useable park area, and identifying areas where land resumption is needed to facilitate stormwater drainage.

During detailed design, the earthworks design needs to incorporate consideration of the whole catchment to achieve the desired treatment outcomes due to timing or various infill sites within the Berrimah North Area.

The Berrimah North Area also has considerable opportunities for stormwater drainage. These opportunities include existing stormwater easements which are to be used, redesigned or extended to provide future development flood immunity. Another advantage is that there are many existing open drains, with further formalisation, will provide major drainage infrastructure for the area. There is also an opportunity to provide stormwater quality treatment through the use of vegetated open drains.

# 3 DATA COLLECTION

A variety of data was collected and used as part of this analysis. The data and sources included:

- Design rainfall for the site based on Australian Rainfall and Runoff (AR & R) and Bureau of Meteorology (BOM) for the site;
- Existing topography for the site and surrounding areas based ESRI Shape Files received from DLPE Land Information Services for the site and surrounding areas;
- Site Inspections (refer to **Appendix B** for the site photos) ;
- Design and as constructed drawings from Department of Infrastructure for Amy Johnson Avenue, Stuart Highway, Vanderlin Drive and McMillans Road;
- Data from the City of Darwin for Infrastructure requirements and standards.

# 4 MODELLING PROCEDURE

Investigation of flood behaviour through the subject site required analysis and modelling of the catchment and flow path behaviour. This involved:

- Hydrologic (Catchment) Analysis, to determine the catchment rainfall-runoff processes to produce peak flows. Hydrologic analysis was completed using data from (AR & R) and BOM.

- Hydraulic Modelling Analysis, which is used to simulate the flood behaviour of the subject site to produce flood levels, flow discharges, flow velocities and preliminary detention basin sizes. The model is also used to simulate conveyance to understand how water gets from one point to another. Hydraulic modelling was completed using 2d XP-STORM software.

The steps used in each of these models for flood event simulation are described in the following sections below.

## 4.1 ASSUMPTIONS

Assumptions that have been made as part of this analysis are included below:

- ADG have interpolated the levels within the existing roads. This was due to the topography information that was provided to ADG omitting the z values within the road reserves;
- The topography data was used to display the flood behaviour in the pre- development model, used for earthworks design and to display the flood behaviour in the post-development model;
- From site investigations it has been assumed that the culverts to the north and south of the Boulter Road – Amy Johnson Avenue intersection have tailwater conditions. The Water Surface Elevation (WSE) is approximately at obvert level. Refer to **Appendix B** for site photos;
- No special considerations have been included to identify ground water or other subsurface geotechnical impacts on stormwater flow;
- The proposed stormwater infrastructure will be paid for by the property owner/developer in accordance with the developer contribution plans to be developed based on a proportional payment based on lot area;
- No site sourced stormwater treatment has been included;
- The downstream boundary condition has been modelled assuming it is free flowing;
- Entrance and Exit Losses for the existing culverts were assumed to be 0.5 and 1 respectively; and
- The pre development model was calibrated to the Rational Method to ensure the peak flow rates were appropriate.

# 5 HYDROLOGIC MODELLING

A hydrologic model was created using the XP-STORM software package to provide inflow hydrographs for the 2d component of the hydraulic model. The XP-STORM model represents the sub-areas that contribute to flows across the site and external catchments. The steps involves include:

- Catchment definition;
- Model construction;
- Parameter derivation;
- Simulation of design rainfall events to define critical duration;
- Discharge flows quantified for use in the hydraulic model; and
- The Pre Development Catchment Delineation Plan is shown in **Appendix D.**

## 5.1 HYDRAULIC MODEL – XP-STORM

A 1d/2d XP-STORM runoff model was created to analyse the pre-development and post-development scenarios. The models include a typical 1d node-link connectivity identifying the catchments and hydraulic parameters. A 2d model to simulate how the runoff enters and surcharges from the 1d network was developed. 2d models show flow in multiple directions on the x-y plane. After calibrating the existing model to acceptable flow rates, based on rational method estimates, the proposed strategy is to reduce all increases of post-development runoff to pre-development levels.

Global storms were used to run all design storm events within the same model. XP-STORM uses Australian Rainfall and Runoff nomographs with an absolute depth multiplier to produce site specific hydrographs for use within the hydraulic analysis, where:

*Depth Multiplier = Rainfall Intensity (mm/hr) x Storm Duration (mins) / 60*

### 5.1.1 XPSTORM Rainfall Parameters

Australian Rainfall and Runoff (AR&R) 1987 Intensity Frequency Duration (IFD) data for the subject site obtained from AusIFD was used for the hydrologic analysis for both the rational method calculations and also for the determination of the XP-STORM absolute depth multipliers. The multipliers were applied to the Zone 4 temporal pattern (applicable to north coast of Australia). **Appendix C** displays tabulated summaries of the adopted rainfall intensities as well as the depth multipliers used for the XP-STORM analysis.

### 5.1.2 Hydrologic Modelling Assumptions and Methodology

The following assumptions were used to create the XP-STORM Models:

- Two separate models were generated, which were (refer to section 1.3 for the pre- development scenario and section 2 for the proposed post- development scenario):
    - Pre – Development; and
    - Post – Development.
- Each model included runoff and nodes for each contributing sub-catchment;
- The sub-catchment areas were split into 0% impervious and 100% impervious areas to best replicate the site runoff using the Laurenson Method within the XP-STORM model;
- The method of infiltration chosen for this model was Uniform Loss which was applied to the pervious areas of the sub-catchments;
- After calibrating the pre-development model to rational method estimates, the adopted pervious area losses ranged from 0 mm-5mm initial and from 0-0.5mm/ha (absolute) continuing (refer to section 5.3 for further details); and
- The models were run at various durations for a constant ARI to determine the critical storm event. A critical storm event is best described as the storm duration for which each catchment or majority of catchments have the highest peak flow. For this site the critical storm was the 25 minute duration storm event. It should be noted that not all of the catchments highest peak was during the 25 minute storm event. However the 25 minute storm event was chosen because a vast majority of the catchments did show the highest peak during this event.

## 5.2 DESIGN FLOW VERIFICATION

A comparison between the peak discharge values obtained for the 1 in 100 ARI storm event using the Rational Method and the XP-STORM pre-development model is contained in the table below. It can be seen below the peak discharges generated by the XP-STORM model are within a 10 per cent difference to the values obtained from Rational Method calculations and are therefore considered appropriate for subsequent hydraulics analysis.

**Table 2 – 1 in 100 year ARI Rational Method vs XP-STORM Generated Peak Discharges**

| | Pre- Development | | | | Post-Development | | | |
|---|---|---|---|---|---|---|---|---|
| Event | Catch ID | Rational Method ($m^3/s$) | XP STORM ($m^3/s$) | Difference (%) | Catch ID | Rational Method ($m^3s$) | XP STORM ($m^3/s$) | Difference (%) |
| 1 in 100 Year ARI | 1 | 3.095 | 3.132 | -1.187 | 1 | 3.253 | 3.244 | 0.291 |
| | 2 | 15.114 | 15.844 | -4.833 | 2 | 10.603 | 9.596 | 9.499 |
| | 3 | 6.600 | 6.755 | -2.34 | 3 | 7.931 | 7.315 | 7.763 |
| | 4 | 10.900 | 10.794 | 0.974 | 4 | 14.448 | 14.251 | 1.363 |
| | 5 | 5.106 | 4.882 | 4.380 | 5 | 12.567 | 12.510 | 0.526 |
| | 6 | 5.678 | 5.688 | -0.173 | 6 | 6.254 | 6.381 | -3.792 |
| | 7 | 6.270 | 6.156 | 1.813 | 7 | 7.033 | 7.337 | -4.324 |
| | 8 | 8.198 | 7.786 | 5.027 | 8 | 8.354 | 8.059 | 5.201 |
| | 9 | 5.316 | 5.137 | 3.373 | 9 | 5.462 | 6.087 | 3.778 |
| | 10 | 2.299 | 2.334 | 1.509 | 10 | 2.224 | 2.422 | -8.888 |
| | 11 | 28.359 | 29.222 | -3.045 | 11 | 36.169 | 35.912 | 8.025 |
| | 12 | 19.528 | 18.600 | 4.753 | 12 | 17.189 | 18.541 | -7.865 |

## 5.3 CALIBRATION

The 1d/2d XP-STORM model calibrations were carried out by using the peak flows calculated by the rational method. The calibration of the model was updated by adjusting the Manning's 'n' roughness values of the impervious and pervious areas. The losses in the pervious infiltration characteristics were also adjusted to best replicate the flows calculated by the rational method.

The table below shows the values adjusted in the model to reach appropriate calibration.

**Table 3 – Pervious Infiltration Calibration**

| Pre Development Catchment | Manning's 'n' (pervious) | | Losses (pervious) | |
|---|---|---|---|---|
| | Impervious | Pervious | Initial | Continuing |
| 1 -12 | 0.2 | 0.0275 | 5 | 0.5 |

The 1D/2D XP-STORM Model's impervious infiltration parameters were set to 0 for initial and continuing losses.

# 6 HYDRAULIC MODELLING

To assess flooding characteristics on and adjacent to the site, a 1D/2D XP-STORM model was established. XP-STORM is capable of simulating flow for both small and large study areas using both 2-dimensional and 1-dimensional flow based on the topographic condition of the study area.

A 2d model conveys water by demonstrating how water moves over land and how it interacts with its terrain as well as the existing system. It is essential in protecting lives, homes and businesses. An advantage of using a 2d XP-STORM model is that the flood water can be simulated in any direction within an x-y plane.

## 6.1 Model Setup

The hydraulic model simulates the dynamic flooding behaviour along the river, minor streams and the floodplain. Setting up the hydraulic model involved:

- Allocation of model boundaries;
- Design the node link node network (1D) including culverts, subsurface pipes and open drainage channels;
- Development of a cross-section database for channel flows; and
- Application of appropriate surface friction (Manning "n").

Topography data of the site and surrounding area provided by DLPE was utilised to create the Digital Elevation Model (DEM) required for XP-STORM modelling of the existing scenario. A grid of 2m was used for modelling to best simulate the topographical condition of the site and increase the accuracy of the model results. The post-development DEM was generated from the preliminary earthworks design for the post-development scenario described in section 6.3.

### 6.1.1 Manning's Coefficient

Based on recommendations from Australian Rainfall and Runoff (AR and R) Book VII Section 1 Aspects of Hydraulic Calculations, orthographic photos and a site inspection, Manning's "n" was applied for the following areas shown in the table below.

**Table 4 – Manning's Table**

| AREA | MANNINGS (n) |
|---|---|
| Developable Lots | 0.02 |
| Open Drainage Channels | 0.045 |
| Road | 0.014 |

### 6.1.2 Inflow Locations

The inflow was modelled in XP-STORM using the hydrology model and inputting the impervious and pervious areas of each catchment. The details of each inflow were presented in Section 5 and the inflow locations for pre and post – development are given in **Appendix J.**

### 6.1.3 Downstream Boundary Condition

From information obtained during site inspections, the following downstream boundary conditions were determined.

- The culverts north and south of Boulter Road showed a water level to be at the obvert of the culverts (refer to site inspection pictures 12-15 in **Appendix B**). This existing water level will significantly affect the hydraulic grade line of the upstream stormwater drainage infrastructure.
- The remaining culverts beneath Amy Johnson Avenue had no ponding therefore they were assumed to be free flowing. The downstream boundary condition was calculated by the model using the ground slope and roughness at the downstream boundary location.
- Sinclair Knight Merz (SKM) carried out a Flood Study for the Rapid Creek Catchment Area which part of the Berrimah North Area Plan contributes to. The discharge from the Berrimah North Area discharges to the Marrara Swamp and RAAF Base, which then flows via the Flood Control Weir into Rapid Creek. The intent of the Berrimah North discharge is not to worsen the Flood levels outlined in the SKM report.

## 6.2 Existing Scenario

The existing scenario for the subject site was analysed for a 1 in 100 ARI storm event. The subject site does not have any external catchments. Refer to **Appendix D** for further details of the pre development catchments. The following sections show and discuss the results of the pre-development scenario hydraulic analysis.

### 6.2.1 Amy Johnson Avenue Culverts

The existing culverts beneath Amy Johnson Avenue have been included in the model. Details of these culverts were obtained from drawings R82-1145 to R82-1172 (1982) completed by the Department of Transport and Works, and are provided in the table below. The culvert details are also shown on the drawings in **Appendix D.**

The culverts are the Boulter Road – Amy Johnson Avenue intersection have a water surface elevation at obvert of the culverts.

**Table 5 – Amy Johnson Avenue Culvert Details**

| Name | Size (mm) | Upstream Invert (mAHD) | Downstream Invert (mAHD) | Length (m) | Manning's (n) | Slope (%) | Entrance Loss | Exit Loss |
|---|---|---|---|---|---|---|---|---|
| CH700 | 6/1200x900 RCBC | 28.00 | 27.83 | 21.96 | 0.014 | 0.81 | 0.5 | 1 |
| CH775 | 6/1200x600 RCBC | 28.00 | 27.80 | 21.96 | 0.014 | 0.9 | 0.5 | 1 |
| CH1100 | 2/1200x450 RCBC | 30.70 | 30.60 | 14.64 | 0.014 | 0.7 | 0.5 | 1 |
| CH1350 | 4/1200x450 RCBC | 32.80 | 32.70 | 14.64 | 0.014 | 0.7 | 0.5 | 1 |
| CH1700 | 2/1200x450 RCBC | 33.70 | 33.60 | 14.64 | 0.014 | 0.7 | 0.5 | 1 |
| CH1925 | 4/1200x450 RCBC | 34.20 | 34.10 | 14.64 | 0.014 | 0.7 | 0.5 | 1 |
| CH2325 | 1/1200x450 RCBC | 34.60 | 34.50 | 15.86 | 0.014 | 0.6 | 0.5 | 1 |
| CH2516 | 3/1200x450 RCBC | 31.20 | 30.60 | 34.16 | 0.014 | 1.7 | 0.5 | 1 |

### 6.2.2 Vanderlin Drive Culvert

The existing culvert configurations beneath Vanderlin Drive have been included in the model. Some of the details of these culverts have been taken from Gilbert and Associates Consulting Engineers design drawings and the remainder of the details where estimate from existing ground levels. The details of the culvert that were used in the model are shown in the table below. The culvert details are also shown on the drawings in **Appendix D.**

**Table 6 - Vanderlin Drive Culvert Details**

| Name | Size (mm) | Upstream Invert (mAHD) | Downstream Invert (mAHD) | Length (m) | Manning's (n) | Slope (%) | Entrance Loss | Exit Loss |
|---|---|---|---|---|---|---|---|---|
| Vanderlin Drive | 8/1200x600 RCBC | 34.235 | 34.1 | 14.6 | 0.014 | 0.92 | 0.5 | 1 |

### 6.2.3 Internal Existing Culverts

There are two existing culverts within the subject site's boundary. One of these culverts is part of the stormwater drainage infrastructure for the Berrimah Business Park (BBP) and is upstream of the culvert beneath Vanderlin Drive. Details of this culvert were taken from drawing 22115_501designed by Gilbert and Associates Consulting Engineers. The other culvert is located upstream of the culvert beneath Vanderlin Drive and downstream of the Berrimah Business Park culvert. The details of this particular culvert are unknown and the details have been assumed to be the same as the BBP culvert upstream. The details of these culverts which were used in the model are shown in the table below. The culvert details are also shown on the drawings in **Appendix D.**

**Table 7 – Internal Culvert Details**

| Name | Size (mm) | Upstream Invert (mAHD) | Downstream Invert (mAHD) | Length (m) | Manning's (n) | Slope (%) | Entrance Loss | Exit Loss |
|---|---|---|---|---|---|---|---|---|
| BBP Culvert | 3/1200x600 RCBC | 34.63 | 34.65 | 16.6 | 0.014 | 0.1 | 0.5 | 1 |
| Unknown Culvert | 3/1200x600 RCBC | 33.8 | 33.78 | 16.6 | 0.014 | 0.1 | 0.5 | 1 |

The BBP culvert's intended purpose is to provide a controlled outflow for the BBP development allowing stormwater runoff to be detained in a constructed swale upstream of the culvert.

