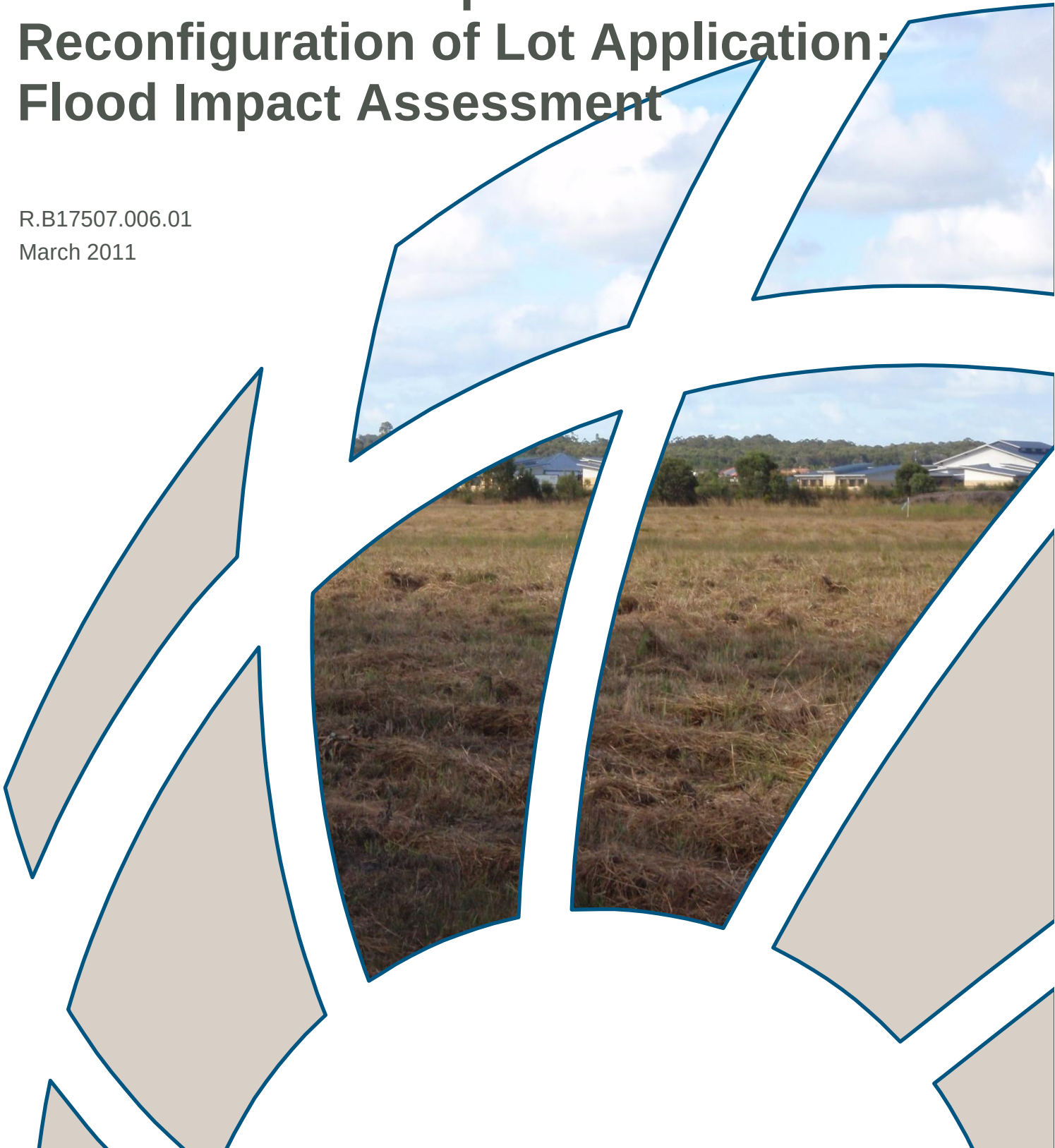


Bellvista II Development Reconfiguration of Lot Application: Flood Impact Assessment

R.B17507.006.01

March 2011



Bellvista II Reconfiguration of Lot Application: Flood Impact Assessment

Prepared For: Stockland

Prepared By: BMT WBM Pty Ltd (Member of the BMT group of companies)

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Title :	Bellvista II Reconfiguration of Lot Application: Flood Impact Assessment
Author :	Joris Jörissen, Philip Pedruco
Synopsis :	This report describes the flood impact assessment undertaken for the proposed 'Bellvista II' development in Caloundra.

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EXECUTIVE SUMMARY

Stockland proposes to develop a 65.5 ha area of land within the Sunshine Coast Regional Council area. The proposed development site is located to the south west of Caloundra town centre and is situated on part of allotment number 22 of RP904298 and part of allotment number 202 of RP190373. This site is within the Urban Development Area (UDA) as declared by the Urban Land Development Area (ULDA) and an Interim Land Use Plan (ILUP) issued by ULDA.

This assessment was prepared to accompany a Development Permit for Reconfiguring a Lot application for the proposed development.

The proposed 'Bellvista II' development consists of commercial, residential, open space, drainage reserves and conservation areas. The proposed layout of the Bellvista II development is enclosed in Appendix A.

BMT WBM was commissioned by Stockland to undertake a Flood Impact Assessment for the proposed Bellvista II development. The Flood Impact Assessment is a progression of the Flood Risk Management Strategy previously prepared by BMT WBM and seeks to address, in greater detail, flooding concerns associated with development of the site.

Hydrological and hydraulic modelling

Hydrological and hydraulic modelling was undertaken to define the flooding conditions of the site under the existing and post-development conditions. In order to derive inflows for a range of storm events and conditions, two hydrologic models were developed using RAFTS-XP software; a regional model covering the entire Bells Creek, Halls Creek, Lamerough Creek and Duck Holes Creek catchments, and a refined local hydrological model of the proposed development site and adjacent areas.

A 1D/2D TUFLOW hydraulic model of the Lamerough Creek floodplain and upstream urban subcatchments was developed to investigate the pre- and post-development flood conditions. Boundary conditions for this Bellvista II TUFLOW model were extracted from a Regional TUFLOW model of the Bells Creek, Halls Creek and Lamerough Creek catchments, which was developed for preliminary investigations in association the Caloundra Downs development project and based on a MIKE-FLOOD model that was established as part of the Caloundra South Flood Study (SKM, 2006). The performance of the Bellvista II TUFLOW model was verified against the Caloundra South Flood Study MIKE-FLOOD model (SKM, 2006). The model shows a good overall consistency in peak modelled flood levels across the Lamerough Creek floodplain.

Flood Characteristics of Existing Site

The hydrological and hydraulic models were used to analyse the flood characteristics of the existing site. The flood characteristics of the site were analysed by simulating the 1, 3, 6 and 12 hour design storm events.

Based on the flooding assessment of the existing site, the following is noted:

- Parts of the proposed urban areas are inundated by the 100 year ARI design flood event. The inundation is primarily caused by uncontrolled stormwater runoff from the various stormwater drains and pipes that enter the site at the northern boundary of the site
- The general flooding pattern on site is characterised by diffuse overland flows with shallow flood depths and moderate peak flow velocities. The maximum inundation depth for the 100 year ARI event is generally less than 0.25m across most of the proposed urban footprint. Around the proposed central channel (proposed drainage corridor between Precinct 1 and 2) flood depths are generally deeper, typically between 0.5 to 1.0m throughout this area.
- The southern part of the site and the adjacent wetland areas directly to the south and southeast of the site flood extensively and store relatively large volumes of flood water during major events. The peak flood depth throughout this area is typically about 1m during the 100 year ARI event. Flood water is mostly slow flowing in these areas with flow velocities generally less than 0.2 m/s

Flood Impact Assessment

The hydrological and hydraulic models were used to assess flood impacts for the 3 month, 1, 5, 50 and 100 year ARI design flood events. As the development site is potentially affected by two sources of flooding (regional flooding from Lamerough Creek and local flooding from the subcatchments to the north of the site), a range of storm durations were assessed for this study, namely the 1, 3, 6 and 12 hour events. For a detailed description of the Flood Impact Assessment undertaken, reference should be made to Section 6 of this report.

Based on the Flood Impact Assessment undertaken, the following can be concluded regarding the flood impacts associated with the proposed development:

- The proposed development will have no significant impact on peak flood levels on the Lamerough Creek floodplain. Upstream and downstream of the property boundary, peak flood levels will not increase by more than 10mm for flood events between the 3 month and the 100 year ARI design flood events with the exception of a one small area during the 50 and 100 year ARI events.
- Immediately to the north of the proposed development, localised flood level impacts are predicted to occur on the open space reserve that is located between Bellvista Boulevard and the Unity College. These flood level impacts will however be confined to the reserve only (no significant flood level impacts are predicted upstream of the open space reserve). Due to the absence of development on the affected land, there will be no impact on existing properties.
- Due to the proposed drainage system of the Bellvista II development, drainage of parts of the existing Bellvista Estate (i.e. areas around the road corridors of Killbride Court and Rosslare Street) are predicted to improve.
- The proposed development will generally not significantly alter the flood flow patterns on the Lamerough Creek floodplain surrounding the development site. Peak velocities on the mapped wetlands and the PMAV areas on the existing Caloundra Aerodrome site will not significantly change due to the development and remain low (generally less than 0.2m/s). Such low flow velocities are considered not to damage vegetation in the area

- The development does not lead to a loss of floodwater storage capacity of the Lamerough Creek floodplain.

Fill Levels

The urban areas of the proposed development will be filled to a minimum of the modelled 100 year ARI flood levels plus 500mm. To ensure that the proposed development has appropriate flood immunity now and in the future, fill levels of the urban areas will be based on modelled 100 year ARI peak flood levels that incorporate an appropriate allowance for potential impacts of climate change.

To determine design flood levels for the development, a climate change impact assessment was undertaken (refer to Section 7) and flood levels were derived based on recommended climate change allowances for the year 2100. The assessment accounted for a possible increase in extreme rainfall intensity, global and regional sea level rise, and changes to storm occurrences and storm intensities (storm surge). The adopted climate allowances are:

- Extreme rainfall intensity/depth increase of +15%
- Mean sea level rise of 0.80m
- Increase in design storm tide levels of 0.95m

State Planning Policy 1/03 Specific Outcomes

Table D-1 in Appendix D describes how the proposed development addresses Specific Outcomes of State Planning Policy 1/03.

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1 INTRODUCTION

1.1 Background & Project Description

Stockland proposes to develop a 65.5 ha area of land within the Sunshine Coast Regional Council area. The proposed development site is located to the south west of Caloundra town centre and is situated on part of allotment number 22 of RP904298 and part of allotment number 202 of RP190373. The site is identified under the *SEQ Regional Plan* as being contained within the Urban Footprint. Minor parts of the proposed urban footprint are located within Flood Management Overlay areas as shown on SCRC's Planning Overlay Map (refer to Map CSP2 of Caloundra City Plan 2004, amended on 27 July 2007).

This assessment was prepared to accompany a Development Permit for Reconfiguring a Lot (ROL) application for the proposed development and has been prepared in accordance with SCRC's *Caloundra City Plan 2004*. Specifically this revision of the report and associated modelling has incorporated the revised ground model, hydrological model and drainage strategy completed by Brown Consulting for the site.

BMT WBM was commissioned by Stockland to undertake a Flood Impact Assessment for the proposed Bellvista II development to address potential flooding issues associated with development of the site.