### 6.2.4 Existing Scenario Flooding and Flow Results

Hydraulic analysis of the site in its existing condition was undertaken to establish and quantify existing flooding patterns and behaviour. Key model outputs characterising flood behaviour include flood level, WSE, discharges and velocities and functions as a function of time for that given flood event. Modelling results for the existing site have been presented in the following:

- The table below lists the existing flood levels for various points during the 1 in 100 year ARI storm events. The locations of these points are shown in **Appendix E**; and
- The existing extent of flooding within the site of the 1 in 100 year ARI storm event is presented in **Appendix E.**

The flood extents displayed are predominately in the area closest to Amy Johnson Avenue where the site slopes to its lowest points. There is flooding around and on the downstream side of the existing culverts beneath Amy Johnson Avenue. Catchments 11 and 12 slope to the east towards Vanderlin Drive and **Appendix E** shows that there is also existing flooding in this area.

The existing scenario model shows that there is some flooding on Amy Johnson Avenue. Flows in a 1 in 100 ARI overtop the road predominately in the area around the Boulter Road – Amy Johnson Avenue adjacent to Marrara Swamp in the order of approximately 0.25 – 0.5 meters. Vanderlin Drive also experiences overtopping in the pre-development case in the order of 0.25 -0.3 meters.

**Table 8 – Existing Peak Flood Levels and Velocities**

| | Point Location | Existing $Q_{100}$ Peak Water Surface Elevation (m AHD) | Existing $Q_{100}$ Flood Velocity (m/s) |
|---|---|---|---|
| 1 in 100 Year ARI | 1 | 34.385 | 0.098 |
| | 2 | 33.294 | 0.717 |
| | 3 | 31.263 | 0.101 |
| | 4 | 29.861 | 0.341 |
| | 5 | 30.963 | 0.239 |
| | 6 | 35.093 | 0.325 |
| | 7 | 35.339 | 0.308 |
| | 8 | 30.472 | 0.622 |
| | 9 | 30.608 | 0.779 |
| | 10 | 32.187 | 0.399 |
| | 11 | 29.427 | 0.00 |
| | 12 | 35.044 | 0.019 |

**Table 9 – Existing Peak Flows**

| | Flow Line | Existing $Q_{100}$ Flood Flow ($m^3/s$) |
|---|---|---|
| 1 in 100 Year ARI | 1 | 3.286 |
| | 2 | 65.294 |
| | 3 | 35.182 |
| | 4 | 70.755 |
| | 5 | 34.535 |

The abovementioned Point and Flow Line locations are displayed in **Appendix E.** These Points and Flow Lines provide a way to compare flood depths, flow and velocities in particular areas for interest. The post-developed data for the selected points and flow lines are discussed in Section 6.3.8 and a full comparison between the existing and post-developed scenario is discussed in Section 7.

## 6.3 Post-Developed Scenario

The post-developed scenario required the proposed area plan layout to be investigated for impacts on neighbouring properties upstream and downstream. To determine the impacts of the proposed area plan on the hydraulics of the catchment, ADG have firstly prepared a preliminary earthworks design surface of the post-developed scenario utilising the 3d modelling program 12d. The earthworks design has been prepared to ensure negligible impacts to the hydraulics of the development, further details of the preliminary earthworks are provided within **Appendix F.** The design used minimum grades to achieve a free draining surface. As **Appendix F** shows the preliminary earthworks design was carried out only in areas in which fill was required to ensure a free draining surface was possible. Additional earthworks will be required beyond what is nominated in this report, only the areas required to be adjusted to suit catchment requirements were modelled. The post development hydraulic model was prepared from the 12d design surface and existing surface obtained from Land Information Services. The following sections discuss the works required as part of the proposed development. There are no proposed upgrades of the existing culverts beneath Amy Johnson Avenue. Refer to **Appendix G** for the Post Development Catchment Plans.

### 6.3.1 Selection Criteria for Treatment Options

Taking into consideration the natural topography, site constraints, downstream boundary conditions and environmental values of the site, the following criteria was used for the selection of the treatment options:

- No worsening of downstream flood extents;
- Maintaining environmental values;
- Use of Crown Land;
- Access;
- Construction Feasibility;
- Total catchment treatment;
- Over sizing of treatment devices to compensate for untreated areas.

### 6.3.2 Selection Criteria for Treatment Locations

Taking into consideration the natural topography, site constraints, downstream boundary conditions and environmental values of the site the following criteria was used for the selection of the treatment locations:

- Maintaining the largest developable area outside of the designated open space areas and restricted development area;
- Ensuring the hydraulic grade line of the existing culverts beneath Amy Johnson Avenue remains unchanged by any proposed drainage infrastructure;
- Minimal interference with existing developments; and
- Incorporation of proposed development schemes within the area plan.

### 6.3.3 Overall Drainage Network

The flat topography of the site and the water surface elevation at obvert of the culverts in some places makes for a challenge to implement conventional pit and pipe drainage throughout the entire area. To provide feasible and constructable drainage network, a combination of underground pipes with kerb and channel road reserve for overland flow, open channels, detention basins and internal access crossing culverts were designed. The following sections describe these networks in further detail. Refer to **Appendix H** for the overall drainage network and specific catchment drainage networks.

### 6.3.4 Pipe Network

It is proposed that the stormwater runoff, where the existing topography allows it, will be piped to the detention basins. This pipe network will be located beneath the existing proposed roads of the Berrimah North Area Plan. The road reserve in these areas will have kerb and channel and provide a major storm event overland flow path. The Manning's roughness value of the roads has been modelled as 0.014. The proposed pipe network and properties are shown in **Appendix H**.

### 6.3.5 Conveyance Channels

It is proposed that the remainder of the site in which stormwater flows cannot be diverted to a pipe network, will be conveyed via an open drainage channel. The newly proposed channels and formalisation of existing channels will ensure that the majority of stormwater flows are directed to detention basins and then to the existing culverts beneath Amy Johnson Avenue. These open channels will also provide detention by using a gabion wall to only allow low flows through the channel until a depth of 200mm. The height of the gabion wall will allow all Q2 and Q5 flows through. Refer to **Appendix K** for the typical sections of the open drains. The typical section also shows that the open channel will be concrete lined in the low flow section and vegetated with grass in the remainder of the channel. This design provides the opportunity to provide stormwater quality treatment by stripping nutrients from the stormwater runoff. The Manning's roughness value through the channels has been modelled as 0.045 representing a landscaped surface through the channel. The proposed channels are shown in **Appendix H** and the properties are shown in the table below.

The safety constraints of all open drainage needs to be considered during detailed design, the table below identifies that the designed channels are in accordance with the criteria of velocity not exceeding 2m/s and the d-v product not exceeding 0.4.

**Table 10 – Channel Parameters**

| Name | Base Width (m) | Channel Depth (m) | Batter Slope (1:x) RHS | Batter Slope (1:x) LHS | Manning's | Freeboard (m) | Velocity (m/s) | D-V Product |
|---|---|---|---|---|---|---|---|---|
| Swale 1-3, 23-24 | 1.5 | 0.4 | 4 | 4 | 0.045 | 0.210-0.570 | 0.96 | 0.4 |
| Swale 4-7, 13, 16-18, 25 | 1.5 | 0.4 | 6 | 4 | 0.045 | 0.190-0.730 | 0.94 | 0.37 |
| Swale 8-11, 14, 26 | 1.5 | 0.4 | 4 | 6 | 0.045 | 0.00-0.990 | 0.94 | 0.37 |
| Swale 19 | 1.5 | 0.3 | 4 | 4 | 0.045 | 0.00 | 0.82 | 0.24 |
| Swale 20, 22 | 1.5 | 0.3 | 6 | 4 | 0.045 | 0.210-0.380 | 0.8 | 0.24 |
| Swale 21 | 1.5 | 0.3 | 4 | 6 | 0.045 | 0.370 | 0.8 | 0.24 |

### 6.3.6 Internal Road Crossings

A preliminary design consideration has been given to how the area plan will provide connectivity with the proposed drainage infrastructure. Culverts and road heights have been designed to allow for flood free access. New stormwater access easements will be required to improve property access and maintenance. Preliminary sizing of the culverts and road heights to convey the flow from each area in the area plan are shown in the table below. The culvert locations are also shown in **Appendix H.**

**Table 11 – Internal Road Crossing Culvert Details**

| Name | Size (mm) | Upstream Invert (mAHD) | Downstream Invert (mAHD) | Length (m) | Manning's (n) | Slope (%) |
|---|---|---|---|---|---|---|
| CC 1 | 600 x 600 RCBC | 31.8 | 31.5 | 28.5 | 0.014 | 1.05 |
| CC 2 | 600 x 600 RCBC | 31.2 | 30.7 | 31.36 | 0.014 | 1.59 |
| CC 3 | 900 x 600 RCBC | 32.4 | 32.27 | 39.44 | 0.014 | 0.33 |
| CC 4 | 600 x 600 RCBC | 33.08 | 32.87 | 41.72 | 0.014 | 0.5 |
| CC 5 | 600 x 600 RCBC | 34.11 | 33.87 | 49.24 | 0.014 | 0.5 |
| CC 6 | 600 x 600 RCBC | 35.42 | 35.26 | 31.12 | 0.014 | 0.5 |
| CC 7 | 600 x 600 RCBC | 36.46 | 36.30 | 32.06 | 0.014 | 0.5 |
| CC 8 | 600 x 600 RCBC | 36.36 | 36.13 | 46.02 | 0.014 | 0.5 |
| CC 9 | 600 x 600 RCBC | 33.35 | 32.0 | 36.05 | 0.014 | 3.76 |
| CC 10 | 600 x 600 RCBC | 34.05 | 33.56 | 38.22 | 0.014 | 1.29 |
| CC 11 | 600 x 600 RCBC | 36.46 | 36.30 | 32.06 | 0.014 | 0.5 |
| CC12 | 600 x 600 RCBC | 36.36 | 36.13 | 46.02 | 0.014 | 0.5 |

### 6.3.7 Detention Basins

The detention basins have been designed to mitigate flows through the site. Due to the area constraints the basin sizes below take into consideration the stormwater runoff which will be detained in the open drains as discussed above in section 6.3.5. It is assumed the minor event will be piped or conveyed by channels to the detention basin and flows from greater intensity events up to and including the 1 in 100 year ARI event will flow towards the basins by a combination of piped and overland flow. Using an iterative approach, the basin outlets were sized to ensure discharge from the proposed detention basins was less than or equal to the pre-development flow rates. The Q100 storage volumes for each of the modelled detention basins are presented in Table 12.

**Table 12 – Detention Basin Volumes and Water Levels**

| Name | Design Storm (ARI) | Detention Volume ($m^3$) | Water Elevation Depth (m) | Freeboard to Crest of Basin (m) |
|---|---|---|---|---|
| Basin 1 | 100 | 1554 | 0.447 | 0.122 |
| Basin 2 | 100 | 205 | 0.312 | 0.39 |
| Basin 3a | 100 | 2500 | 0.856 | 0.318 |
| Basin 3b | 100 | 2000 | 0.815 | 0.430 |
| Basin 4 | 100 | 5106 | 0.554 | 0.32 |
| Basin 5 | 100 | 5290 | 0.110 | 0.34 |
| Basin 6 | 100 | 17750 | 1.372 | 0.6 |

**Table 13 – Detention Basin Outlet Configuration**

| Basin Description | Outlet from Basin | Emergency Overflow Weir |
|---|---|---|
| Basin 1 | 375mm RCP or equivalent orifice | 5m wide at 0.5m above basin invert |
| Basin 2 | 375mm RCP or equivalent orifice | 5m wide at 1m above basin invert |
| Basin 3a | 375mm RCP or equivalent orifice | 5m wide at 0.6m above basin invert |
| Basin 3b | 375mm RCP or equivalent orifice | 4m wide at 0.4m above basin invert |
| Basin 4 | 375mm RCP or equivalent orifice | 10m wide at 1.4m above basin invert |
| Basin 5 | 375mm RCP or equivalent orifice | 5m wide at 0.2m above basin invert |
| Basin 6 | 225mm RCP or equivalent orifice | 5m wide at 1.1m above basin invert |

The above design is preliminary only and is subject to detailed design.

The proposed detention basins successfully mitigate the post-development flows to below pre-development conditions at the culverts beneath Amy Johnson Avenue. For more information refer to Section 6.2.

### 6.3.8 Post Development Scenario Results

Key model characterising flood behaviour include flood level as a function of time for a given flood event. The flood levels and discharges upstream and downstream of the subject site, incorporating the proposed development, were determined using XP-STORM. Modelling results for the post developed site have been presented in the following:

- **Appendix I** presents the Post-Development Model Key Features of the XP-STORM hydraulic model;
- The tables below list the mitigated post development flood levels, velocities and flows during the 1 in 100 year ARI storm event.

**Table 14– Post-Development Flood Levels, Velocities and Flow**

| Storm Event | Name | Developed $Q_{100}$ Peak Water Surface Elevation (m AHD) | Developed $Q_{100}$ Flood Velocity (m/s) |
|---|---|---|---|
| 1 in 100 Year ARI | 1 | 34.366 | 0.057 |
| | 2 | 33.181 | 0.00 |
| | 3 | 31.264 | 0.021 |
| | 4 | 27.995 | 0.493 |
| | 5 | 30.879 | 0.00 |
| | 6 | 34.752 | 0.00 |
| | 7 | 35.34 | 0.202 |
| | 8 | 30.61 | 0.913 |
| | 9 | 30.925 | 0.012 |
| | 10 | 32.71 | 0.477 |
| | 11 | 29.008 | 0.756 |
| | 12 | 35.046 | 0.060 |

**Table 15 – Post-Development Flows**

| | Flow Line | Developed $Q_{100}$ Flood Flow ($m^3/s$) |
|---|---|---|
| 1 in 100 Year ARI | 1 | 0.00 |
| | 2 | 63.576 |
| | 3 | 29.914 |
| | 4 | 41.361 |
| | 5 | 69.502 |

The inundation map for the Post-Development 1 in 100 year ARI storm event is included in **Appendix I.**

# 7 IMPACT ASSESSMENT

Tabulated data analysis was performed to determine the impacts of the proposed development. Flood level afflux was investigated and is discussed in the following sections.

## 7.1 Peak Flood Levels

### 7.1.1 Impact Assessment

The table below presents the results of the flood level afflux, which indicates there are areas where the flood levels and velocities have increased. The flood level increases discussed below do not impact existing properties. Points 4, 8, 9, 10 and 11 are all within the subject site. Post Development results include the effects of the proposed open drains and pipe network identified in the Section above.