It is noted that a number of policy papers have been released in draft, namely Draft SEQ Climate Change Management Plan (DIP, 2009), Draft Queensland Coastal Plan (DERM, 2009) and Caloundra South Position Paper (SCRC, 2009). If adopted, the proposed scheme would need to be re-assessed in the context of the policies set out in these papers.

1.2 Site Description

1.2.1 Site Characteristics

The proposed development is located on a part of allotment number 22 of RP904298 and part of allotment number 202 of RP190373. The site lies to the south west of Caloundra town centre and immediately to the south of the existing residential precinct referred to as 'Bellvista I'. The Caloundra Aerodrome bounds the proposed development site along its eastern boundary. The locality of the site is presented in Figure 1-1.

The site lies within the Lamerough Creek catchment; a catchment of approximately 18 km² that drains into Bells Creek and is generally characterised by relatively low terrain grades. Existing land-use varies throughout the catchment. Upstream of the site along Lamerough Creek, the catchment is predominantly forested with some small and medium scale agricultural operations in the upper reaches. Significant urbanisation has occurred in the local catchment to the north of the site. In addition, significant wetlands and PMAV areas occur around the site. The site was previously utilised as a pine plantation and is presently vacant cleared land (See photograph in Figure 1-2).

The site is potentially affected by flooding from 2 sources; Lamerough Creek to the south and west of the site; and stormwater runoff from the local catchments to the north of the site.

Minor parts of the site are affected by flooding of Lamerough Creek, which runs along the southern edge of the proposed development. Around the subject site, this creek has a poorly defined channel with flood flows generally dispersing over a relatively wide, waterlogged area.

The site is also affected by flooding from stormwater runoff from the local upstream catchment. This local catchment covers an area of about 250 ha and includes the existing residential areas to the immediate north of the subject site. Presently the drainage across the site is not formalised and this leads to shallow flooding over part of the site.

1.2.2 Existing Site Topography and Drainage

The existing topography of the site varies from predominantly flat to slightly sloping to the south. The highest elevation is approximately 8mAHD within the north-eastern corner of the site, whilst the lowest point is approximately 1mAHD within the southern low-lying area of the site.

Presently, stormwater runoff from the local upstream catchment drains into the subject site through various stormwater drains and pipes. Although three small drains transverse through the existing site from the Bellvista I development, during significant flood events, most stormwater runoff from the northern catchments exceeds the capacity of these channels and flows through the site as shallow 'sheet' flow.

The existing topography of the site is illustrated in Figure 1-3.

1.2.3 Description of the Proposed Development

The proposed Bellvista II development covers an area of approximately 65.5 hectares. It is proposed that the site will contain a variety of land uses including urban residential, commercial, public open space, drainage reserves and conservation areas. The proposed layout plan of the Bellvista II development is enclosed in Appendix A.

The proposed site topography will vary from the existing situation. Filling of the urban areas of the proposed development (i.e. residential and commercial lots and major roads) is proposed to provide a minimum flood immunity of 1 in 100 years including an appropriate allowance for climate change impacts.

Three major drainage channels are proposed to convey external and internal flows through the site to a number of discharge locations along the perimeter of the site. The discharge locations have been selected to best maintain existing runoff conditions.

The three proposed major drainage channels are:

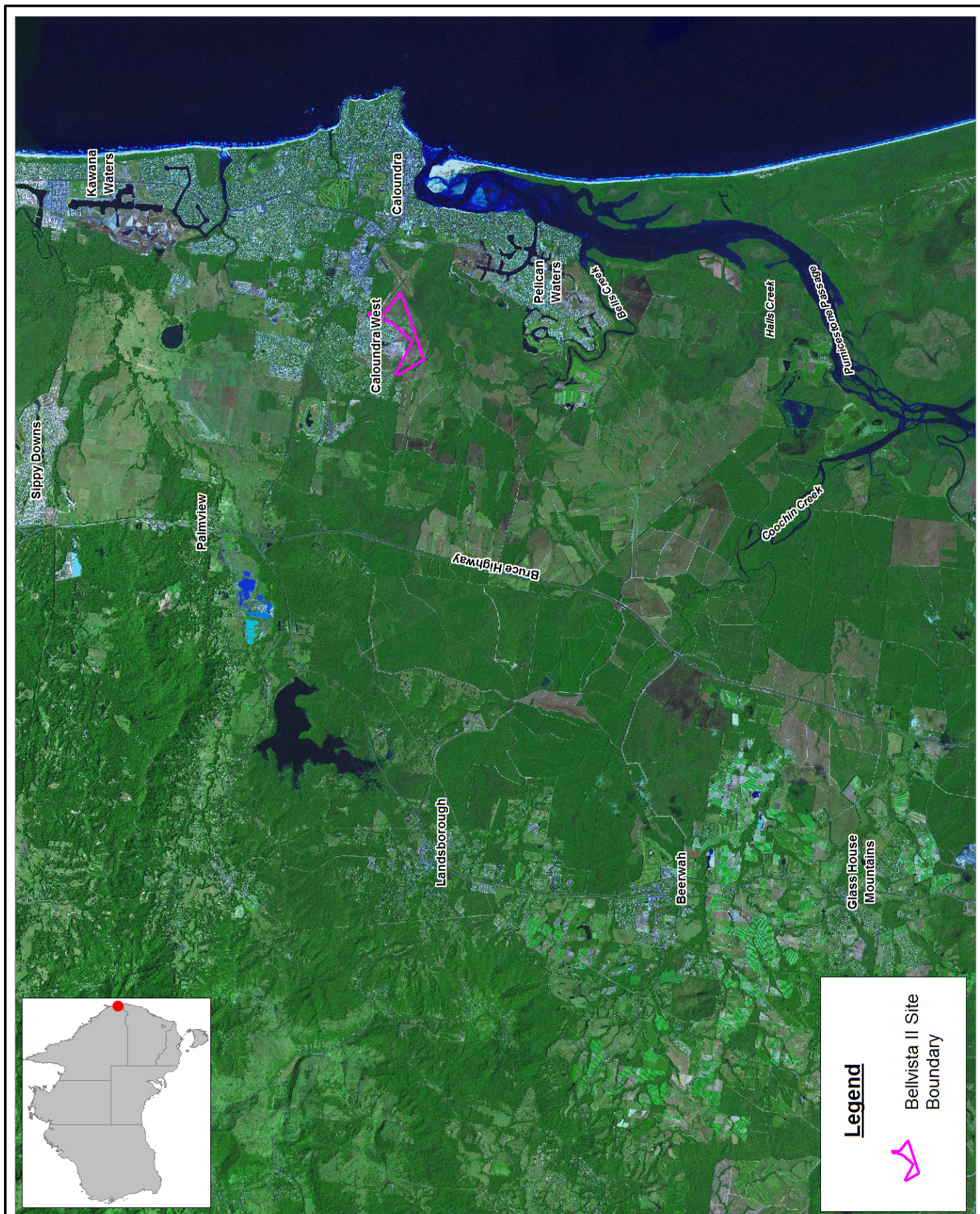
- A drainage corridor adjacent to Bellvista Boulevard (underground pipes with high-flow swale)
- A drainage channel between Precinct 1 and 2; and
- A drainage channel between Precinct 1 and the existing Caloundra Aerodrome site.

Final site surface levels and falls are subject to further design following ROL approval.

1.3 Report Scope

This Flood Impact Assessment assesses the impacts of the proposed Bellvista II urban residential development and recommends flood management measures where appropriate. The objectives of the report are to:

- Define the flooding characteristics of the existing site;
- Assess the flood impacts caused by the proposed development; and
- Determine minimum floor levels for the proposed development



Legend

Bell Vista II Site
Boundary



Title:
Locality Map

Figure:
1-1

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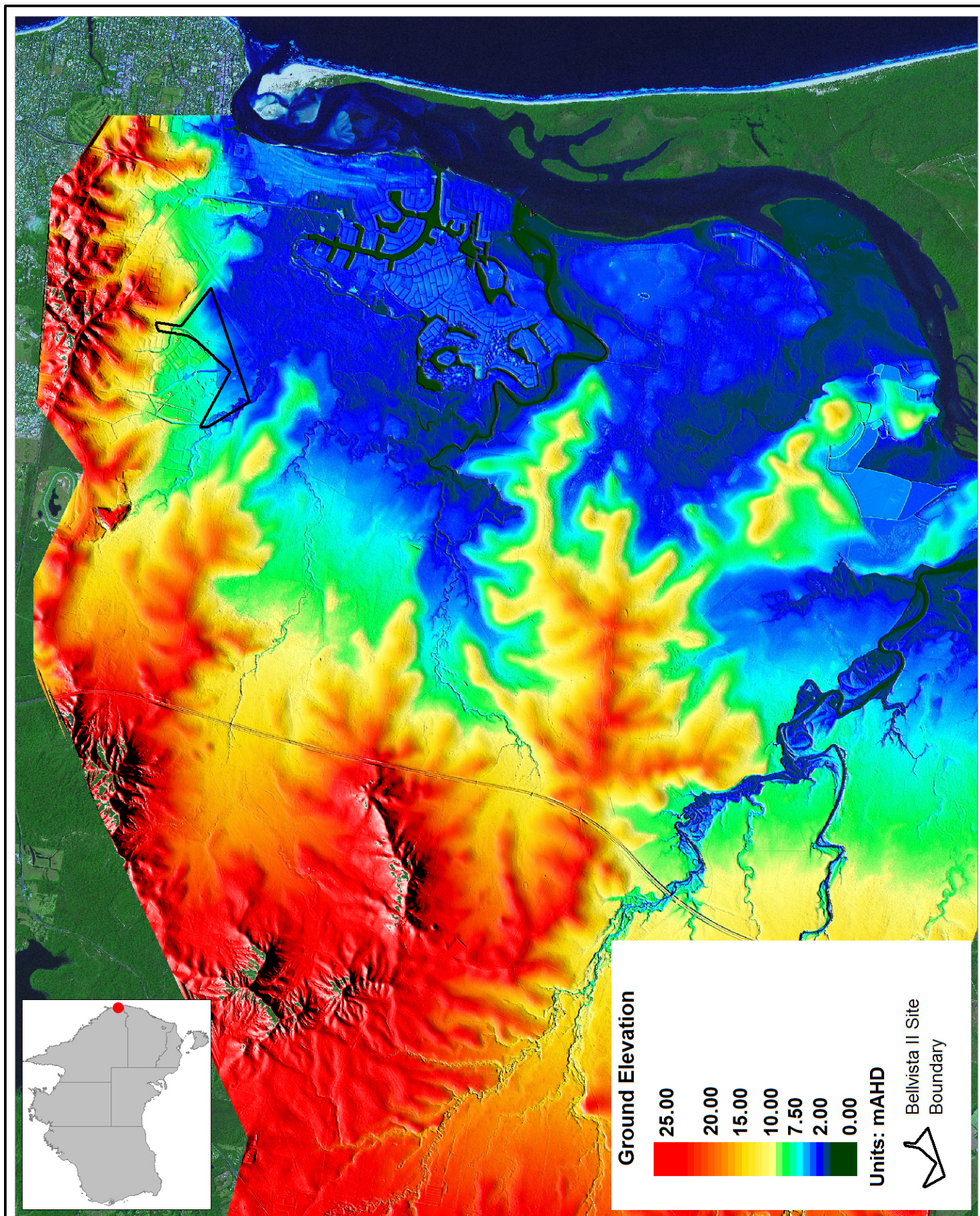
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Figure 1-2 Existing Development Site (cleared of major vegetation)



Title:
Existing Topography of the Caloundra Downs Region

Figure:
1-3

Rev:
A

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Approx. Scale



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2 PREVIOUS STUDIES

A number of flooding investigations of the Bellvista II area have been reviewed for the purpose of this study, including:

- Caloundra South Flood Study – Caloundra Local Growth Management Strategy (SKM, 2006)
- Bellvista II Development: Flood Risk Management Strategy (BMT WBM, 2010)

A summary of these flood studies is provided below.