A summary of the afflux results include:

- A change in elevation exceeding 0.5m at Point 10 in a 1 in 100 year ARI storm event correlates with a low area the north western corner of the existing school. This is due to the fact that Point 10 is located on the existing sports fields which are in a low laying area. There is no impact on existing properties caused by this increase;
- Points 8 and 9 have a change in elevation of 0.14 and 0.32m respectively from pre to post-development because these points are located within the restricted development area at the end of Boulter Road associated with the Marrara Swamp and due to the increased flows from development the redistricted development area acts as a natural detention area. There is no impact on existing properties caused by this increase;
- The increase in velocities at Points 4, 8, and 11 were expected due to the large catchment area to be collected via the proposed open drain adjacent to Boulter Road. This increase will not cause any impact on existing properties. The velocity increase at Point 10 s located in the existing sports field and does not impact existing developments; (Refer to **Appendix I** for Q100 Flood Extents)

The negative values shown in the table below represent that the post- development water surface elevation and velocities are less than that of the pre- development scenario.

Overall the table below shows that the post-development flows have been mitigated.

**Table 16 – Existing and Post-Development Peak Flood Levels and Affluxes**

| Storm Event | Point | $Q_{100}$ Peak Water Surface Elevation (m AHD) | | $Q_{100}$ Peak Flood Velocity (m/s) | | Water surface Elevation Afflux (m) | Water Velocity Afflux (m/s) |
|---|---|---|---|---|---|---|---|
| | | Existing | Post Development | Existing | Post Development | | |
| 1 in 100 Year ARI | 1 | 34.385 | 34.366 | 0.098 | 0.057 | -0.019 | -0.041 |
| | 2 | 33.294 | 33.181 | 0.717 | 0.00 | -0.113 | -0.717 |
| | 3 | 31.263 | 31.264 | 0.101 | 0.021 | 0.001 | -0.080 |
| | 4 | 29.861 | 27.995 | 0.341 | 0.493 | -1.866 | 0.152 |
| | 5 | 30.963 | 30.879 | 0.239 | 0.00 | -0.084 | -0.239 |
| | 6 | 35.093 | 34.752 | 0.325 | 0.00 | -0.341 | -0.325 |
| | 7 | 35.339 | 35.34 | 0.308 | 0.202 | 0.001 | -0.106 |
| | 8 | 30.472 | 30.61 | 0.622 | 0.913 | 0.138 | 0.291 |
| | 9 | 30.608 | 30.925 | 0.779 | 0.012 | 0.317 | -0.767 |
| | 10 | 32.187 | 32.71 | 0.399 | 0.477 | 0.523 | 0.078 |
| | 11 | 29.427 | 29.008 | 0.701 | 0.756 | -0.419 | 0.055 |
| | 12 | 35.044 | 35.046 | 0.057 | 0.060 | 0.002 | 0.003 |

## 7.2 Peak Discharge at Lawful Point of Discharge

A comparison of pre-development peak discharge and post-development discharge at the nominated Flow Lines are shown in the table below. The pre-development peak discharges are maintained for the 1 in 100 year ARI storm event at four of flow lines.

**Table 17 - Existing and Post-Development Peak Discharge and Affluxes**

| Event | Flow Line | Pre $Q_{100}$ Peak Discharge ($m^3/s$) | Post $Q_{100}$ Peak Discharge ($m^3/s$) | Afflux ($m^3/s$) |
|---|---|---|---|---|
| 1 in 100 year ARI | Flow Line 1 | 3.286 | 0.00 | -3.286 |
| | Flow Line 2 | 65.294 | 63.576 | -1.718 |
| | Flow Line 3 | 35.182 | 29.914 | -5.268 |
| | Flow Line 4 | 70.755 | 69.502 | -1.253 |
| | Flow Line 5 | 34.535 | 41.361 | 6.836 |

Table 17 above shows that there is an overall decrease in flows for the post-developed scenario at Flow Lines 1-4. Flow line 5 however shows an increase this increase in flow is because the flow line is positioned within the site before the detention basin for that particular catchment. The overall discharge point for the eastern side is Flow Line 3 and it shows an overall decrease in flow. Therefore the increased flow at Flow Line 5 is not causing any damage to existing properties and is mitigated once the flow reaches the detention basin.

As assessment has also been carried out to check the overall volumes discharging to Ironstone and Knuckey Lagoons and there was found to be no worsening in the overall discharging volumes.

An increase in the volume of stormwater discharging from the Berrimah North Area is expected in developed areas because of the increase in impervious areas reducing the amount of runoff that can be infiltrated.

Due to the Knuckey Lagoons being a sensitive receiving environment with limited storage capacity it was determined through liaison with key stakeholders that directing part of Catchment 11 towards Rapid Creek would decrease the overall volume discharging to the Lagoon Area.

# 8 ALTERNATIVE SOLUTIONS

There are possible alternative solutions which could provide a feasible option to address stormwater drainage in the Berrimah North area. These options include:

- Site specific treatment instead of catchment wide basins. This would include each owner/developer to provide detention for their site.
- Over sizing the detention basins in appropriate locations to compensate for the non-treatable areas.

# 9 DEVELOPER CONTRIBUTION

In order to provide stormwater drainage infrastructure to the area within the Berrimah North Area Plan a Developer Contribution Plan will be implemented. The Berrimah North Area has been broken into 9 separate developer contribution plan areas. The developer contribution plan will

ensure that all lots with the same discharge point will contribute to the associated stormwater infrastructure in its' specific catchment.

The initial Developer Contribution Plan's costing details are located in **Appendix L** and a summary of the preliminary costs per hectare for stormwater drainage infrastructure is shown below in Table 18.

It is expected that the City of Darwin will finalise the Contribution Plan for the Berrimah North Area and include various other influencing factors. The Catchment areas were derived by delineating the areas associated with a single point of discharge.

**Table 18 – Summary of Developer Contribution**

| | Summary of Costs |
|---|---|
| **Area** | **Contribution ($/ha)** |
| Overall | $11,161.21 |
| 1 | $13,404.78 |
| 2 | $9,811.03 |
| 3 | $10,051.34 |
| 4 | $6,854.15 |
| 5 | $3,547.10 |
| 6 | $9,719.24 |
| 7 | $10,896.81 |
| 8 | $2.20 |
| 9 | $1,617.00 |
| *** includes undevelopable area** | |

# 10 CONCLUSION

This study has reviewed the hydrology and hydraulics of the site for pre and post- development scenarios and investigated the impact of the proposed development on upstream and downstream properties. This study has looked at the impact of filling the site to allow for the proposed development areas and other minor drainage through the site.

Based on this study the following conclusions have been drawn;

- No external catchments;

- All of the minor afflux is considered to be within modelling tolerances and is not likely to cause any damage to existing properties;
- Stormwater infrastructure is required to mitigate the post-development flows.

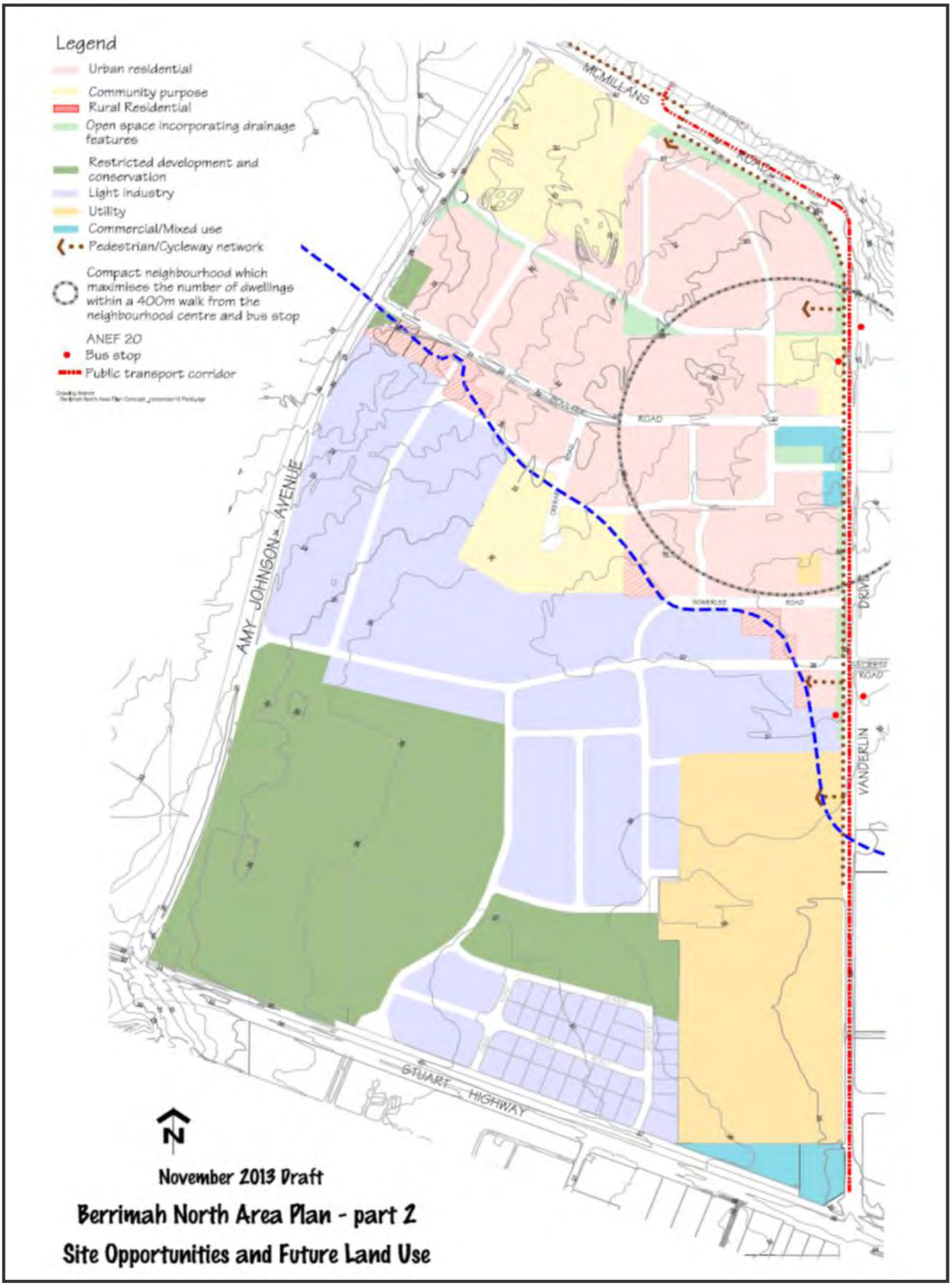
In summary,

The proposed area plan for Berrimah North will not have adverse impacts on downstream Marrara Swamp, RAAF Base/Darwin Airport and Rapid Creek or Ironstone and Knuckey Lagoons. However, significant earthworks design is required to ensure free surface drainage from future developments within the Berrimah North Area Plan.

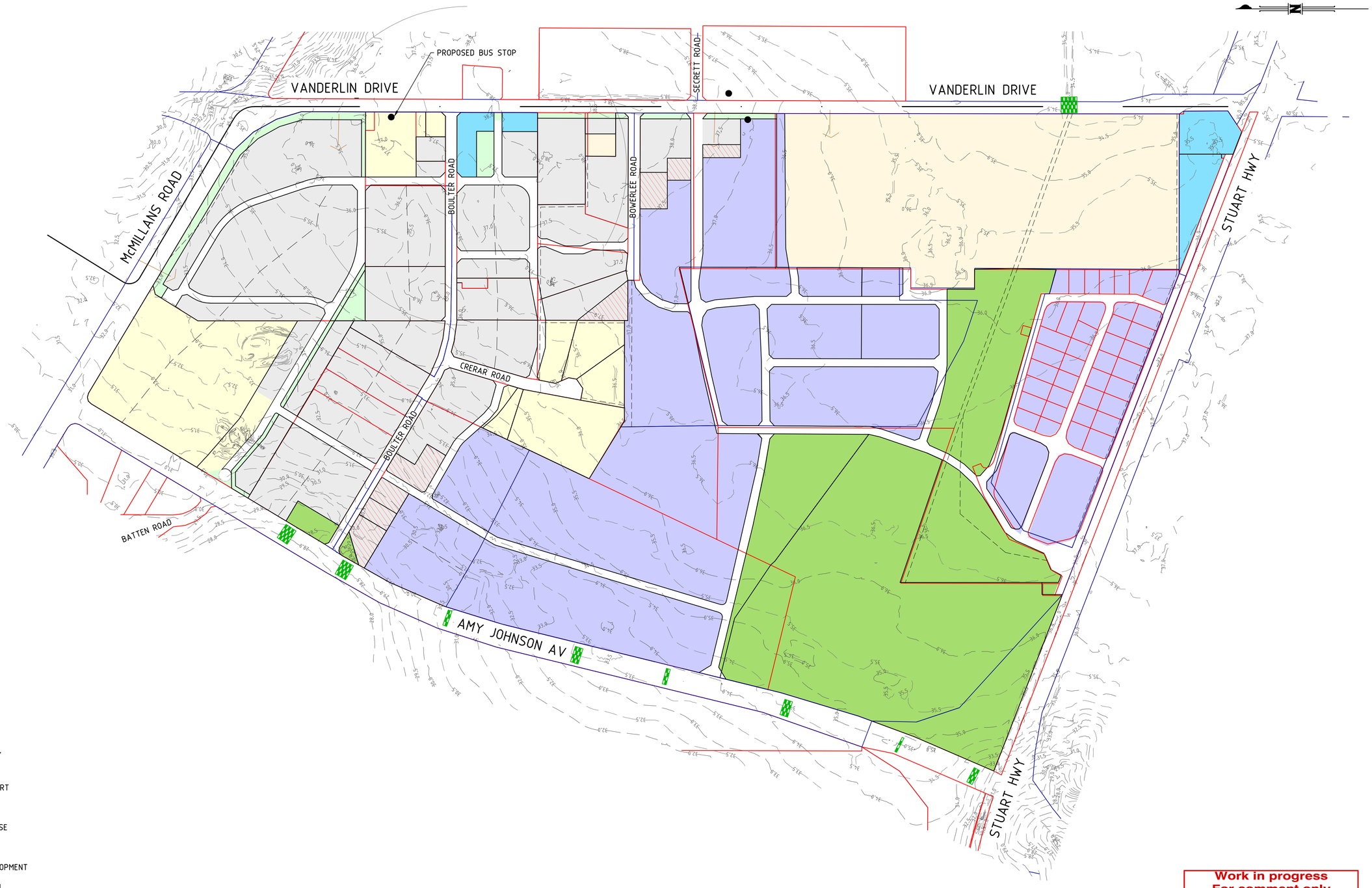
The proposed layout and infrastructure nominated in this report is a first iteration showing the feasibility of development in the area. Variations to the road alignments, open channel drain configurations, inclusions of stormwater improvement devices and changes to the development plan can all be configured and included in future revisions of this hydraulic model and report.