2.1 Caloundra South Flood Study (SKM, 2006)

The *Caloundra South Flood Study* was carried out in 2006 by SKM. The study, which involved a modelling assessment of the Caloundra South Investigation Area, was undertaken as part of the development of a Local Growth Management Strategy for Caloundra City. The Flood Study used hydrological and hydraulic models to investigate flooding characteristics of seven coastal catchments that discharge into Pumicestone Passage.

The study area of the *Caloundra South Flood Study* included the Lamerough Creek catchment; the catchment in which the Bellvista II site is located.

The hydrological model for the *Caloundra South Flood Study* was developed using the hydrological modelling software RAFTS-XP. The land use delineation (required to define representative catchment roughness and fraction impervious in a hydrological model) were interpreted from aerial photography. The Bellvista II site is located within subcatchment LC06, a catchment area of 298 ha. The reported 100 year ARI peak discharge from this subcatchment is 81 m³/s.

To assess the flooding behaviour of the study area, two hydraulic models were developed as part of the *Caloundra South Flood Study*. The models were developed using the MIKE-FLOOD hydraulic modelling package. The Bellvista II area is included in the northern model. This MIKE-FLOOD model consists of a dynamically linked 1D (MIKE11) / 2D (MIKE21) hydrodynamic model. The MIKE-FLOOD model was forced with inflows derived from the RAFTS-XP model and applied as source point inflows throughout the MIKE-FLOOD model domain.

The *Caloundra South Flood Study* MIKE-FLOOD model has not been calibrated to historical flood events due to the absence of reliable region-specific data.

The ground elevations for the MIKE-FLOOD model were based on a Digital Elevation Model (DEM), which was derived from Airborne Laser Survey (ALS) data and bathymetric surveys of the key waterway channels and cover the entire Bells Creek and Lamerough Creek catchments.

The design flood conditions for three return periods were assessed in the *Caloundra South Flood Study*, namely the 10, 50 and 100 year ARI flood events. The design flood conditions were determined by consideration of a range of freshwater flood events and storm tide events.

Based on Connell Wagner's 2003 and 2005 studies, the Caloundra South Flood Study concluded that storm tide events and freshwater flood events are statistically independent in the Caloundra South area. Consequently, a tidal cycle based on spring tides was adopted for the assessment of

freshwater flood events, and no significant rainfall was applied for the assessment of storm tide inundation. Design storm tide levels in the *Caloundra South Flood Study* were based on levels from the *Caloundra City Storm Tide Study* (Connell Wagner, 2003), with the addition of 200mm for sea level rise.

The study concluded that for Lamerough Creek flood events in the Bellvista region, the critical storm duration (i.e. resulting in the highest peak flood levels) was a 6 hour duration storm event.

2.2 Bellvista II Development: Flood Risk Management Strategy (BMT WBM, 2010)

The Bellvista II Development: Flood Risk Management Strategy (BMT WBM, 2010) was completed on behalf of Stockland to accompany a Material Change of Use (MCU) application for the proposed development and was prepared in accordance with Sunshine Coast Regional Council's *Caloundra City Plan 2004*.

The flows were determined from two hydrologic models created in RAFTS-XP software; a regional model based on the *Caloundra South Flood Study* (SKM, 2006); and a local hydrological model of the proposed development site and adjacent areas (i.e. subcatchments LC04, LC06 and LC07 of the regional model). These flows were applied to a hydraulic model that was developed of the study area and surroundings. Given the complexity of flow in this region it was decided to develop a high-resolution 1D/2D TUFLOW model of the Lamerough Creek floodplain in the vicinity of the site together with upstream urban subcatchments. This model is therefore, capable of simulating the flood flow behaviour resulting from local flooding processes (stormwater runoff) and regional flooding (flooding from Lamerough Creek).

The Bellvista II TUFLOW model was simulated using the same design flood events as modelled in the *Caloundra South Flood Study*. The results of the Bellvista II TUFLOW model were compared with predictions of the *Caloundra South Flood Study* MIKE-FLOOD model (SKM, 2006). It is noted that *Caloundra South Flood Model* is a regional flood model and will only predict flooding due to regional flood events (i.e. due to fluvial and coastal flooding). The overall the results of the Bellvista model showed a high level of consistency in peak modelled levels compared to the regional (Lamerough Creek) flood events, with differences generally within 0.1m.

The Bellvista II flood modelling showed parts of the subject site are inundated by the 100 year ARI design flood event. The inundation was caused by stormwater runoff from the various stormwater drains and pipes from the north of the site and floodwater flows from Lamerough Creek that enter the site from the western and southern boundary. Generally this was diffuse overland flows with shallow flood depths and moderate peak flow velocities. The southern part of the site and the adjacent wetland areas directly to the south and southeast of the site flood extensively and store relatively large volumes of flood water during major events. The peak flood depth throughout this area is typically about 1m during the 100 year ARI event. Flood water is mostly slow flowing in these areas with flow velocities generally less than 0.2 m/s.

In this investigation, all residential, mixed use residential and roads were assumed to be filled to above the 100 year ARI design flood level. Filling will be required to ensure that all urban areas are above the design flood level of the 100 year ARI Lamerough Creek flood events. The recommended

minimum fill levels of the individual residential allotments are 500mm above the 100 year ARI design flood level (include allowances for climate change impacts).

The proposed development is considered unlikely to have significant impacts on the flood behaviour of Lamerough Creek, due to the fact that the hydraulic conveyance of Lamerough Creek will not be significantly affected by the development and the principal flood flow patterns of Lamerough Creek will not be altered.

This report concluded that further analysis will be required to investigate potential flood impacts on these areas and incorporate appropriate mitigation measures into the detailed design. The developed Bellvista II TUFLOW model is a suitable modelling tool to assess these potential flood impacts.

3 HYDROLOGICAL MODELLING ASSESSMENT

3.1 Introduction

In line with the hydrological modelling philosophy presented in the Bellvista II Development: Flood Risk Management Strategy (BMT WBM, 2010), two hydrologic models were constructed using the RAFTS-XP modelling software. The two RAFTS-XP models are;

- a regional model covering the entire Bells Creek, Halls Creek, Lamerough Creek and Duck Holes Creek catchments; and
- a local hydrological model of the proposed development site and adjacent areas (i.e. subcatchments LC04, LC06 and LC07 of the regional model).

These models were used to derive inflow hydrographs for a range of storm events and conditions. This section describes the hydrological modelling undertaken for this study.

3.2 RAFTS-XP Model Layout

3.2.1 Regional Hydrological Model

The regional RAFTS-XP model includes the entire catchments of Bells Creek, Halls Creek, Lamerough Creek and Duck Holes Creek. The catchments have been divided into 30 subcatchments. The regional model was developed based on the RAFTS-XP model developed by SKM for the *Caloundra South Flood Study* (SKM, 2006).

3.2.2 Local Hydrological Model

For the purposes of this assessment, subcatchments LC04, LC06 and LC07 of the regional RAFTS-XP model were further subdivided into 56 subcatchments to develop a local RAFTS-XP hydrological model. The subcatchment delineation was based on an assessment of local topography and delineation of the existing and proposed drainage system as provided by Brown Consulting (Brown Consulting, 2011). The subcatchment boundaries and model layout of the local RAFTS-XP model are presented in Figure 3-1.

3.3 RAFTS-XP Model Set Up

Percent impervious and Manning's 'n' for existing land use types have been adopted from the *Caloundra South Flood Study* (SKM, 2006) and from the Concept Stormwater Management Plan (Brown Consulting, 2011). Percent impervious for developed land use types was based on the Bellvista II layout plan provided by Brown Consulting.

The land use types for the existing and developed local RAFTS-XP models are shown in Figure 3-2 and Figure 3-3 respectively. The pervious Manning's 'n', and impervious and pervious areas for each of the subcatchments in the RAFTS-XP models are detailed in Appendix B.

3.4 Hydrological Design Conditions

3.4.1 Design Rainfall Intensities and Depths

The CRC-Forge method was used to estimate design rainfall intensities for design rainfall events with an average return period between 5 and 100 years. The design rainfall intensities of 1 year ARI design rainfall events, were derived using the AR&R method. CRC-Forge and AR&R design rainfalls were compared in the *Caloundra South Flood Study* (SKM, 2006) and the CRC-Forge method was found to result in slightly higher design rainfall depths.

To be conservative, no areal reduction was adopted for the purposes of this assessment (i.e. an areal reduction factor of 1 was adopted). The design rainfall intensities used in the study are presented in Table 3-1 and design rainfall depths in Table 3-2.

Table 3-1 CRC-Forge Design Rainfall Intensities (mm/hr)

Event Duration	Average Recurrence Interval (years)			
	5	10	50	100
30 min	93.3	104.0	138.0	158.0
1 hour	64.4	72.0	95.9	109.9
3 hours	33.0	37.7	52.1	59.7
6 hours	21.5	24.9	35.2	40.3
12 hours	14.0	16.4	23.8	27.3

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CRC_FORGE_Rainfall_Intensities

Table 3-2 CRC-Forge Design Rainfall Depths (mm)

Event Duration	Average Recurrence Interval (years)			
	5	10	50	100
30 min	46.7	52.0	69.0	79.0
1 hour	64.4	72.0	95.9	109.9
3 hours	99.0	113.0	156.4	179.1
6 hours	128.9	149.1	211.3	242.0
12 hours	168.1	197.0	286.1	327.6

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Table.xls\CRC_FORGE_Rainfall_Intensities

3.4.2 Design Temporal Rainfall Pattern

Design temporal rainfall patterns from AR&R Zone 3 were adopted for the purposes of this assessment.

3.4.3 Runoff Losses

The initial and continuing losses for the hydrologic model from the *Caloundra South Flood Study* (SKM, 2001) were adopted. These are presented in Table 3-3.

Table 3-3 Runoff Losses

Catchment Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	10	5
Impervious	0	0

3.4.4 Hydrograph Lag

Routing between catchments, or hydrograph lag, was determined by assuming that flow velocities were 1m/s and calculating the reach length between subareas. However, hydrograph lag only affected those subareas external to the hydraulic model domain as all internal, or local, hydrographs were applied directly to the model without any routing.

3.4.5 Potential Hydrological Impacts of Climate Change

To assess the potential impacts of climate change on the runoff characteristics of the Bells Creek, Halls Creek, Lamerough Creek and Duck Holes Creek catchments, a climate change assessment was undertaken (refer to Section 7). Based on this climate change assessment, an increase in event rainfall intensities of 15% was adopted as an allowance for potential climate change impacts.

3.5 Proposed Works Affecting Runoff Behaviour

The proposed development includes changes to the characteristics of the catchment. The site is currently undeveloped. The development of the catchment will increase impervious surfaces, increased connectivity watercourses through the introduction of formal drainage and reduce catchment 'roughness' (i.e. decrease Manning's 'n') with the addition of roads, houses and other development features. These changes tend to increase peak runoff rates. The developed land use types are presented in Figure 3-3.

The pervious Manning's 'n', and impervious and pervious areas, for each of the subcatchments in the local RAFTS-XP model are detailed in Appendix B. Due to the development, the total impervious area on the Bellvista II site will increase from zero to approximately 31.7 hectares.