# Appendix A
# Berrimah North Area Plan (November 2013)


Legend
Australian noise exposure forecast
Defence (area control) regulations
Approach splay/ public safety area
Access from arterial road network
Catchment & sub.catchment
Discharge control structure
North - Eastern Catchment
North - Western Catchment
South - Eastern catchment
No structures
Structure above 7.5m
November 2013 Draft
Berrimah North Area Plan - part 1
Site Constraints and Strategic Infrastructure


Legend
Urban residential
Community purpose
Rural Residential
Open space incorporating drainage features
Restricted development and conservation
Light industry
Utility
Commercial/Mixed use
Pedestrian/Cycleway network
Compact neighbourhood which maximises the number of dwellings within a 400m walk from the neighbourhood centre and bus stop
ANEF 20
Bus stop
Public transport corridor
MCMILLANS
AMY JOHNSON AVENUE
STUART HIGHWAY
VANDERLIN
N
November 2013 Draft
Berrimah North Area Plan - part 2
Site Opportunities and Future Land Use

XREFS:




## LEGEND

- EXISTING LOT BOUNDARY
- EXISTING EASEMENT BOUNDARY
- EXISTING SURFACE CONTOURS (12.0)
- EXISTING STORM WATER CULVERT
- PROPOSED COMMERCIAL
- PROPOSED COMMUNITY PURPOSE
- PROPOSED LIGHT INDUSTRY
- PROPOSED RESTRICTED DEVELOPMENT
- PROPOSED URBAN RESIDENTIAL
- PROPOSED URBAN RESIDENTIAL HIGH DENSITY
- PROPOSED UTILITIES
- PROPOSED OPEN SPACE

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


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| | Project No.: 15988 / Drawn By: JD / Scale at A1: 1:5000 | |



Title: POST DEVELOPMENT BERRIMAH NORTH AREA PLAN

Drawing No.: SK10 Revision: 04

PLOT DATE: 7/9/2014 10:10 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK10_POST DEVELOPMENT AREA PLAN.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix B
# Site Photos


**Figure 15 – Photo 1**


**Figure 16 – Photo 2**


**Figure 17 – Photo 3**

**Figure 18 – Photo 4**


**Figure 19 – Photo 5**


**Figure 20 – Photo 6**

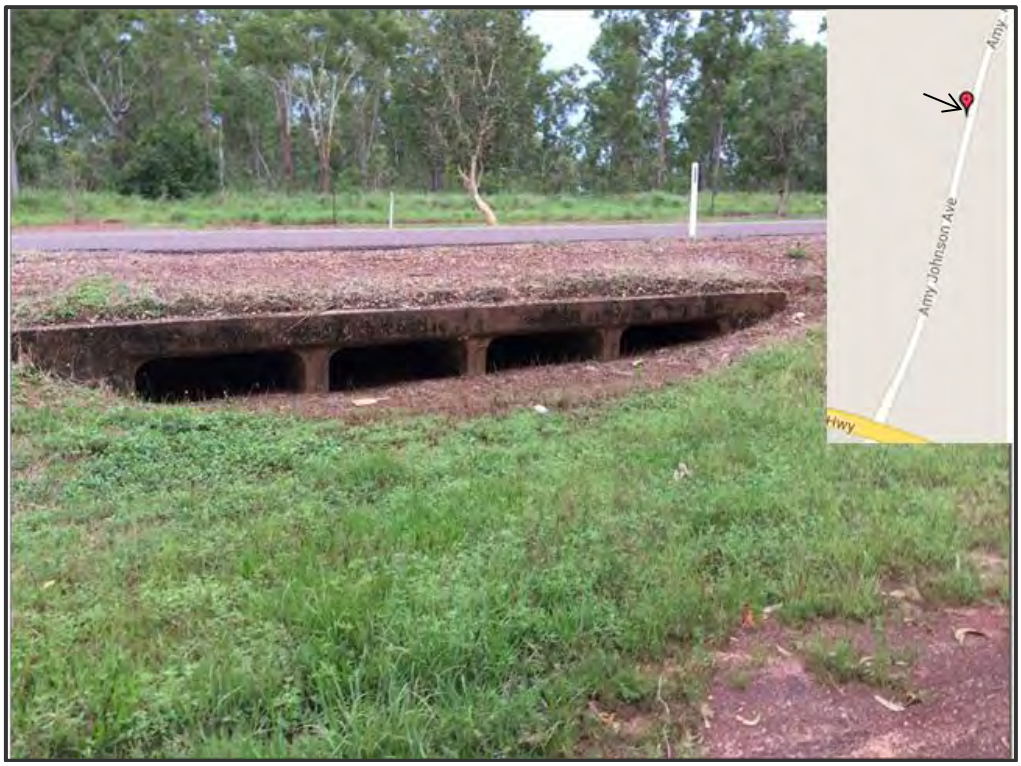



**Figure 21 – Photo 7**


**Figure 22 – Photo 8**


**Figure 23 – Photo 9**


**Figure 24 – Photo 10**


**Figure 25 – Photo 11**


**Figure 26 – Photo 12**


**Figure 27 – Photo 13**


**Figure 28 – Photo 14**


**Figure 29- Photo 15**

# Appendix C
# XP-STORM Rainfall Parameters

**Table 19– Adopted Intensity Frequency Data (mm/hr)**

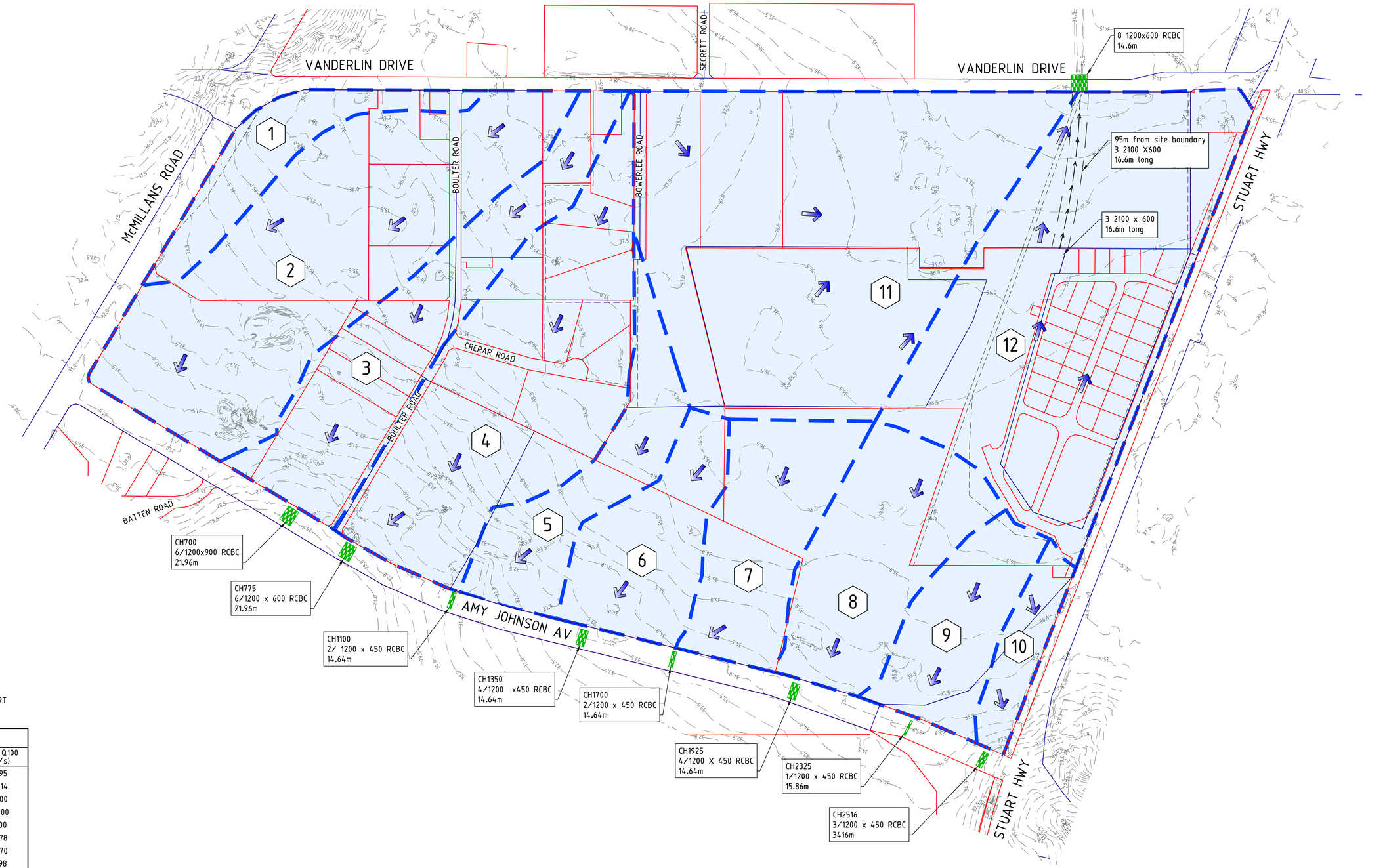
| Storm Duration (mins) | Average Recurrence Interval (Years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| **15** | *98* | *123* | *148* | *163* | *185* | *215* | *238* |
| **20** | *86* | *108* | *130* | *143* | *162* | *188* | *208* |
| **25** | *77* | *97* | *117* | *128* | *145* | *168* | *186* |
| **30** | *70* | *89* | *106* | *117* | *133* | *154* | *170* |
| **45** | *57* | *72* | *86* | *95* | *107* | *124* | *137* |
| **60** | *48.5* | *61* | *73* | *81* | *91* | *106* | *117* |
| **90** | *36* | *45.5* | *55* | *60* | *68* | *79* | *88* |
| **120** | *29.1* | *36.7* | *44.2* | *48.7* | *55* | *64* | *71* |
| **180** | *21.4* | *27.1* | *32.6* | *36* | *40.9* | *47.4* | *53* |
| **270** | *15.7* | *19.9* | *24.1* | *26.6* | *30.2* | *35.1* | *38.9* |

**Table 20– XP-STORM Rainfall Multipliers Applied to Temporal Patterns (mm)**

| Storm Duration (mins) | Average Recurrence Interval (Years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| **15** | *24.5* | *30.8* | *37.0* | *40.8* | *46.3* | *53.8* | *59.5* |
| **20** | *28.7* | *36.0* | *43.3* | *47.7* | *54.0* | *62.7* | *69.3* |
| **25** | *32.1* | *40.4* | *48.8* | *53.3* | *60.4* | *70.0* | *77.5* |
| **30** | *35.0* | *44.5* | *53.0* | *58.5* | *66.5* | *77.0* | *85.0* |
| **45** | *42.8* | *54.0* | *64.5* | *71.3* | *80.3* | *93.0* | *102.8* |
| **60** | *48.5* | *61.0* | *73.0* | *81.0* | *91.0* | *106.0* | *117.0* |
| **90** | *54.0* | *68.3* | *82.5* | *90.0* | *102.0* | *118.5* | *132.0* |
| **120** | *58.2* | *73.4* | *88.4* | *97.4* | *110.0* | *128.0* | *142.0* |
| **180** | *64.2* | *81.3* | *97.8* | *108.0* | *122.7* | *142.2* | *159.0* |
| **270** | *70.7* | *89.6* | *108.5* | *119.7* | *135.9* | *158.0* | *175.1* |

# Appendix D
# Pre Development Catchment Delineation Plan

XREFS:




## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT
- 1 — CATCHMENT LABEL
- CATCHMENT BOUNDARY
- FLOW PATH
- EXISTING STORMWATER CULVERT

## CATCHMENT TABLE

| CATCHMENT | AREA (ha) | FRACTION IMPERVIOUS (Fi %) | FLOW Q100 (m3/s) |
|---|---|---|---|
| 1 | 9.657 | 20 | 3.095 |
| 2 | 46.124 | 20 | 15.114 |
| 3 | 24.204 | 25 | 6.600 |
| 4 | 39.732 | 20 | 10.900 |
| 5 | 14.111 | 0 | 5.100 |
| 6 | 13.864 | 0 | 5.678 |
| 7 | 16.393 | 0 | 6.270 |
| 8 | 20.266 | 0 | 8.198 |
| 9 | 12.296 | 0 | 5.316 |
| 10 | 5.259 | 0 | 2.299 |
| 11 | 65.290 | 15 | 28.359 |
| 12 | 55.750 | 10 | 19.528 |

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


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Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:5000



Title: PRE DEVELOPMENT CATCHMENTS
Drawing No.: SK02
Revision: 03

PLOT DATE: 7/9/2014 10:08 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK02_PRE DEVELOPMENT CATCHMENTS.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

XREF'S:


## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT
- 1 — CATCHMENT LABEL
- CATCHMENT BOUNDARY
- FLOW PATH
- EXISTING STORMWATER CULVERT

## NOTES:

REFER DRAWING SK02 FOR CATCHMENT TABLE

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


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| | Project No.: 15988 | Drawn By: JD | Scale at A1: 1:5000 |



Title: PRE DEVELOPMENT CATCHMENT ON AERIAL PHOTO

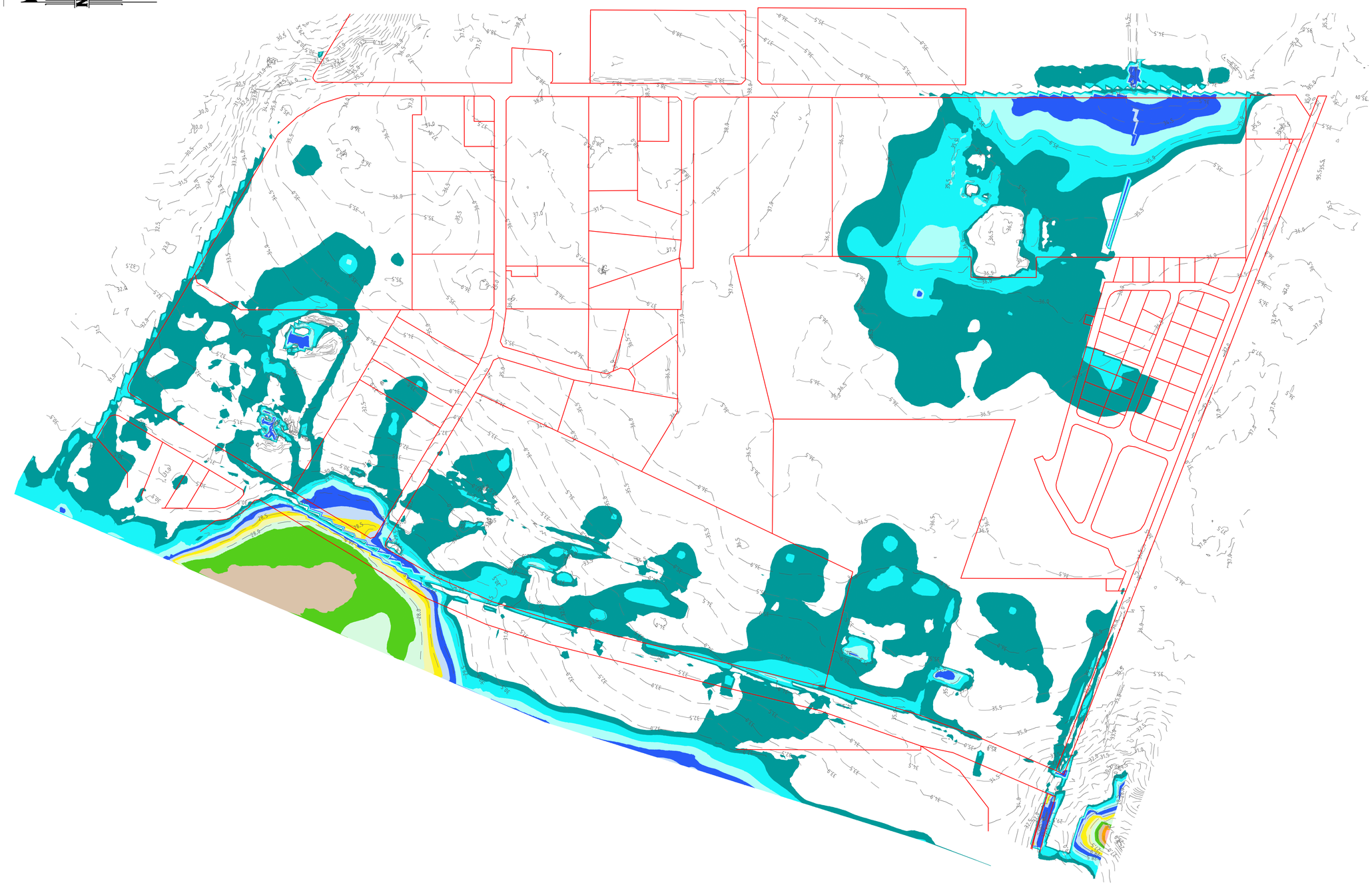
Drawing No.: SK03 Revision: 02

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

PLOT DATE: 7/9/2014 10:09 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK03_PRE DEVELOPMENT CATCHMENT AERIAL PHOTO.DWG