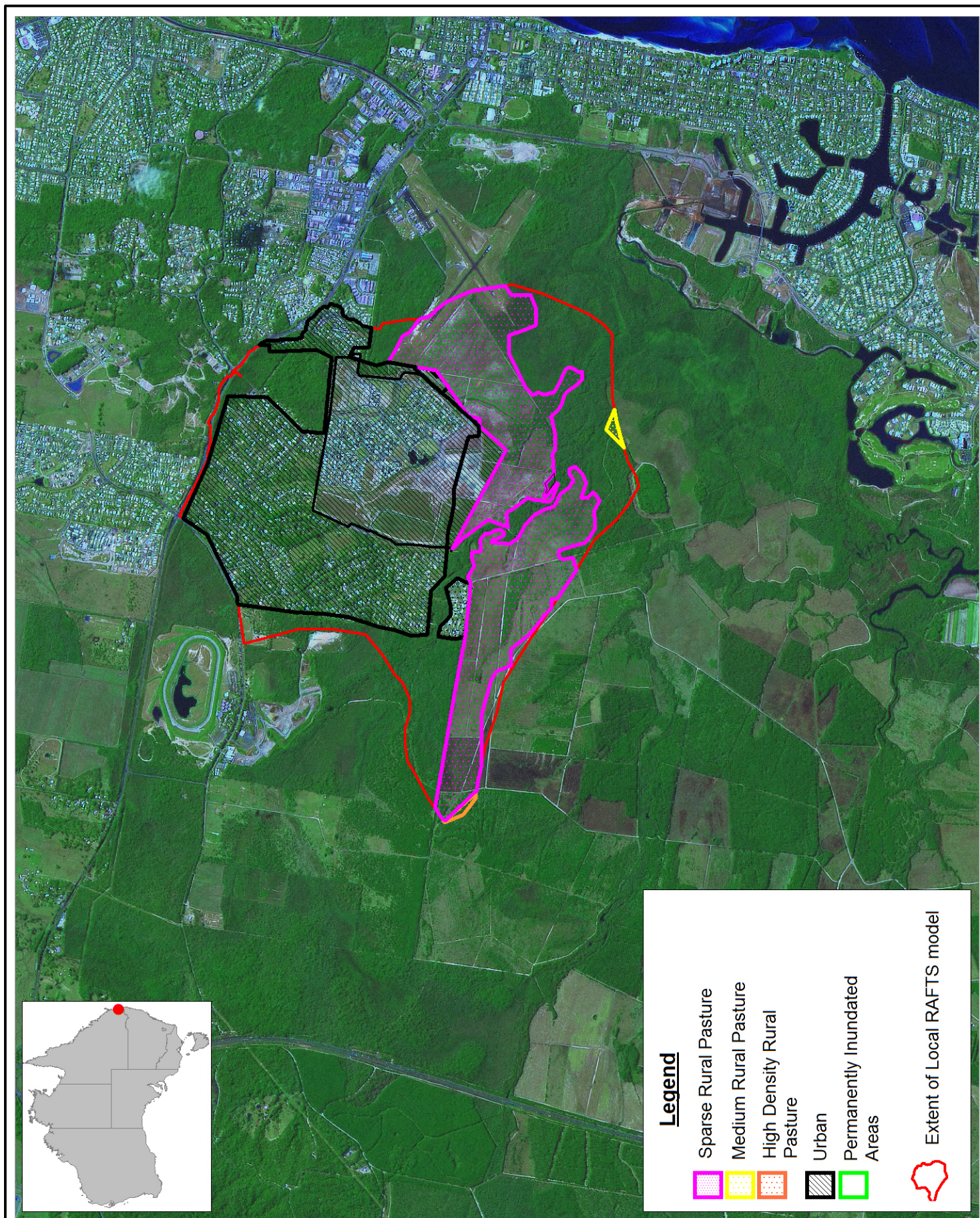
3.6 Hydrological Modelling Results

The relatively flat nature of the site means that runoff in the existing case is comparatively slow to respond. The increase in impervious area, introduction of drainage infrastructure and reduced Manning's 'n' in the developed case mean that the affected subcatchments are faster to respond to rainfall. This can be seen in the existing and post-development runoff hydrographs shown in Figure 3-4 for subcatchment LC6_7_2_b_1; which is located in Precinct 1 (refer to Figure 3-1 for the location).

Peak flows at each subcatchment for the 1, 5, 50 and 100 year ARI events (existing and developed case) are provided in Table C-1 to Table C-3 in Appendix C. The Q100 peak flows for the climate change scenario are compared with present-day Q100 peak flows in Table C-4 in Appendix C.

3.6.1 Critical Storm Duration

For the Lamerough Creek floodplain, the 6 hour and 12 hour storm event were found to be critical (i.e. resulting in the highest peak flood flows) for the 100 year ARI event; whereas for the local subcatchments entering the site, the critical duration was found to vary between the 1 hour and 3 hour storm event.

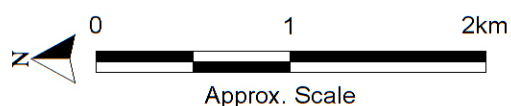


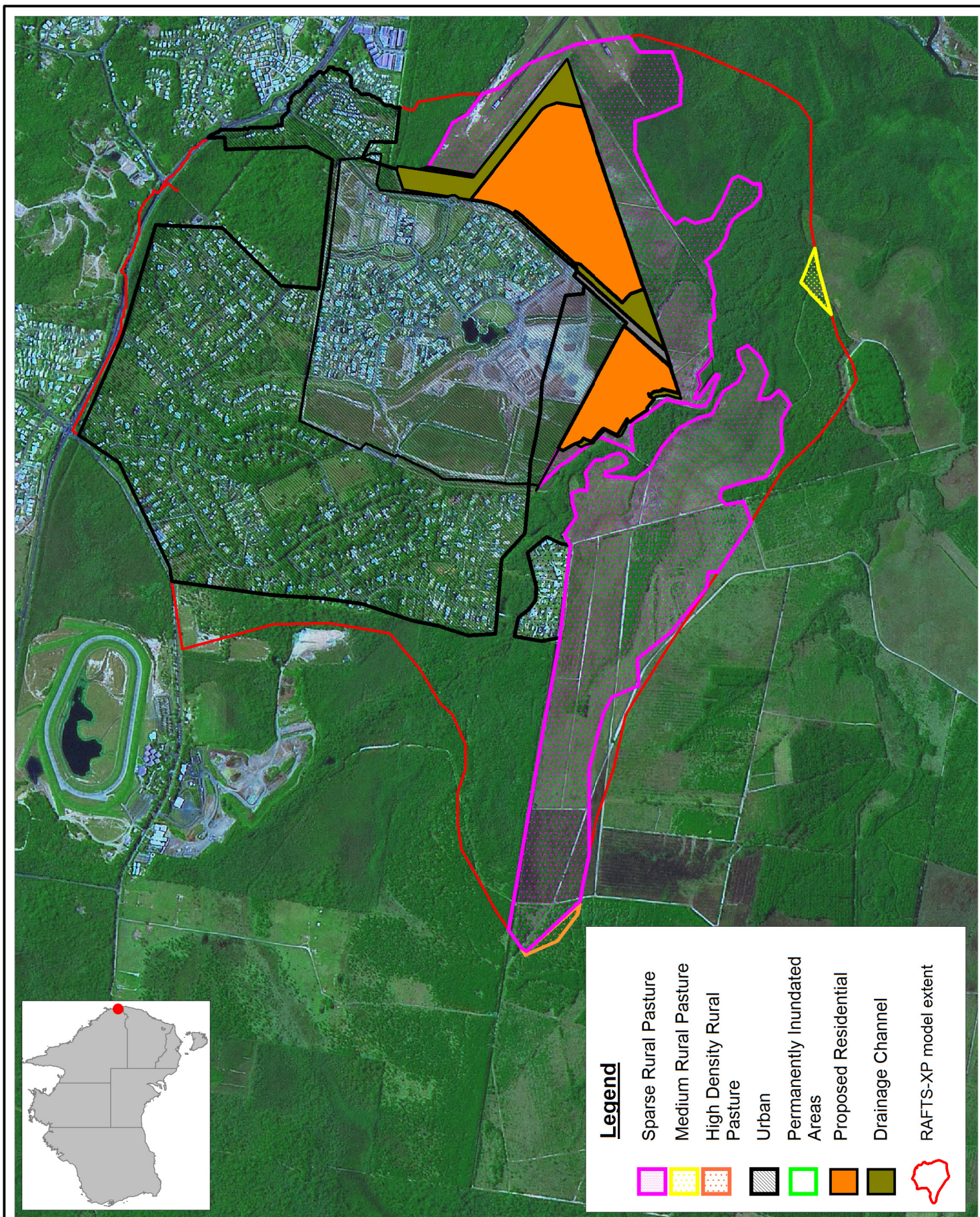
Title:
Land Use Deliniation for Base Case Model

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Title:
Land Use Deliniation for Developed Case Model

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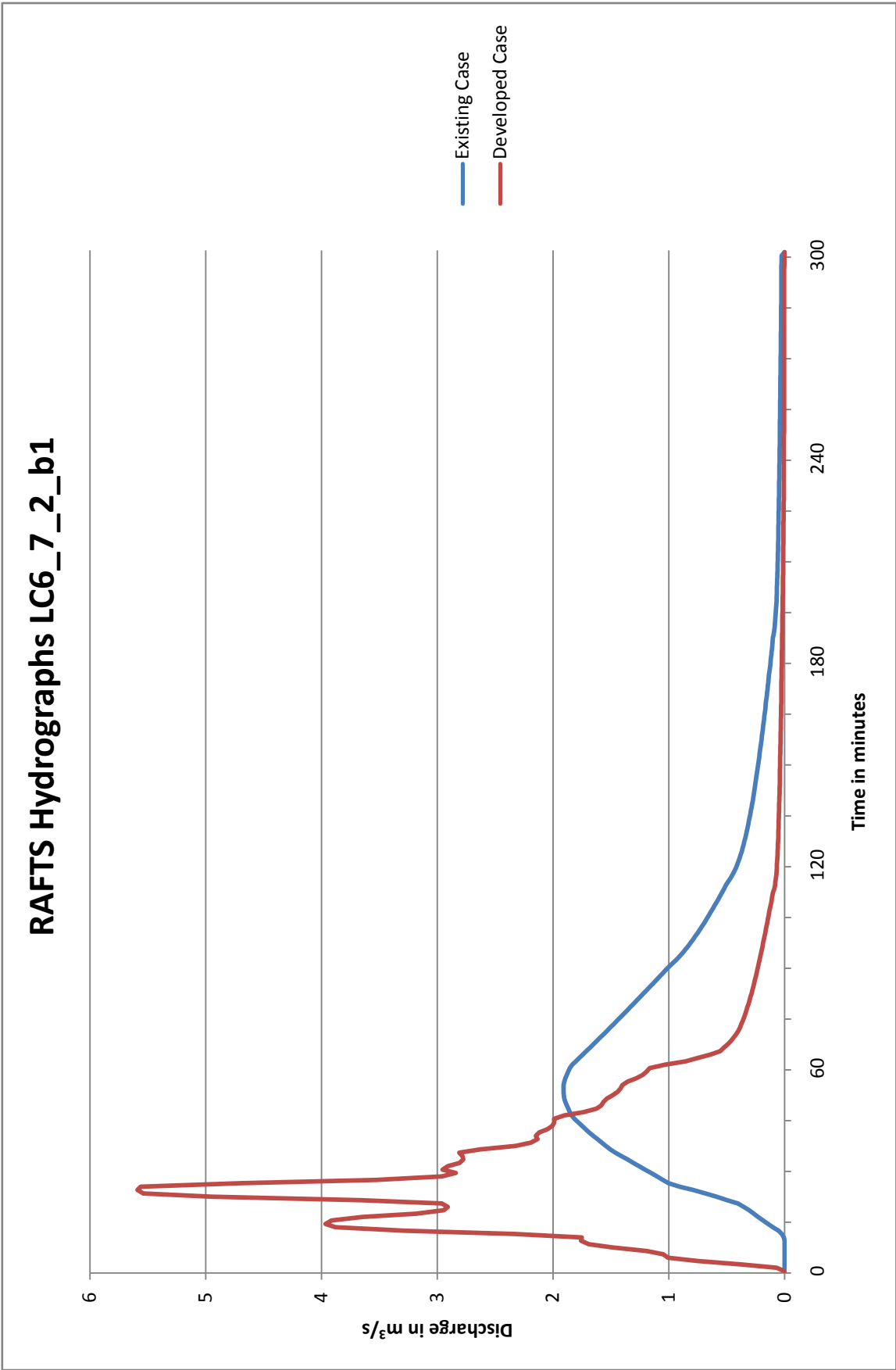


Figure 3-4 Modelled RAFTS-XP Flow Hydrographs at Subcatchment LC6_7_2_b1 for 100 year ARI, 1 Hour Design Storm Event

4 HYDRAULIC MODEL DEVELOPMENT

4.1 Introduction

In order to define the flood risk on the Bellvista II site and assess the potential impacts of the proposed development, a hydraulic model was developed of the study area and surroundings. Given the complexity of flow in this region it was decided to establish a high-resolution 1D/2D TUFLOW model of the Lamerough Creek floodplain and upstream urban subcatchments in the vicinity of the proposed development site.

Two TUFLOW models were developed; a Regional TUFLOW model and the Bellvista II TUFLOW model. The purpose of the Regional TUFLOW model was to extract boundary conditions for the Bellvista II hydraulic model. The Regional TUFLOW model, which was developed for preliminary investigations in association the Caloundra Downs development project, is based on Council's MIKE-FLOOD model produced by SKM as part of the *Caloundra South Flood Study* (SKM, 2006). The Regional TUFLOW model includes the catchments of the Bells Creek, Halls Creek and Lamerough Creek.

The Bellvista II TUFLOW model incorporated details of the local catchment including the existing urban areas to the immediate north.

4.2 Model Area

The model area of the Bellvista II TUFLOW model covers the Lamerough Creek floodplain from upstream of Koala Court (approximately 1 km north-west of the site boundary) down towards Pelican Waters (approximately 1.5 km south-east of the site boundary), as well as the existing Bellvista development to the north which drains into the Bellvista II site. The extent of the Bellvista II TUFLOW model is shown in Figure 4-1.

The floodplain area and Lamerough Creek have been represented within a 2D model domain, which covers an area of approximately 7.6 km² and is based on a 5m by 5m square grid. Each square grid element contains information on ground topography (sampled from a DEM), surface resistance to flow (Manning's 'n' roughness coefficient) and initial water level.

To more accurately represent flows in the three channels draining into the Bellvista II site (from the central lake and along the western and eastern edges of the existing Bellvista development), these channels and a number of hydraulic structures have been represented as 1D elements in the TUFLOW model and dynamically linked to the 2D model domain.

4.3 Topography

The ground topography for the Bellvista II 2D model domain was sampled from two DEMs:

- **1m Site DEM:** The topography for the Bellvista II site (and a small area of the upstream Bellvista II site, including Bellvista Boulevard) was based on a 1m DEM derived from ground survey undertaken by Conics in July 2008 and provided to BMT WBM as a 12d TIN by Brown Consulting in June 2009. Figure 1-3 shows the topography of the 1m site DEM.

- **5m Caloundra South Flood Study DEM:** The topography for the remainder of the model area was based on the 5m DEM produced for the *Caloundra South Flood Study* (SKM, 2006) from ALS survey.
- Linear features that potentially influence the flow behaviour, such as natural gullies and creeks, levees and embankments, were incorporated into the model using 3D 'breaklines' to ensure that these were contained within the model grids and accurately represented in the model.

4.4 Channels and Hydraulic Structures

The topography of the three 1D channels draining into the site from the existing Bellvista development was based on cross-sections extracted from the ground survey undertaken by Conics in July 2008.

The details of the culvert crossings and hydraulic structures within the adjacent Bellvista development were also based on as-built drawings and supplemented with additional ground survey undertaken by Conics for the purpose of this study. The location of the 1D channels and hydraulic structures included in the TUFLOW model are shown in Figure 4-2.

Details of the proposed drainage channels, development ground levels and culverts were provided by Brown Consulting.

4.5 Hydraulic Roughness

Roughness coefficients represent the resistance to flood flows in channels and floodplains. In the hydraulic model, the adopted Manning's 'n' roughness coefficients were based on those adopted in the *Caloundra South Flood Study* and in the developed areas were adopted from Brown Consulting (Brown Consulting, 2011). The values adopted from the *Caloundra South Flood Study* are listed in Table 4-1 and those from Brown Consulting in site. The land use delineation was based on aerial photography, is shown in Figure 4-1 and proposed development plans.

Table 4-1 Adopted Manning's 'n' Roughness Coefficients in TUFLOW Model

Land Use	Manning's 'n'
Forested	0.120
Very high dense rural	0.100
Urban Blocks	0.090
Medium rural pasture	0.050
Permanently inundated areas	0.045
Sparse rural pasture	0.040
Roads and airstrips	0.020
Maintained parkland	0.045
Proposed waterway corridors	0.060
Proposed Urban Areas	0.100

4.6 Boundary Conditions

The following boundaries were defined for the base case hydraulic model:

- Upstream inflow hydrograph from Lamerough Creek from the Regional model;

- Upstream inflow hydrographs from 3 tributaries (subcatchments LC12_04, LC06_03_01 and LC06_02) from the local RAFTS-XP model;
- Rainfall runoff hydrographs from 3 subcatchment (LC07_02, LC07_03, and LC07_04) from the local RAFTS-XP model, applied as a 1D lateral inflow to the western channel of the existing Bellvista development;
- Rainfall runoff hydrograph from 1 subcatchment (LC06_03_10) from the local RAFTS-XP model, applied as a 1D lateral inflow to the central channel of the existing Bellvista development;
- Rainfall runoff hydrographs from 6 subcatchment (LC06_04_03, LC06_04_04, LC06_04_02, LC06_05, LC6_7_4_a_1, LC6_7_4_a_3) from the local RAFTS-XP model, applied as a 1D lateral inflow to the eastern channel of the existing Bellvista;
- Rainfall runoff hydrographs from the 43 remaining subcatchments from the local RAFTS-XP model, applied as 2D 'source-area' inflows which distribute the inflows over the 2D domain or directly to the drainage channels as appropriate; and
- Water level time series at the 2 downstream boundaries (towards Golden Beach and Bells Creek) from the Caloundra Downs Base Case TUFLOW model.

The following boundaries were defined for the base case hydraulic model:

- Upstream inflow hydrograph from Lamerough Creek from the Regional model;
- Upstream inflow hydrographs from 3 tributaries (subcatchments LC12_04, LC06_03_01 and LC06_02) from the local RAFTS-XP model;
- Rainfall runoff hydrographs from 3 subcatchment (LC07_02, LC07_03, and LC07_04) from the local RAFTS-XP model, applied as a 1D lateral inflow to the western channel of the existing Bellvista development;
- Rainfall runoff hydrograph from 1 subcatchment (LC06_03_10) from the local RAFTS-XP model, applied as a 1D lateral inflow to the central channel of the existing Bellvista development;
- Rainfall runoff hydrograph from 2 subcatchment (LC06_03_11, LC06_04_05) from the local RAFTS-XP model, applied as a 1D inflows to the underground culverts draining to the Bellvista Boulevard drain;
- Rainfall runoff hydrographs from 9 subcatchment (LC06_04_03, LC06_04_04, LC06_04_02, LC06_05, LC6_7_4_a_1, LC6_7_4_a_3, LC6_7_4_a_2, LC6_7_4_a_4, LC6_7_4_a_5) from the local RAFTS-XP model, applied as a 1D lateral inflow to the eastern channel of the existing Bellvista development;
- Rainfall runoff hydrographs from the 38 remaining subcatchments from the local RAFTS-XP model, applied as 2D 'source-area' inflows which distribute the inflows over the 2D domain or directly to the drainage channels as appropriate; and
- Water level time series at the 2 downstream boundaries (towards Golden Beach and Bells Creek) from the Caloundra Downs Base Case TUFLOW model.

Section 3 summarises the development of the RAFTS-XP hydrological models used as boundary conditions for the hydraulic models. The locations of the Bellvista II TUFLOW model boundaries are presented in Figure 4-3 and Figure 4-4.

4.7 Model Verification

Both the Regional and the Bellvista II TUFLOW models were verified against the *Caloundra South Flood Study* (SKM, 2006) MIKE-FLOOD model.

The model area of the Regional TUFLOW model covers the entire Bells Creek, Halls Creek and Lamerough Creek catchments. The floodplain area and watercourses within the modelled area (including Lamerough Creek) have been represented within a 2D model domain.

The performance of the Regional TUFLOW model was verified against the *Caloundra South Flood Study* MIKE-FLOOD model for a range of flood events (namely 10, 50 100 year ARI flood events). The model predictions showed a high level of consistency in the vicinity of the site and its surroundings. In the vicinity of the Bellvista II site, the 100 year ARI peak flood levels predicted by the Regional TUFLOW model are within 0.05m of the peak flood levels predicted by the MIKE-FLOOD model. (The Regional TUFLOW model predicts slightly higher levels.) It is noted that neither models have been calibrated to historical flood events due to the absence of reliable data.

The Bellvista II TUFLOW model was simulated using the same design flood events as modelled in the *Caloundra South Flood Study* (SKM, 2006). The results of the Bellvista II TUFLOW model were compared with predictions from the *Caloundra South Flood Study* MIKE-FLOOD model (SKM, 2006). It is noted that the *Caloundra South Flood Study* MIKE-FLOOD model is a regional flood model and will only predict flooding due to regional flood events (i.e. due to fluvial and coastal flooding).

The modelled 100 year ARI peak flood levels vary between 5.3mAHD in the north-western edge of the Bellvista II site to 2.7mAHD at the south-eastern edge.

A comparison between the modelled peak flood levels from the Bellvista II TUFLOW model and the *Caloundra South Flood Study* are shown in Figure 4-5 and Figure 4-6. These figures show the comparison of peak flood levels at various locations across the Lamerough Creek floodplain for the 100 and 50 year ARI design flood events. It can be seen that overall the results show an agreement in peak modelled levels for these regional (Lamerough Creek) flood events, with differences generally within 0.05m. This is considered to be a close agreement.

There are some minor areas where the extent of flooding predicted by the MIKE-FLOOD model differs from that predicted by the TUFLOW model, mainly at the existing development around Koala Court. Differences in peak flood levels and extents are primarily due to the additional detail in the Bellvista II model which also incorporates flooding from the local catchment runoff together with regional flooding.

Additional reasons for differences are likely to be the finer resolution of the Bellvista II TUFLOW model (i.e. a 5m grid as opposed to the MIKE-FLOOD 12m grid) as well as the different approach adopted for applying inflows. In the MIKE-FLOOD model, inflow boundaries were applied as source points at the centre of the subcatchment, whilst in the TUFLOW model, the inflows were generally

distributed over wetted areas of the subcatchment or over drainage channels. The adopted approach in the TUFLOW model is considered to be more appropriate.