# Appendix E
# Pre Development Catchment Flood Extents

XREFS:



## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT

## NOTES:

REFER DRAWING SK02 FOR CATCHMENT TABLE

## FLOOD LEGEND

- 100m TO 3.00m
- 3.00m TO 2.75m
- 2.75m TO 2.50m
- 2.50m TO 2.25m
- 2.25m TO 2.00m
- 2.00m TO 1.75m
- 1.75m TO 1.50m
- 1.50m TO 1.25m
- 1.25m TO 1.00m
- 1.00m TO 0.75m
- 0.75m TO 0.50m
- 0.50m TO 0.25m
- 0.25m TO 0.00m

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0 100 200 300m

SCALE 1:5000

AT ORIGINAL SIZE (A1)


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Discipline: CIVIL

Status: PRELIMINARY

| Designed By | Checked By | Approved By |
|---|---|---|
| NB | MVI | MVI |

| Project No. | Drawn By | Scale at A1 |
|---|---|---|
| 15988 | JD | N.T.S. |



Title: PRE DEVELOPMENT FLOOD EXTENTS

Drawing No.: SK04

Revision: 03


PLOT DATE: 7/9/2014 10:09 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK04_FLOOD EXTENTS (PRE).DWG


FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix F
# Preliminary Bulk Earthworks

XREF'S:

LEGEND

PROPOSED CUT

PROPOSED FILL

VANDERLIN DRIVE

SECRETT ROAD

VANDERLIN DRIVE

McMILLANS ROAD

STUART HWY

BOWERLEE ROAD

BOULTER ROAD

BOULTER ROAD

CRERAR ROAD

ROAD 1

ROAD 2

ROAD 2

ROAD 3

ROAD 4

ROAD 5

ROAD 6

ROAD 7

ROAD 8

ROAD 9

ROAD 10

ROAD 11

ROAD 12

ROAD 13

ROAD 13

ROAD 13

ROAD 14

ROAD 15

ROAD 16

ROAD 17

ROAD 18

ROAD 19

EXISTING DEVELOPMENT

BATTEN ROAD

AMY JOHNSON AV

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|---|---|---|---|---|
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0 100 200 300m

SCALE 1:5000

AT ORIGINAL SIZE (A1)


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| | Project No.: 15988 / Drawn By: JD / Scale at A1: 1:5000 | |



Title: BULK EARTHWORKS LAYOUT PLAN

Drawing No.: SK30

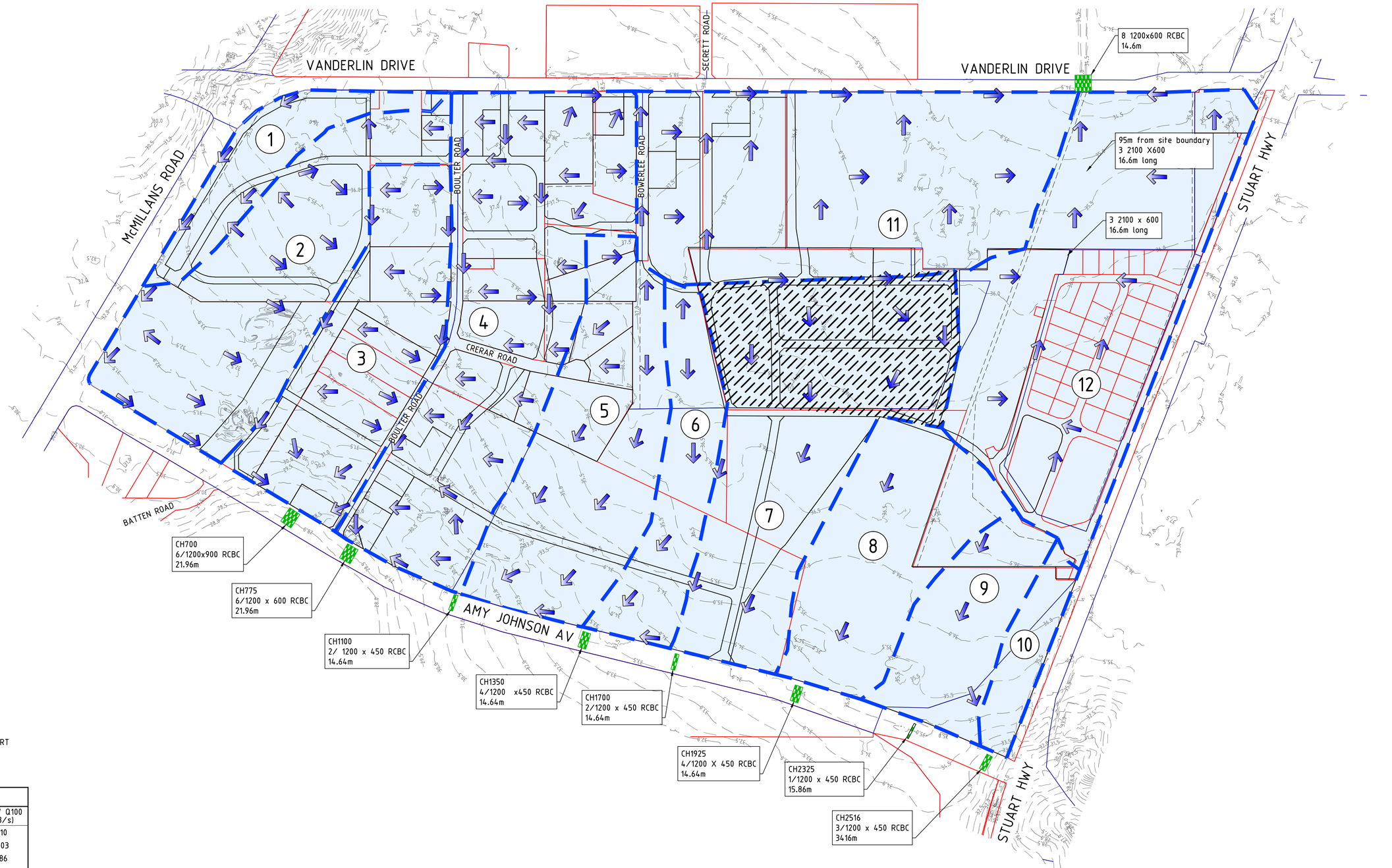
Revision: 02

PLOT DATE: 7/9/2014 10:14 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK30_BULK EARTHWORKS.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix G
# Post Development Catchment Plans

XREFS:




## LEGEND

- EXISTING SURFACE CONTOURS (12.0)
- EXISTING LOT BOUNDARY
- (5) CATCHMENT LABEL
- CATCHMENT BOUNDARY
- FLOW PATH
- EXISTING STORM WATER CULVERT
- CHANGE IN DISCHARGE POINT

## CATCHMENT TABLE

| CATCHMENT | AREA (ha) | FRACTION IMPERVIOUS (Fi %) | FLOW Q100 (m3/s) |
|---|---|---|---|
| 1 | 9.072 | 80 | 4.010 |
| 2 | 31.008 | 80 | 10.603 |
| 3 | 24.382 | 80 | 9.286 |
| 4 | 44.419 | 80 | 16.918 |
| 5 | 27.584 | 80 | 7.176 |
| 6 | 12.783 | 80 | 7.797 |
| 7 | 39.210 | 60 | 21.880 |
| 8 | 21.043 | 0 | 9.004 |
| 9 | 12.576 | 0 | 6.402 |
| 10 | 5.205 | 0 | 2.814 |
| 11 | 53.146 | 80 | 26.310 |
| 12 | 42.350 | 80 | 17.189 |

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


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Approved By: MVI
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Drawn By: JD
Scale at A1: 1:5000



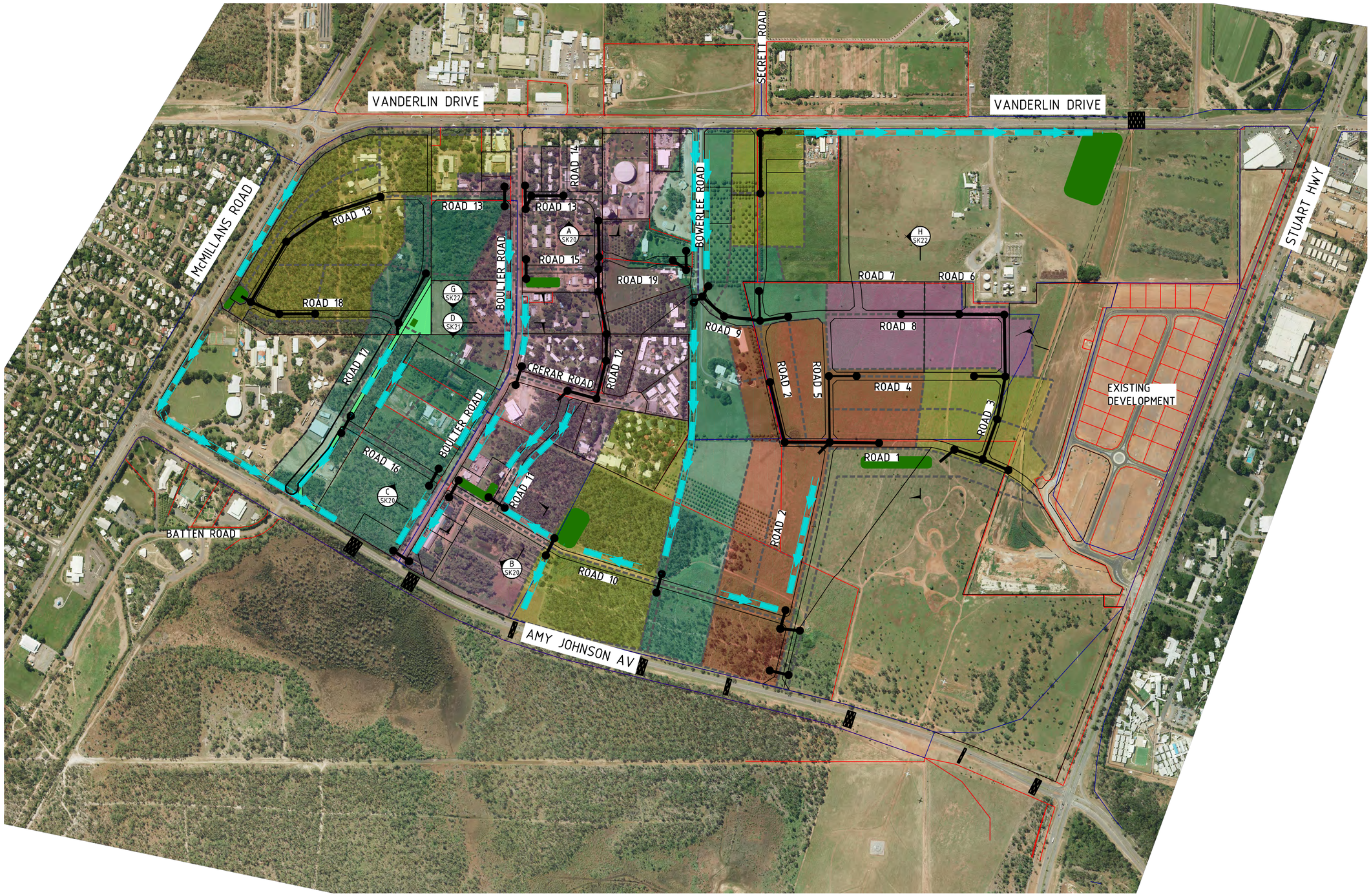
Title: POST DEVELOPMENT CATCHMENTS
Drawing No.: SK12
Revision: 04

PLOT DATE: 7/9/2014 10:10 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK12_POST DEVELOPMENT CATCHMENTS.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix H
# Post Development Schematic Stormwater Network

XREF'S:




## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- PROPOSED DRAINAGE CHANNEL
- PROPOSED DRAINAGE NETWORK
- PROPOSED DETENTION BASIN
- EXISTING CULVERTS
- PROPOSED ROAD NETWORK
- LINEAR PARK/DETENTION AREA

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)

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Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:5000



Title: POST DEVELOPMENT SCHEMATIC UNDER GROUND STORMWATER NETWORK
Drawing No.: SK13
Revision: 04

PLOT DATE: 7/9/2014 10:11 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK13_POST DEVELOPMENT DRAINAGE NETWORK.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

XREF'S:


## LEGEND

- EXISTING SURFACE CONTOURS (12.0)
- PROPOSED DRAINAGE CHANNEL
- PROPOSED DRAINAGE NETWORK
- CREST OF ROAD - (TOP OF CATCHMENT)
- PROPOSED DETENTION BASIN
- EXISTING CULVERTS
- PROPOSED ROAD NETWORK
- PROPOSED CATCHMENTS
- LINEAR PARK/DETENTION AREA
- PROPOSED DISCHARGE POINT
- CC02 CULVERT CROSSING NUMBER

## CATCHMENT TABLE

| CATCHMENT No. | AREA (Ha) |
|---|---|
| 1A | 2.16 |
| 1B | 2.26 |
| 1C | 4.36 |
| 1D | 4.13 |
| 1E | 2.19 |
| 1F | 1.98 |
| 2A | 1.24 |
| 2B | 3.15 |
| 2C | 1.27 |
| 2D | 2.56 |
| 2E | 4.82 |
| 2F | 3.34 |
| 2G | 6.71 |
| SCH | 13.44 |

## SWALE TABLE

| SWALE NO. | LENGTH (m) | DEPTH (m) | BASE WIDTH (m) |
|---|---|---|---|
| 1 | 326 | 0.4 | 1.5 |
| 2 | 900 | 0.4 | 1.5 |
| 3 | 200 | 0.4 | 1.5 |
| 4 | 95 | 0.4 | 1.5 |
| 5 | 275 | 0.4 | 1.5 |

## BASIN TABLE

| BASIN NO. | AREA ($m^2$) | DEPTH (m) |
|---|---|---|
| 1 | 1554 | 0.8 |
| 2 | 205 | 0.9 |

## NOTE:

REFER BERRIMAH NORTH DRAINAGE STUDY 15988 C R001 FOR FURTHER DETAILS AND CALCULATIONS

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| 02 | 08.04.14 | Issued for Information | JD | MVI |
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0 50 100 150m
SCALE 1:2500
AT ORIGINAL SIZE (A1)


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Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:2500

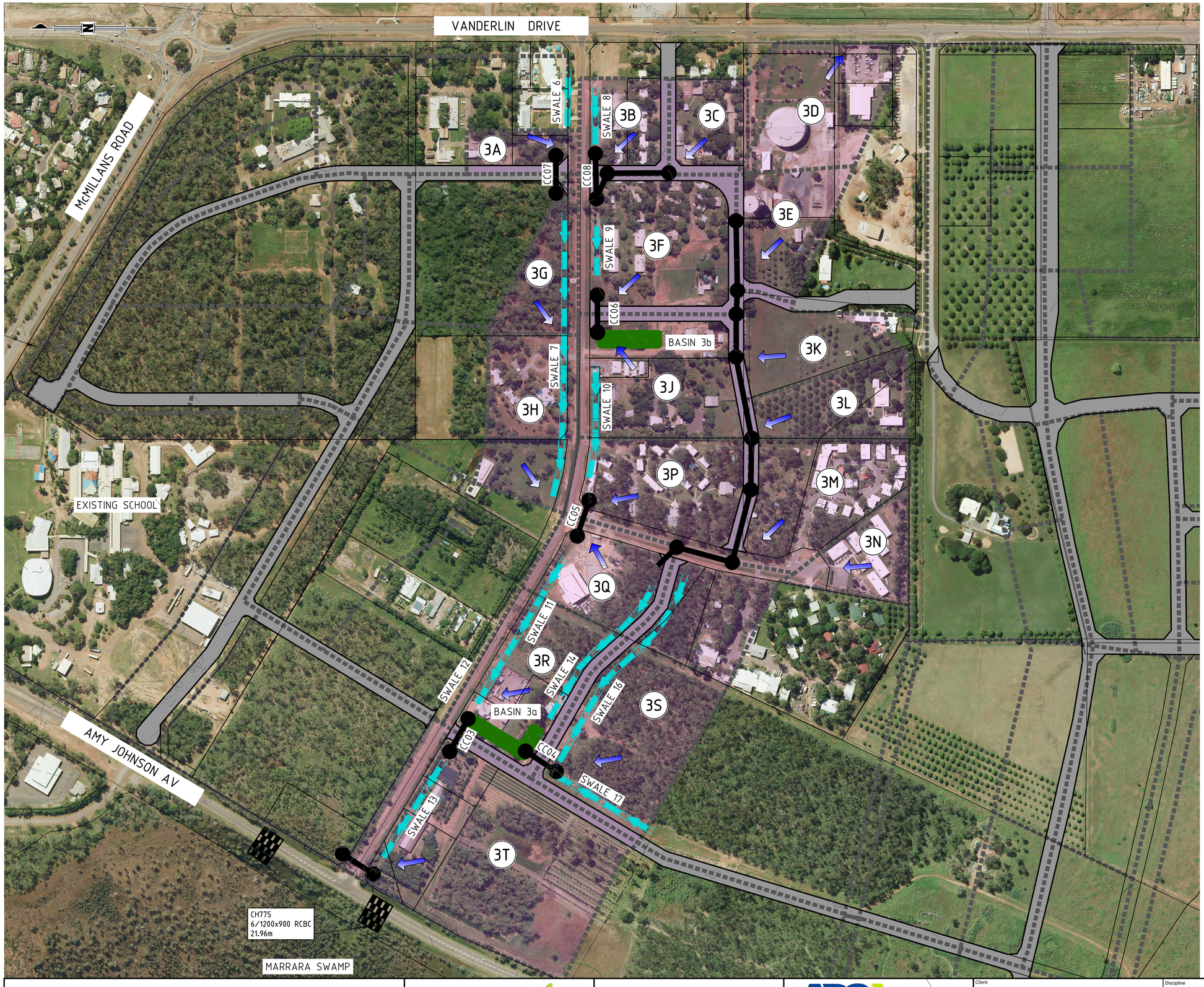


Title: POST DEVELOPMENT CATCHMENT AREA 1 & 2 SHEET 1 OF 4
Drawing No.: SK14
Revision: 04

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm


PLOT DATE: 7/9/2014 10:11 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK14_POST DEVELOPMENT CATCHMENT1 PLAN.DWG

XREF's:




## LEGEND

- EXISTING SURFACE CONTOURS (12.0)
- PROPOSED DRAINAGE CHANNEL
- PROPOSED DRAINAGE NETWORK
- CREST OF ROAD - (TOP OF CATCHMENT)
- PROPOSED DETENTION BASIN
- EXISTING CULVERTS
- PROPOSED ROAD NETWORK
- PROPOSED CATCHMENTS
- PROPOSED DISCHARGE POINT
- CC02 CULVERT CROSSING NUMBER

## NOTE:

REFER BERRIMAH NORTH DRAINAGE STUDY 15988 C R001 FOR FURTHER DETAILS AND CALCULATIONS

## CATCHMENT TABLE

| CATCHMENT No. | AREA (Ha) |
|---|---|
| 3A | 1.15 |
| 3B | 1.48 |
| 3C | 1.45 |
| 3D | 2.49 |
| 3E | 1.89 |
| 3F | 3.86 |
| 3G | 1.39 |
| 3H | 2.61 |
| 3J | 3.49 |
| 3K | 1.83 |
| 3L | 1.82 |
| 3M | 2.92 |
| 3N | 1.33 |
| 3P | 3.12 |
| 3Q | 2.00 |
| 3R | 2.97 |
| 3S | 5.67 |
| 3T | 6.61 |

## SWALE TABLE

| SWALE NO. | LENGTH (m) | DEPTH (m) | BASE WIDTH (m) |
|---|---|---|---|
| 6 | 140 | 0.4 | 1.5 |
| 7 | 400 | 0.4 | 1.5 |
| 8 | 140 | 0.4 | 1.5 |
| 9 | 130 | 0.4 | 1.5 |
| 10 | 200 | 0.4 | 1.5 |
| 11 | 290 | 0.4 | 1.5 |
| 13 | 200 | 0.4 | 1.5 |
| 14 | 300 | 0.4 | 1.5 |
| 16 | 320 | 0.4 | 1.5 |
| 17 | 170 | 0.4 | 1.5 |

## BASIN TABLE

| BASIN NO. | AREA ($m^2$) | DEPTH (m) |
|---|---|---|
| 3a | 2500 | 0.5 |
| 3b | 2000 | 0.5 |

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9 July 2014

PRELIMINARY
NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 04 | 27.05.14 | Issued for Information | JD | MVI |
| 03 | 21.05.14 | Issued for Information | JD | MVI |
| 02 | 08.04.14 | Issued for Information | JD | MVI |
| 01 | 01.04.14 | Issued for Information | JD | KG |

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0 50 100 150m
SCALE 1:2500
AT ORIGINAL SIZE (A1)


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Client: CITY OF DARWIN
Project Name: BERRIMAH NORTH AREA DRAINAGE STUDY
Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1:

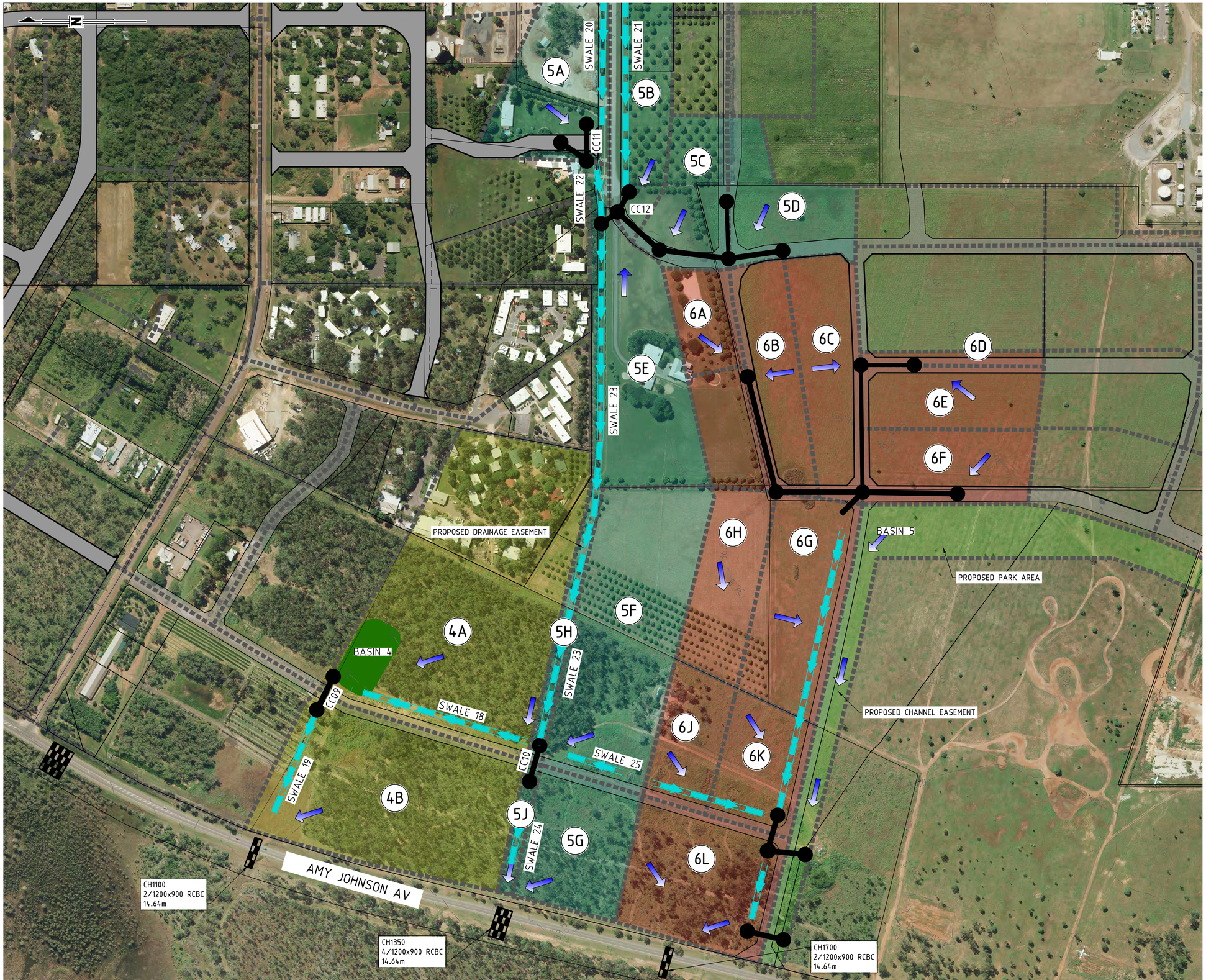


Title: POST DEVELOPMENT CATCHMENT AREA 3 SHEET 2 OF 4
Drawing No.: SK15
Revision: 04

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm


PLOT DATE: 7/9/2014 10:12 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK15_POST DEVELOPMENT CATCHMENT2 PLAN.DWG

XREF'S:




## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- PROPOSED DRAINAGE CHANNEL
- PROPOSED DRAINAGE NETWORK
- CREST OF ROAD – (TOP OF CATCHMENT)
- PROPOSED DETENTION BASIN
- EXISTING CULVERTS
- PROPOSED ROAD NETWORK
- PROPOSED CATCHMENTS
- PROPOSED PARK AREA
- PROPOSED DISCHARGE POINT
- CC02 — CULVERT CROSSING NUMBER

## NOTE:

REFER BERRIMAH NORTH DRAINAGE STUDY 15988 C R001
FOR FURTHER DETAILS AND CALCULATIONS

## CATCHMENT TABLE

| CATCHMENT No. | AREA (Ha) |
|---|---|
| 4A | 9.34 |
| 4B | 6.01 |
| 5A | 3.77 |
| 5B | 3.59 |
| 5C | 1.87 |
| 5E | 4.33 |
| 5F | 5.59 |
| 5G | 2.39 |
| 5H | 0.68 |
| 5J | 0.35 |
| 6A | 2.37 |
| 6B | 2.17 |
| 6C | 2.55 |
| 6D | 0.45 |
| 6E | 1.96 |
| 6F | 2.18 |
| 6G | 2.32 |
| 6H | 2.32 |
| 6J | 1.57 |
| 6K | 1.33 |
| 6L | 1.38 |

## SWALE TABLE

| SWALE NO. | LENGTH (m) | DEPTH (m) | BASE WIDTH (m) |
|---|---|---|---|
| 18 | 260 | 0.4 | 1.5 |
| 19 | 160 | 0.3 | 1.5 |
| 20 | 300 | 0.3 | 1.5 |
| 21 | 390 | 0.3 | 1.5 |
| 22 | 65 | 0.4 | 1.5 |
| 23 | 680 | 0.4 | 1.5 |
| 24 | 140 | 0.4 | 1.5 |
| 25 | 130 | 0.4 | 1.5 |

## BASIN TABLE

| BASIN NO. | AREA ($m^2$) | DEPTH (m) |
|---|---|---|
| 4 | 5106 | 1.0 |

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|---|---|---|---|---|
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| 02 | 08.04.14 | Issued for Information | JD | MVI |
| 01 | 01.04.14 | Issued for Information | JD | KG |

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0 50 100 150m
SCALE 1:2500
AT ORIGINAL SIZE (A1)


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Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:2500



Title: POST DEVELOPMENT CATCHMENT AREA 4, 5 & 6 SHEET 3 OF 4
Drawing No.: SK16
Revision: 03

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

PLOT DATE: 7/9/2014 10:12 AM FILENAME: J:\15000\15988 – BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK16_POST DEVELOPMENT CATCHMENT3 PLAN.DWG

XREF'S:


## LEGEND

- EXISTING SURFACE CONTOURS (12.0)
- PROPOSED DRAINAGE CHANNEL
- PROPOSED DRAINAGE NETWORK
- CREST OF ROAD - (TOP OF CATCHMENT)
- PROPOSED DETENTION BASIN
- EXISTING CULVERTS
- PROPOSED ROAD NETWORK
- PROPOSED CATCHMENTS
- PROPOSED UTILITY AREA
- EXISTING DRAINAGE STORAGE AREA
- EXISTING DEVELOPMENT
- PROPOSED PARK AREA
- PROPOSED DISCHARGE POINT
- CC02 CULVERT CROSSING NUMBER

## NOTE:

REFER BERRIMAH NORTH DRAINAGE STUDY 15988 C R001
FOR FURTHER DETAILS AND CALCULATIONS

## CATCHMENT TABLE

| CATCHMENT No. | AREA (Ha) |
|---|---|
| 7A | 1.15 |
| 7B | 0.97 |
| 7C | 1.54 |
| 7D | 1.82 |
| 8A | 1.95 |
| 8B | 0.91 |
| 8C | 3.39 |
| 8D | 2.85 |
| 8E | 1.03 |
| 9A | 2.20 |
| 9B | 1.36 |
| 9C | 1.76 |
| 9D | 2.14 |

## SWALE TABLE

| SWALE NO. | LENGTH (m) | DEPTH (m) | BASE WIDTH (m) |
|---|---|---|---|
| 26 | 260 | 0.4 | 1.5 |

## BASIN TABLE

| BASIN NO. | AREA ($m^2$) | DEPTH (m) |
|---|---|---|
| 5 | 5290 | 0.4 |
| 6 | 17750 | 0.7 |

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|---|---|---|---|---|
| 03 | 21.05.14 | Issued for Information | JD | MVI |
| 02 | 08.04.14 | Issued for Information | JD | MVI |
| 01 | 01.04.14 | Issued for Information | JD | KG |

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0 50 100 150m
SCALE 1:2500
AT ORIGINAL SIZE (A1)


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|---|---|---|
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| | Project No.: 15988 / Drawn By: JD / Scale at A1: 1:2500 | |



Title: POST DEVELOPMENT CATCHMENT AREA - 7, 8 & 9 SHEET 4 OF 4

Drawing No.: SK17 Revision: 03


PLOT DATE: 7/9/2014 10:12 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK17_POST DEVELOPMENT CATCHMENT4 PLAN.DWG


FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix I
# Post Development Flood Extents

XREFS:

## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT

## FLOOD LEGEND

- 100m TO 3.00m
- 3.00m TO 2.75m
- 2.75m TO 2.50m
- 2.50m TO 2.25m
- 2.25m TO 2.00m
- 2.00m TO 1.75m
- 1.75m TO 1.50m
- 1.50m TO 1.25m
- 1.25m TO 1.00m
- 1.00m TO 0.75m
- 0.75m TO 0.50m
- 0.50m TO 0.25m
- 0.25m TO 0.00m

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| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 03 | 09.07.14 | Issued for Information | JD | MVI |
| 02 | 21.05.14 | Issued for Information | JD | MVI |
| 01 | 08.04.14 | Issued for Information | JD | MVI |

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


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Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: N.T.S.