Note that direct comparisons cannot be made for local flood behaviour (e.g. on the smaller tributaries draining into the site or across much of the proposed Bellvista II development area) as these areas are predominantly upstream of the inflow boundaries to the MIKE-FLOOD model. Furthermore, peak flood levels in this area are generally a result of more local flood events (i.e. shorter duration storms), which were not modelled as part of the *Caloundra South Flood Study*.

4.7.1 Rational Method

In addition to the model verification against an established calibrated model, modelled results were also compared to Rational Method results. Rational Method calculations were completed at two locations; immediately upstream of the confluence of the western channel and Lamerough Creek; and on the central channel upstream of Bellvista Boulevard.

The Rational Method calculations were completed in accordance with the advice published in Queensland Urban Drainage Manual (QUDM) (2007). Fraction impervious values were determined as outlined above, rainfall intensities were obtained using the methodology outlined in ARR and the time of concentration was determined from hydraulic modelling results (where these were available). Where hydraulic modelling results were not available velocities were determined to be 1.5m/s and 1.2m/s for the Western and Central channels respectively. These values are lower than recommended by QDUM but consistent with the hydraulic model results.

The results of the Rational Method calculations are presented in Table 4-2 and Table 4-3 together with the results of the hydrologic (RAFTS) and hydraulic (TUFLOW) models. These tables indicate a close agreement between the Rational Methods results and the RAFTS results for the 5 year ARI, however, for larger events (50 and 100 year ARI) the results diverge. This is a common result that is attributed to the accounting of storage in the hydrological model.

It is also of note that the hydraulic model results are lower than both the Rational Method and RAFTS results for a given ARI. This due to the explicit accounting of storage in the hydraulic model, the ability of the hydraulic model to dynamically partition flow between conveyance corridors and overland flow areas and the impact of roughness.

Table 4-2 Central Channel comparison of Rational Method results against RAFTS and TUFLOW

ARI	Rational Method	RAFTS	TUFLOW
5	24.4	26.0	15.3
50	44.0	40.7	23.0
100	51.0	47.6	26.2

Table 4-3 Western Channel comparison of Rational Method results against RAFTS and TUFLOW

ARI	Rational Method	RAFTS	TUFLOW
5	28.5	23.9	19.5
50	51.0	36.1	29.1
100	59.0	41.8	33.8

4.8 Sensitivity analysis: Losses

Sensitivity analysis of the pervious losses has been undertaken. This analysis involved altering the initial loss for pervious areas from 10mm to 0mm. This has been completed for the local hydrological model only. It was not considered necessary to investigate the sensitivity of the regional model as it has been calibrated to known flood events and the model is known to perform well. Furthermore, the regional model predominately influences flood levels downstream of the site which are insensitive to changes in inflows. For instance, the difference between the 100 year ARI and the 1 year ARI flood levels in this area is approximately 300mm (c.f. 100 year flood level of approximately 2.8m AHD). This compares to the difference between the inflows from the regional model which are almost an order of magnitude ($51.7\text{m}^3/\text{s}$ to $8.1\text{m}^3/\text{s}$).

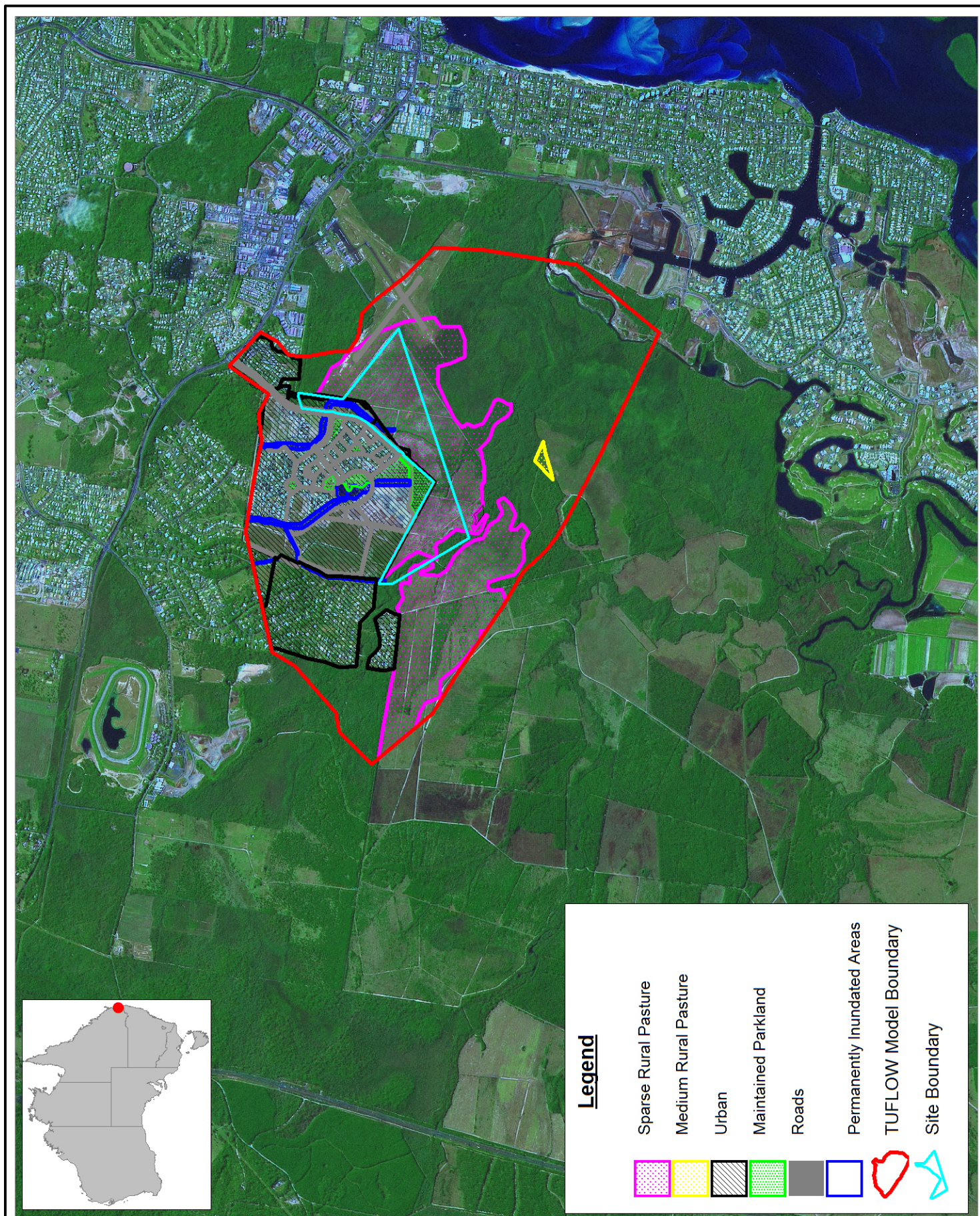
The results of this analysis are summarised in Table 4-4. The results demonstrate that the area to the south of the proposed development is insensitive to the change in initial losses in the local hydrological model. However, the impact of these changes is more pronounced for more frequent event as expected.

The impact of the decreased initial loss is greater in the channels as the figures in Table 4-4 indicate, however, these increases are confined to the channels.

The sensitivity analysis results indicate that there are no significant or disproportionate impacts on flood level due to the decrease of the pervious initial loss value to 0mm. Furthermore the flood models perform as expected to these changes, that is, the hydrological model results show increased flows and the hydraulic model shows increased flood levels. It should be noted that it is extremely unlikely that antecedent conditions corresponding to pervious initial loss of 0mm would occur in conjunction with a 1 in 100 year storm. Should this occur the resulting flood event would exceed the 1 in 100 year recurrence interval.

Table 4-4 Results of Sensitivity Analysis

ARI (years)	Maximum Impact (mm)			
	Western Channel	Central Channel	Eastern Channel	Wetland
1	50	50	500	30
5	50	50	100	0
50	50	50	100	0
100	50	50	100	0



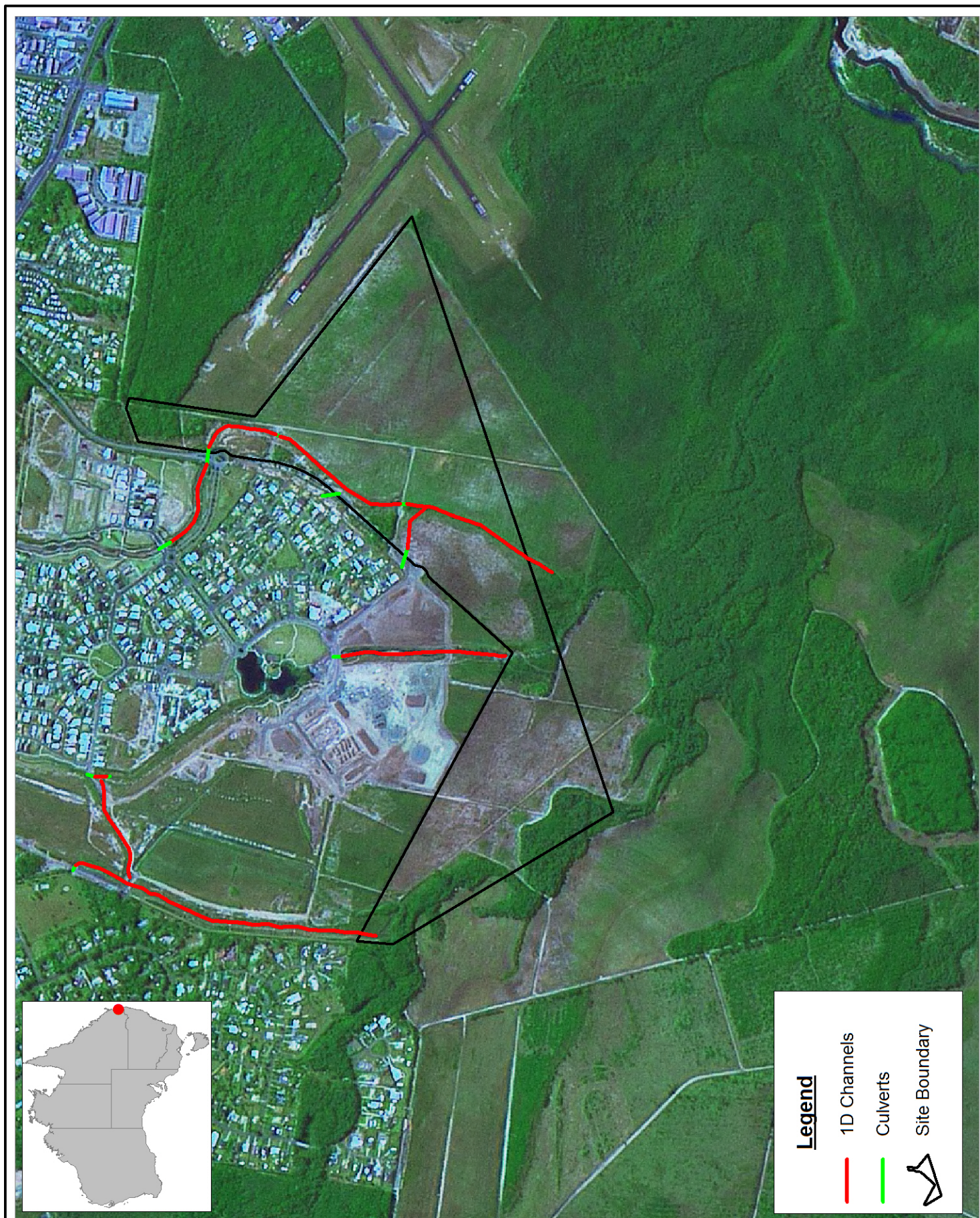
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TUFLOW Model Extent and Land Use - Base Case

Figure:
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Title:
**TUFLOW Model 1D Channel and Structures
 Base Case**

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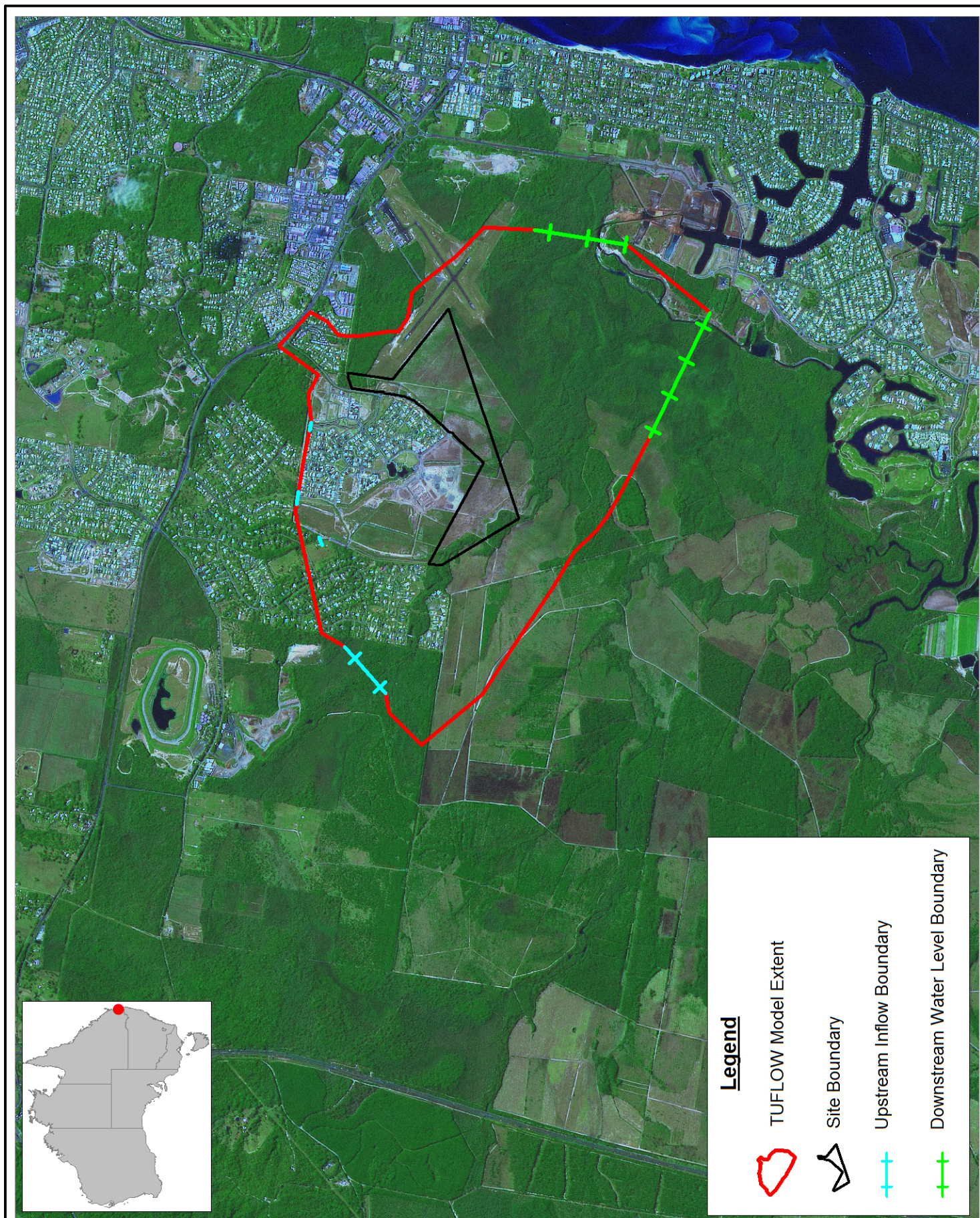
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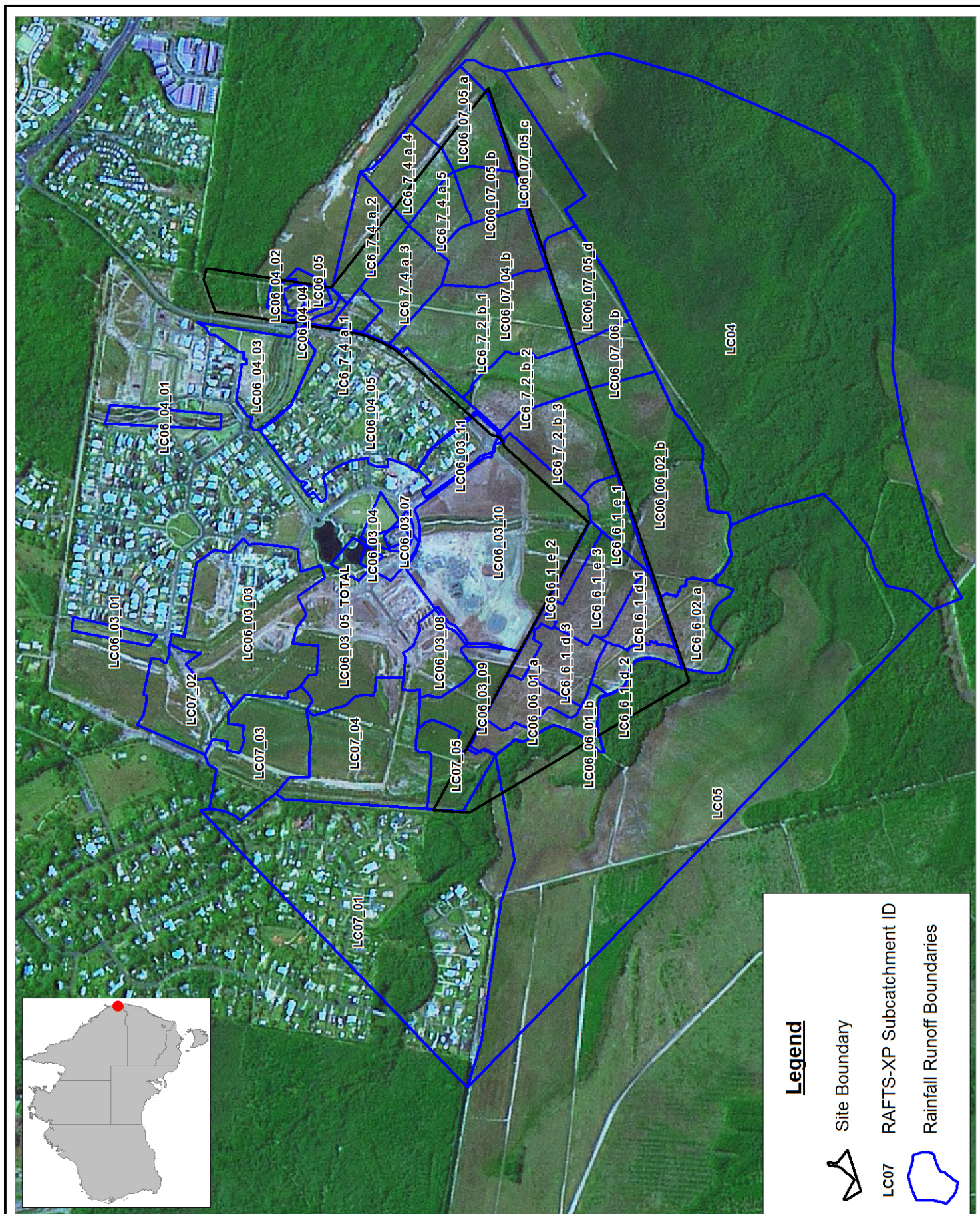
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TUFLOW Model Upstream Inflows and Downstream Water Level Boundaries

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**Internal Inflow Boundaries of TUFLOW Model
Base Case**

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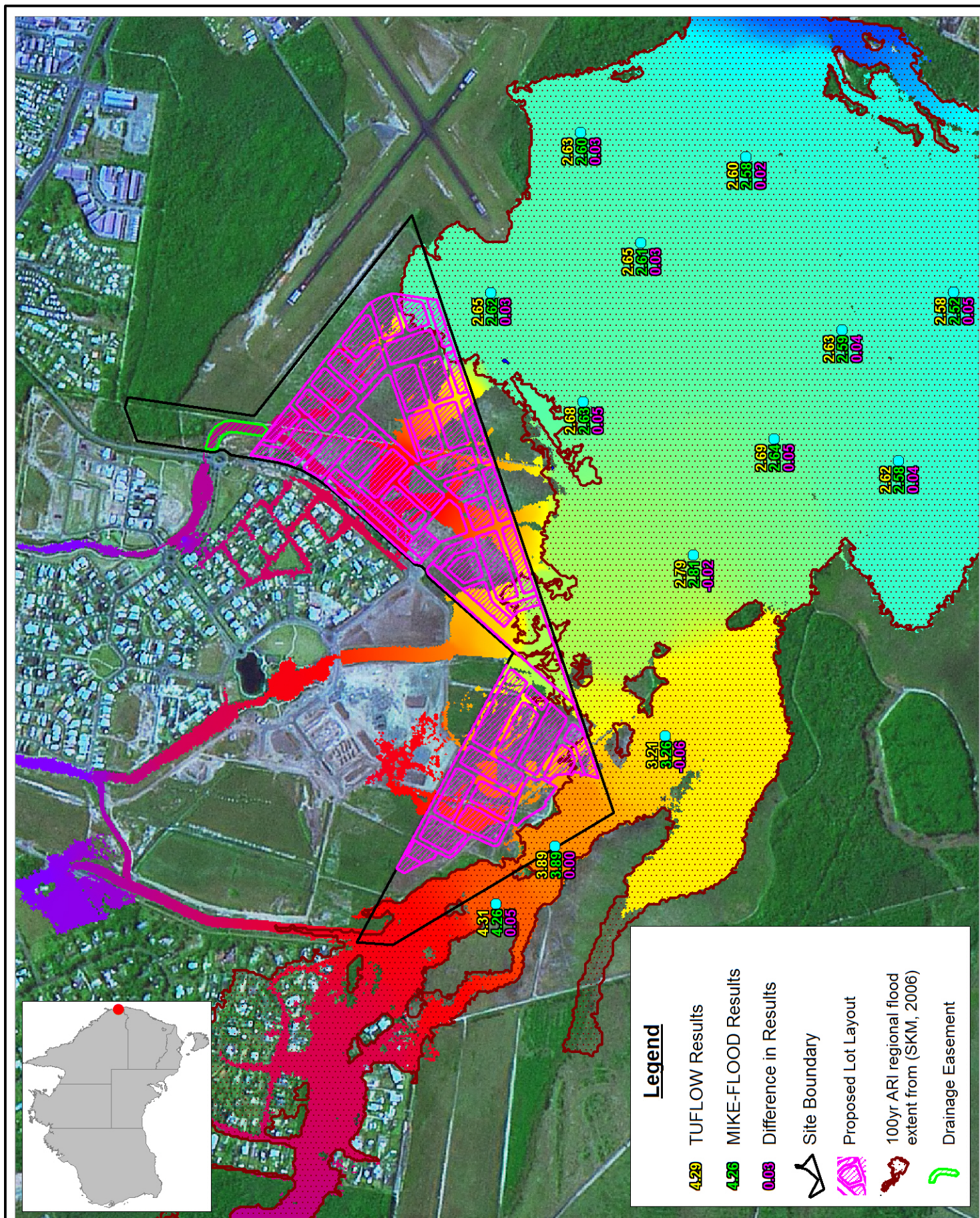
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Title:
**TUFLOW Model Comparison with MIKE-FLOOD Model:
 Q100 Peak Flood Levels**