Title: POST DEVELOPMENT FLOOD EXTENTS
Drawing No.: SK18
Revision: 03

PLOT DATE: 7/9/2014 10:13 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK18_FLOOD EXTENTS (POST).DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix J
# Inflow Locations form XP-STORM

XREFS:

## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT
- Catch 7 — CATCHMENT INFLOW LOCATION

## NOTES:

REFER DRAWING SK02 FOR CATCHMENT TABLE


PRELIMINARY

NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 01 | 21.05.14 | Issued for Information | JD | MVI |

PLOT DATE: 7/9/2014 10:09 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK05_PRE DEV INFLOW.DWG

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0 100 200 300m

SCALE 1:5000

AT ORIGINAL SIZE (A1)


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| Project Name: BERRIMAH NORTH AREA DRAINAGE STUDY | Designed By: NB / Checked By: MVI / Approved By: MVI | |
| | Project No.: 15988 / Drawn By: JD / Scale at A1: 1:5000 | |

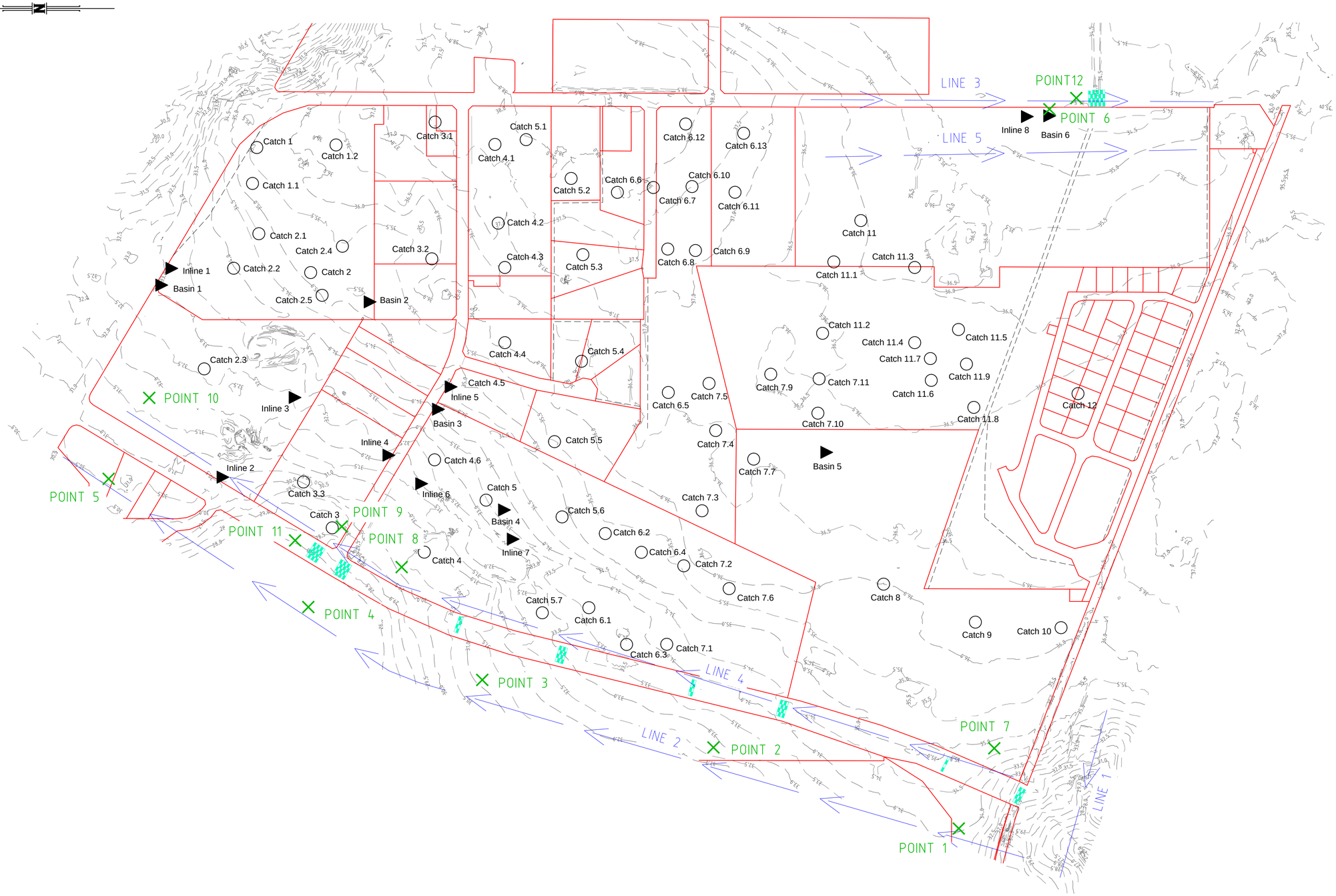


Title: PRE DEVELOPMENT INFLOW LOCATIONS

Drawing No.: SK05 Revision: 01

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

XREFS:




## LEGEND

- EXISTING SURFACE CONTOURS (12.0)
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT
- Catch 7 — CATCHMENT INFLOW LOCATION
- Inline 8 / Basin 6 — BASIN/INLINE LOCATION
- EXISTING FLOW LINE
- EXISTING POINT OF INTREST

## NOTES:

REFER DRAWING SK02 FOR CATCHMENT TABLE

PRELIMINARY
NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 02 | 09.07.14 | Issued for Information | JD | MVI |
| 01 | 21.05.14 | Issued for Information | JD | MVI |

SCALE 1:5000
AT ORIGINAL SIZE (A1)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Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:5000



Title: POST DEVELOPMENT INFLOW LOCATIONS
Drawing No.: SK09
Revision: 02

PLOT DATE: 7/9/2014 10:09 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK09_POST DEV INFLOW.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix K
# Proposed Road Network and Typical Sections

XREFS:


## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- PROPOSED ROAD NETWORK
- ROADS CHANGED FROM BERRIMAH NORTH DRAFT AREA PLAN

| NAME | ROAD RESERVE | ROAD WIDTH | DRAINAGE CHANNEL | KERB | DRAINAGE | ROAD LENGTH |
|---|---|---|---|---|---|---|
| 1 | 22m | 11.0m | NA | YES | PIPE NETWORK | 717 |
| 2 | 22m | 11.0m | ch0 - ch.500 | 500 - END | PIPE TO CHANNEL | 800 |
| 3 | 20m | 11.0m | NA | YES | PIPE NETWORK | 380 |
| 4 | 20m | 11.0m | NA | YES | PIPE NETWORK | 446 |
| 5 | 20m | 11.0m | NA | YES | PIPE NETWORK | 960 |
| 6 | 20m | 8.0m | NA | YES | N/A | 80 |
| 7 | 20m | 8.0m | NA | YES | N/A | 80 |
| 8 | 20m | 11.0m | NA | YES | PIPE NETWORK | 625 |
| 9 | 20m | 11.0m | NA | YES | PIPE NETWORK | 210 |
| 10 | 20m | 11.0m | RHS. | LHS. | CULVERT / CHANNEL | 1250 |
| 11 | 20m | 11.0m | BOTH SIDES | NO | CHANNEL | 353 |
| 12 | 20m | 11.0m | NA | YES | PIPE NETWORK | 500 |
| 13 | 20m | 11.0m | NA | YES | PIPE NETWORK | 1047 |
| 14 | 20m | 8.0m | NA | YES | PIPE NETWORK | 170 |
| 15 | 20m | 8.0m | NA | YES | PIPE NETWORK | 192 |
| 16 | 20m | 8.0m | RHS. | LHS. | CULVERT / CHANNEL | 285 |
| 17 | 20m | 11.0m | ch250 - ch.835 | LHS.=250 RHS =ALL | CULVERT / CHANNEL | 620 |
| 18 | 20m | 11.0m | NA | YES | PIPE NETWORK | 380 |
| 19 | 20m | 8.0m | NA | YES | PIPE NETWORK | 225 |

| NAME | ROAD RESERVE | ROAD WIDTH | DRAINAGE CHANNEL | KERB | DRAINAGE | ROAD LENGTH |
|---|---|---|---|---|---|---|
| BOULTER ROAD | 30 | 10 | BOTH SIDES | NO | CHANNEL | 914 |
| BOWERLEE ROAD | 22 | 10 | BOTH SIDES | NO | CHANNEL | 415 |
| CRERAR ROAD | 20 | 10.4 | N/A | YES | PIPE NETWORK | 325 |

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|---|---|---|---|---|
| 04 | 09.07.14 | Issued for Information | JD | MVI |
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| 02 | 06.05.14 | Issued for Information | JD | MVI |
| 01 | 08.04.14 | Issued for Information | JD | MVI |

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0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


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Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:5000



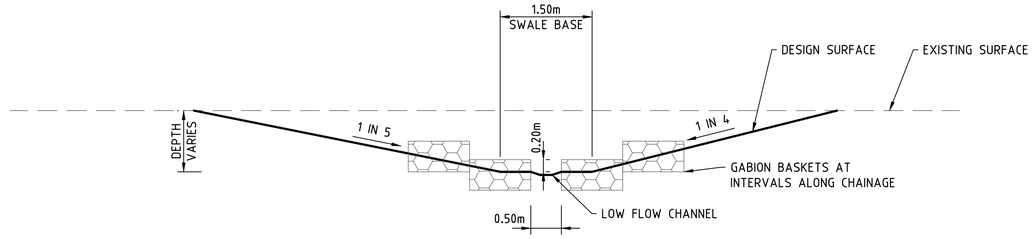
Title: POST DEVELOPMENT
ROAD NETWORK ON AERIAL PHOTO

Drawing No.: SK11
Revision: 04

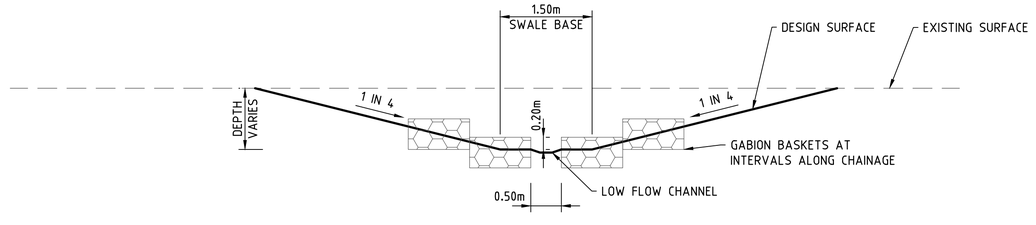
FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

PLOT DATE: 7/9/2014 10:10 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK11_POST DEVELOPMENT ROAD NETWORK ON AERIAL.DWG

XREF's:




TYPICAL SECTION 2
SCALE 1:50




TYPICAL SECTION 1
SCALE 1:50

NOTE:
FOR DARWIN CITY COUNCIL STANDARD ROAD RESERVE TYPICAL SECTIONS REFER DRAWING DDCC-101

**Work in progress**
**For comment only**
**Design team review**
9 July 2014

PRELIMINARY
NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 01 | 21.05.14 | Issued for Information | JD | MVI |

CITY OF DARWIN

0 1 2 3 4 5m
SCALE 1:100
AT ORIGINAL SIZE (A1)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| | Project No.: 15988 / Drawn By: JD / Scale at A1: AS SHOWN | |



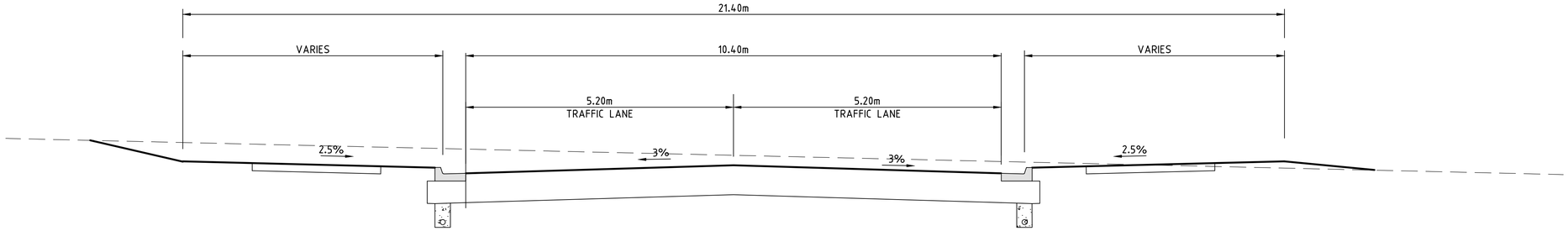
Title: TYPICAL OPEN DRAIN SECTIONS

Drawing No.: SK19
Revision: 01

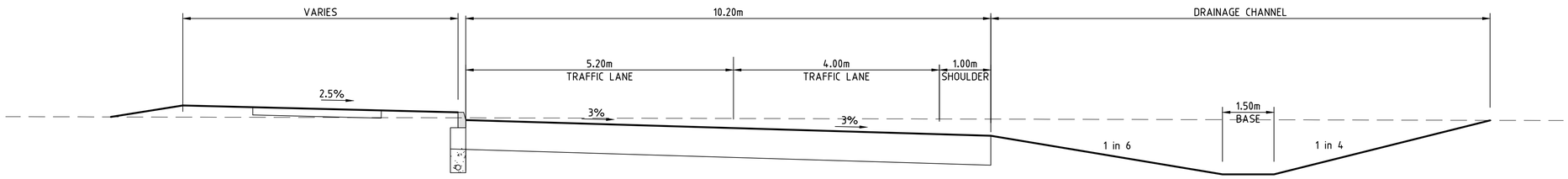

PLOT DATE: 7/9/2014 10:13 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK19_TYPICAL OPEN DRAIN SECTIONS.DWG


FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

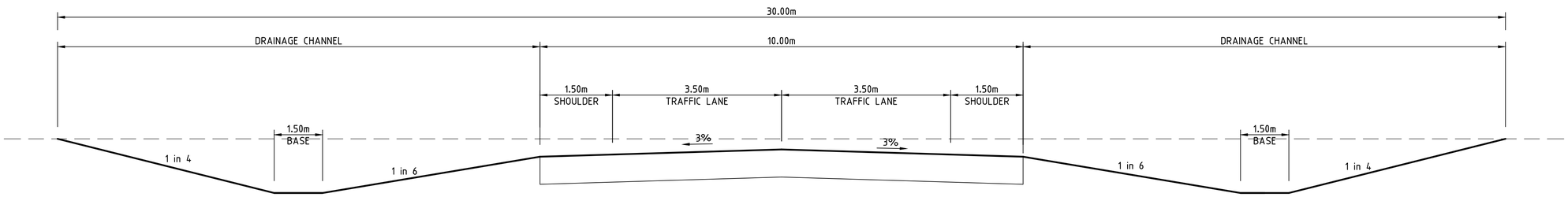
XREFS:




## TYPICAL SECTION A - ROAD
SCALE 1:50




## TYPICAL SECTION B - ROAD WITH DRAINAGE CHANNEL
SCALE 1:50




**NOTE:**
FOR DARWIN CITY COUNCIL STANDARD ROAD RESERVE TYPICAL SECTIONS REFER DRAWING DDCC-101

## TYPICAL SECTION C - ROAD WITH DRAINAGE CHANNEL
SCALE 1:50

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9 July 2014

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| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 02 | 21.05.14 | Issued for Information | JD | MVI |
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0 1 2 3 4 5m
SCALE 1:100
AT ORIGINAL SIZE (A1)


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|---|---|---|---|
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| | Project No.: 15988 | Drawn By: JD | Scale at A1: N.T.S. |



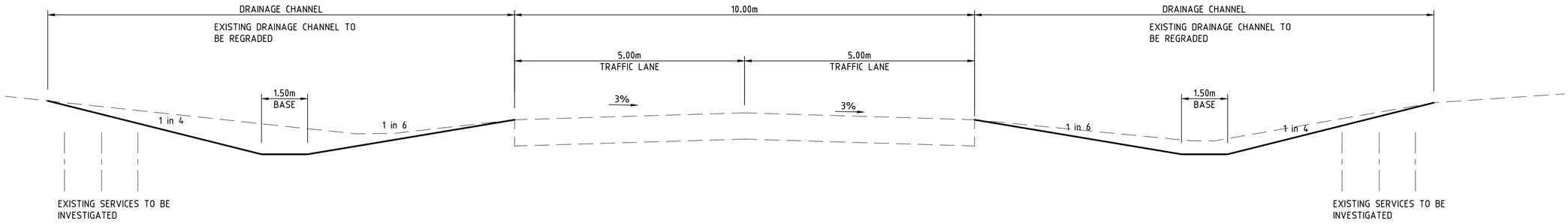
Title: POST DEVELOPMENT TYPICAL SECTIONS SHEET 1 OF 3

Drawing No.: SK20 | Revision: 02


PLOT DATE: 7/9/2014 10:13 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK20 TO 23_TYPICAL SECTIONS.DWG

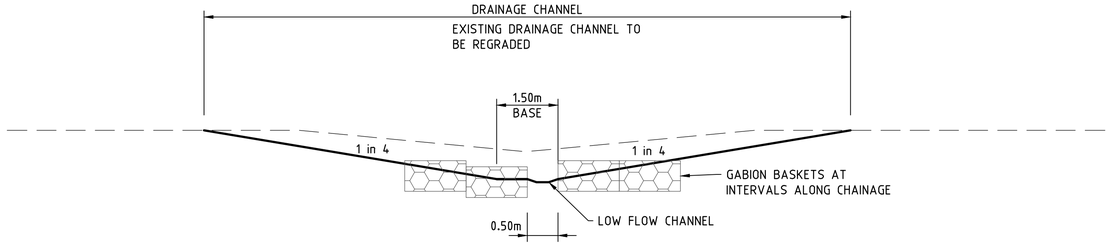

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

XREFS:



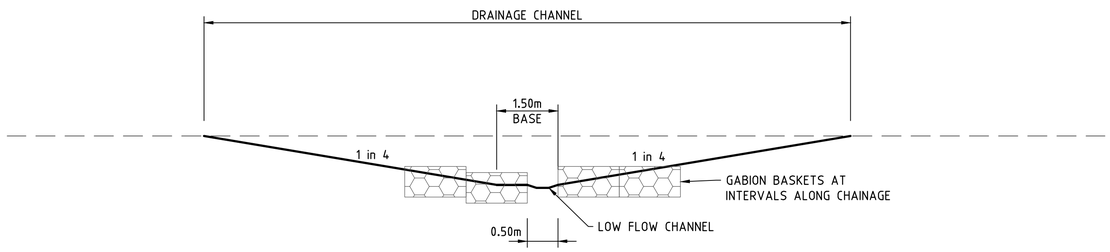

## TYPICAL SECTION D - ROAD WITH EXISTING DRAINAGE CHANNEL

SCALE 1:50




## TYPICAL SECTION E - EXISTING DRAINAGE CHANNEL

SCALE 1:50




## TYPICAL SECTION F - DRAINAGE CHANNEL

SCALE 1:50

**NOTE:**
FOR DARWIN CITY COUNCIL STANDARD ROAD RESERVE TYPICAL SECTIONS REFER DRAWING DDCC-101

**Work in progress**
**For comment only**
**Design team review**
9 July 2014

PRELIMINARY
NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 02 | 21.05.14 | Issued for Information | JD | MVI |
| 01 | 08.04.14 | Issued for Information | JD | MVI |

CITY OF DARWIN

0 1 2 3 4 5m
SCALE 1:100
AT ORIGINAL SIZE (A1)


**Darwin Office**
Suite 4, Level 1, TEM House,
5 Edmunds Street, Darwin, Northern Territory 0800
GPO Box 2422, Darwin, Northern Territory 0801
T 1300 657 402 F +618 8981 9887
E info@adgce.com W www.adgce.com
AUSTRALASIA / ASIA / EUROPE / MIDDLE EAST


Client: CITY OF DARWIN
Project Name: BERRIMAH NORTH AREA DRAINAGE STUDY
Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: N.T.S.

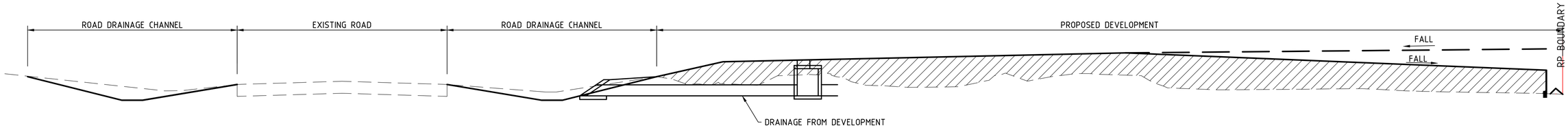


Title: POST DEVELOPMENT TYPICAL SECTIONS SHEET 2 OF 3
Drawing No.: SK21
Revision: 02

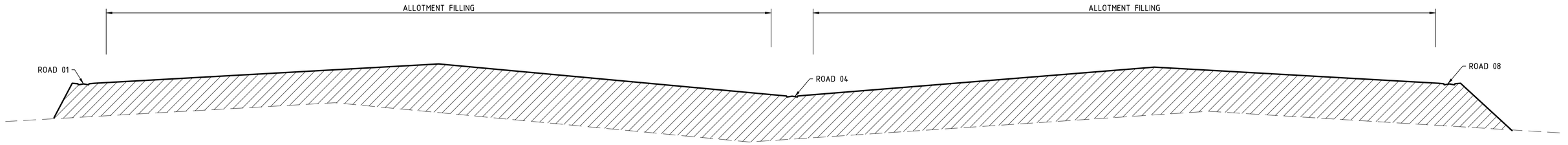
PLOT DATE: 7/9/2014 10:13 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK20 TO 23_TYPICAL SECTIONS.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

XREF's:




TYPICAL SECTION G - EXISTING & ALOTMENT FILL
SCALE 1:100




TYPICAL SECTION H - ALOTMENT FILLING
SCALE NTS

**Work in progress**
**For comment only**
**Design team review**
9 July 2014

PRELIMINARY
NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 02 | 21.05.14 | Issued for Information | JD | MVI |
| 01 | 08.04.14 | Issued for Information | JD | MVI |

CITY OF DARWIN

0 1 2 3 4 5m
SCALE 1:100
AT ORIGINAL SIZE (A1)


**Darwin Office**
Suite 4, Level 1, TEM House,
5 Edmunds Street, Darwin, Northern Territory 0800
GPO Box 2422, Darwin, Northern Territory 0801
T 1300 657 402 F +618 8981 9887
E info@adgce.com W www.adgce.com
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Client: CITY OF DARWIN
Project Name: BERRIMAH NORTH AREA DRAINAGE STUDY
Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: N.T.S.



Title: POST DEVELOPMENT TYPICAL SECTIONS SHEET 3 OF 3
Drawing No.: SK22
Revision: 02

PLOT DATE: 7/9/2014 10:13 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK20 TO 23_TYPICAL SECTIONS.DWG

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

# Appendix L
# Developer Contribution Details

XREF'S:


## LEGEND

- 12.0 — EXISTING SURFACE CONTOURS
- EXISTING LOT BOUNDARY
- EXISTING EASEMENT
- 1 — CATCHMENT LABEL
- DEVELOPER CONTRIBUTION BOUNDARY
- FLOW PATH
- EXISTING STORMWATER CULVERT

**Work in progress**
**For comment only**
9 July 2014

PRELIMINARY
NOT FOR CONSTRUCTION

| Rev | Date | Description | By | Chk |
|---|---|---|---|---|
| 02 | 09.07.14 | Issued for Information | JD | MVI |
| 01 | 21.05.14 | Issued for Information | JD | MVI |

CITY OF DARWIN

0 100 200 300m
SCALE 1:5000
AT ORIGINAL SIZE (A1)


ADG
**Darwin Office**
Suite 4, Level 1, TEM House,
5 Edmunds Street, Darwin, Northern Territory 0800
GPO Box 2422, Darwin, Northern Territory 0801
T 1300 657 402 F +618 8981 9887
E info@adgce.com W www.adgce.com
AUSTRALASIA / ASIA / EUROPE / MIDDLE EAST


Client: CITY OF DARWIN
Project Name: BERRIMAH NORTH AREA DRAINAGE STUDY
Discipline: CIVIL
Status: PRELIMINARY
Designed By: NB
Checked By: MVI
Approved By: MVI
Project No.: 15988
Drawn By: JD
Scale at A1: 1:5000



Title: DEVELOPER CONTRIBUTION AREAS
Drawing No.: SK31
Revision: 02

FULL SIZE ON ORIGINAL 0 10 20 30 40 50 60 70 80 90 100mm

PLOT DATE: 7/9/2014 10:14 AM FILENAME: J:\15000\15988 - BERRIMAH NORTH DRAINAGE STUDY\CIVIL\DWG\15988-SK31_DEVELOPER CONTRIBUTION AREAS.DWG

**SITE:** Berrimah North Area

**Local Authority (COUNCIL):** City of Darwin

| ITEM | DESCRIPTION | UNITS | ESTIMATED RATE ($/unit) | ESTIMATED COST Quantity (Units) | ESTIMATED COST Amount ($) |
|---|---|---|---|---|---|
| | PART A - CIVIL PREPARATION | | | | $451,290 |
| | PART B - EARTHWORKS | | | | $616,896 |
| | PART D - STORMWATER DRAINAGE | | | | $1,811,218 |
| | **Sub Total** | | | | **$2,879,404** |
| | PART J - ALLOWANCES | | | | $547,087 |
| | **Contract Price** | | | | **$3,426,491** |

| | PART A - CIVIL PREPARATION | | | | |
|---|---|---|---|---|---|
| 1 | Site establishment | ha | 970 | 307 | 297,790 |
| 2 | Erosion and Sediment Control Structures (silt fences) | ha | 500 | 307 | 153,500 |
| | **TOTAL PART A - CIVIL PREPARATION** | | | | **$451,290** |

| | PART B - EARTHWORKS | | | | |
|---|---|---|---|---|---|
| 1 | Earthworks | | | | |
| | a) Cut for open drains | $m^3$ | 24 | 25704 | 616,896 |
| | b) Allotment fill (not included - developers cost) | $m^3$ | 0.0 | 0 | 0 |
| | **TOTAL PART B - EARTHWORKS** | | | | **$616,896** |

| | PART D - STORMWATER DRAINAGE | | | | |
|---|---|---|---|---|---|
| 1 | Stormwater pipe drainage (375 - 525) | m | 250 | 3700 | 925,000 |
| 2 | Rock protection (Gabions) | $m^3$ | 260 | 100 | 26,000 |
| 3 | Concrete lining in open drain | $m^3$ | 312 | 81 | 25,272 |
| 4 | Grass treatment in open drains (including topsoil) | m2 | 14 | 9639 | 134,946 |
| 5 | Detention Basin | Item | 100,000.00 | 7 | 700,000 |
| | **TOTAL PART D - STORMWATER DRAINAGE** | | | | **$1,811,218** |

| | PART J - ALLOWANCES | | | | |
|---|---|---|---|---|---|
| | Allowances for Design and Documentation | Item | 0.04 | 1 | 115,176 |
| | Allowances for Contingency (15%) | item | 0.15 | 1 | 431,911 |
| | **TOTAL PART J - ALLOWANCES** | | | | **$547,087** |

**Brisbane**
584 Milton Road, Cnr Sylvan Rd
Toowong, QLD 4066
PO Box 1492
Toowong BC, QLD 4066
**Phone:** +61 07 3300 8800
**Fax:** +61 07 3871 2266
**Email:** bris@adgce.com

**Darwin**
Suite 4, Lvl 1, 5 Edmunds Street
Darwin, NT 0800
GPO Box 2422
Darwin, NT 0801
**Phone:** +61 08 8944 6300
**Fax:** +61 08 8981 9887
**Email:** info@adgce.com

**Sunshine Coast**
Level 3, 2 Emporio Place
Maroochydore QLD 4558
PO Box 5014
Maroochydore BC, QLD 4558
**Phone:** +61 07 5444 0400
**Fax:** +61 07 5444 0536
**Email:** info@adgce.com

**Gold Coast**
Suite 201, Lvl 1, 1 Short Street
Southport, QLD 4215
PO Box 208
Southport, QLD 4215
**Phone:** +61 07 5552 4700
**Fax:** +61 07 5528 4723
**Email:** info@adgce.com

**Melbourne**
22 - 204/218 Dryburgh Street
North Melbourne, Vic 3051
**Phone:** +61 03 9269 6300
**Fax:** +61 03 9328 4599
**Email:** info@adgce.com

**Perth**
51 Forrest Street
Subiaco WA 6008
PO Box 443
Subiaco WA 6904
**Phone**: +61 08 9217 0900
**Email:** info@adgce.com

**Gladstone**
35 Lord Street, Cnr Glenlyon St
Gladstone, QLD 4680
**Phone:** +61 07 4972 9455
**Email:** info@adgce.com

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