Figure:
4-5

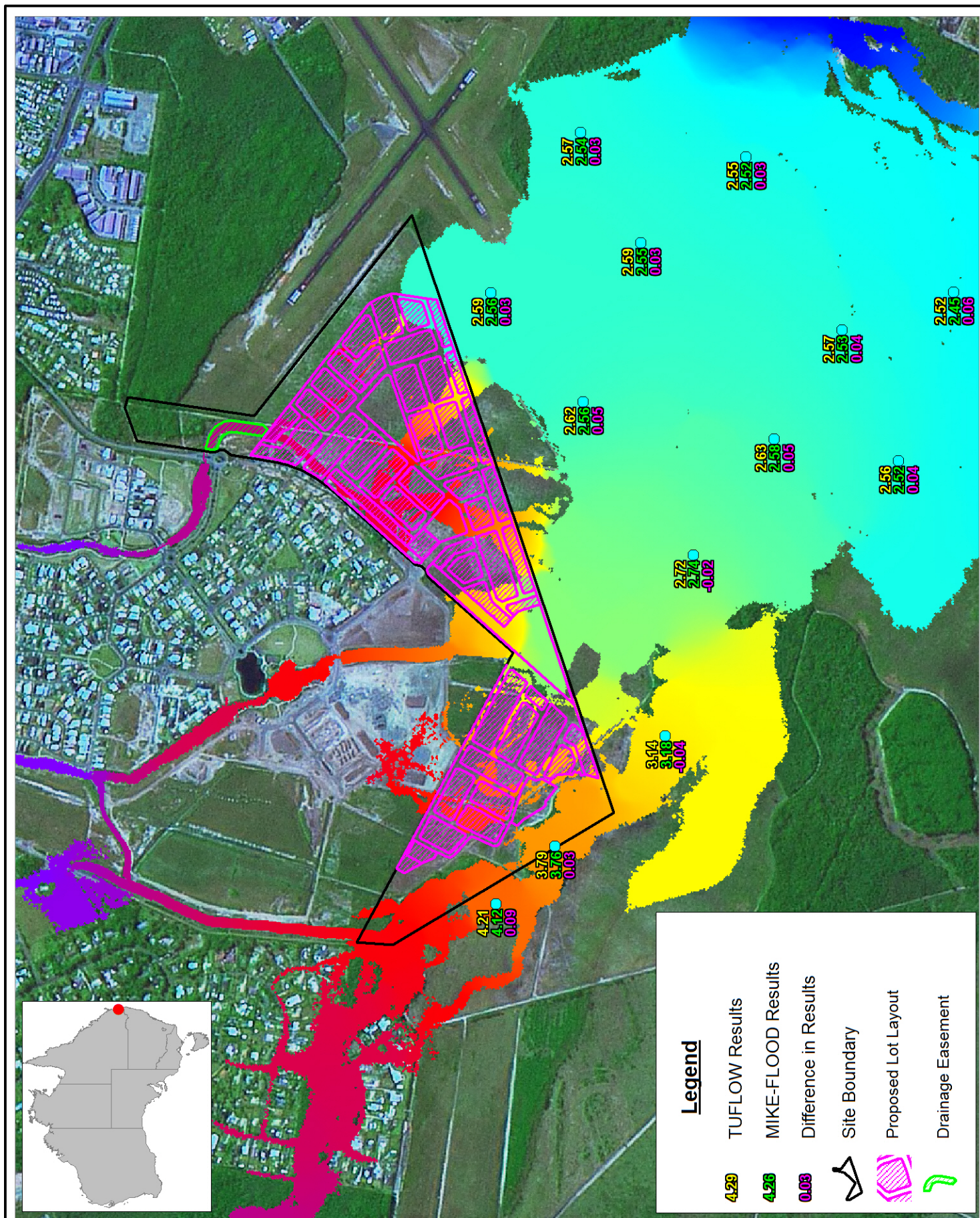
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Title:
**TUFLOW Model Comparison with MIKE-FLOOD Model:
 Q050 Peak Flood Levels**

Figure:
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5 FLOODING ASSESSMENT OF EXISTING SITE

5.1 Base Case Scenarios

The flood model was used to derive existing 100 year, 50 year, 5 year, 1 year and 3 month ARI design flood levels. As the development site is in an area that is affected by two sources of flooding (regional flooding from Lamerough Creek and local flooding from the subcatchments to the north of the site), a range of storm durations has been investigated as part of this study, namely the 1, 3, 6 and 12 hour storm duration events. The inflow and downstream boundary conditions for the model were derived from model simulations of these same storm events using the local XP-RAFTS hydrological model and Regional TUFLOW model (as outlined in Section 4).

5.2 Results of Base Case Scenarios

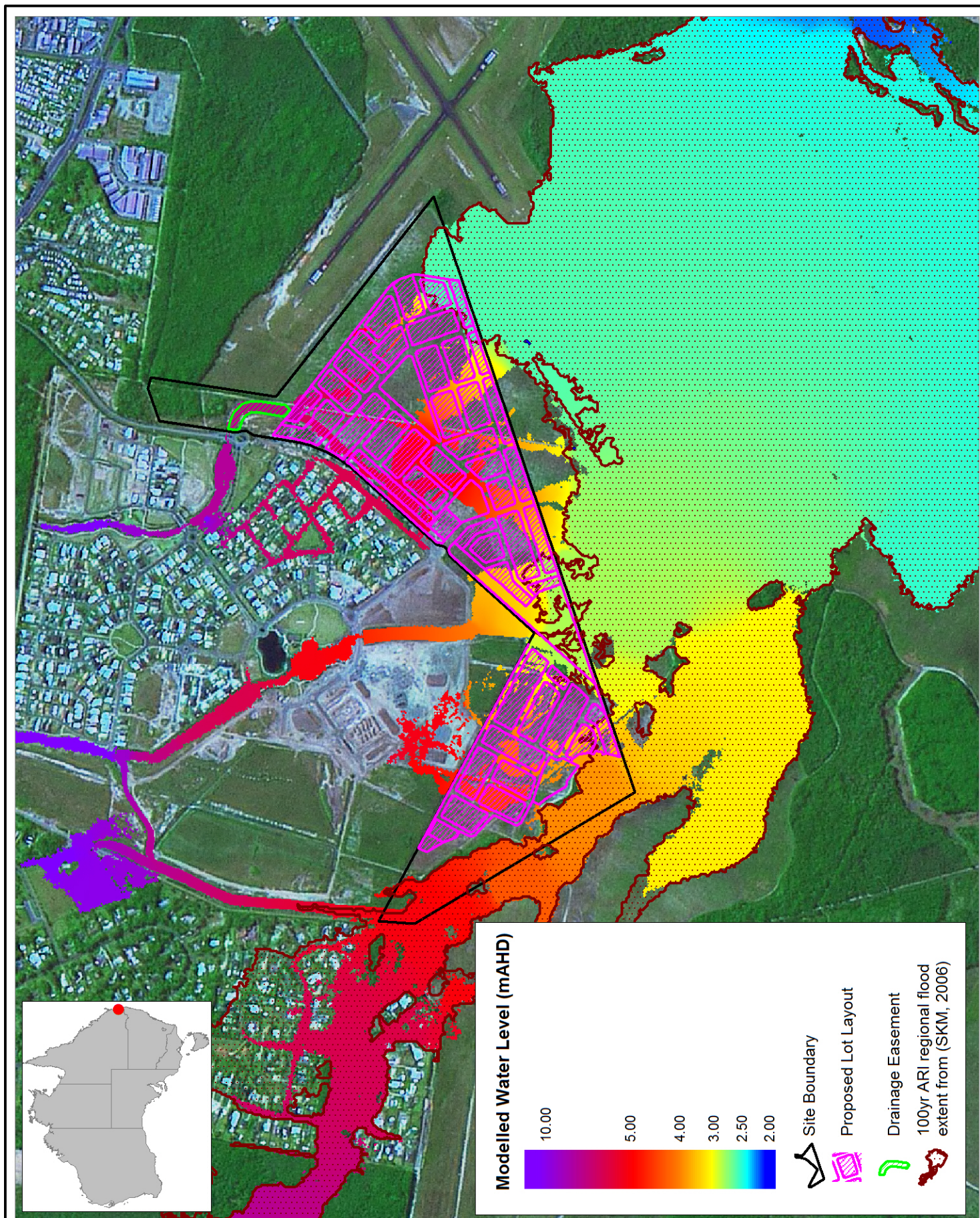
The flood model for the Base Case (i.e. the existing or pre-development conditions) was simulated for the 3 month, 1, 5, 50 and 100 year ARI design flood events. The resulting peak flood levels are presented in Figure 5-1 to Figure 5-5, peak flow velocities in Figure 5-6 to Figure 5-10 and peak flood depths in Figure 5-11 to Figure 5-15.

Regarding the existing flooding behaviour of the site and surroundings, the following is noted:

- The site is potentially affected by flooding from 2 sources; Lamerough Creek to the south and west of the site; and stormwater runoff from the local catchments to the north of the site.
- The critical storm duration varies throughout the study area with shorter events critical in the upper parts and longer duration events in the lower parts. The central parts of the existing Bellvista site (including the drain along Unity College) are most sensitive to the 1 hour design storm, while the critical duration for the areas on the Lamerough Creek floodplain is about 12 hour storm.
- Parts of the site are affected by flooding of Lamerough Creek, which runs along the southern edge of the proposed development, during the 1 in 100 year design flood events. Flooding is largely confined to areas outside of the proposed urban development with the exception of some minor shallow flooding to the south of proposed Precinct 1 and 2. Around the subject site, this creek has a poorly defined channel with flood flows generally dispersing over a relatively wide, waterlogged area.
- The site is also subject to flooding from stormwater runoff from the local upstream catchment, an urban area of about 200 ha, including existing residential areas to the immediate north of the site. The drainage across the site is not formalised and this leads to shallow flooding over part of the site.
- During a 100 year ARI flood, the peak discharge entering the site via the drainage corridor along Unity College is approximately $33\text{m}^3/\text{s}$ and the peak discharge from the eastern drain is approximately $25\text{m}^3/\text{s}$. The peak discharge in Lamerough Creek is about $72\text{m}^3/\text{s}$ in a 100 year ARI flood event.
- Overland flow the north of the site is characterised by diffuse overland flows with shallow flood depths and moderate peak flow velocities. The maximum inundation depth for the 100 year ARI event is generally less than 0.25m across most of the site. As expected around the proposed

central channel (proposed drainage corridor between Precinct 1 and 2) flood depths are generally deeper; typically between 0.5 to 1.0m.

- The southern part of the site and the adjacent wetland areas directly to the south and southeast of the site flood extensively and store large volumes of flood water during major events. The peak flood depth throughout this area is typically about 1m during a 100 year ARI design flood event. Flood water is mostly slow flowing in these areas with flow velocities generally less than 0.2 m/s.



Title:
100 year ARI Peak Flood Levels for Base Case

Figure:
5-1

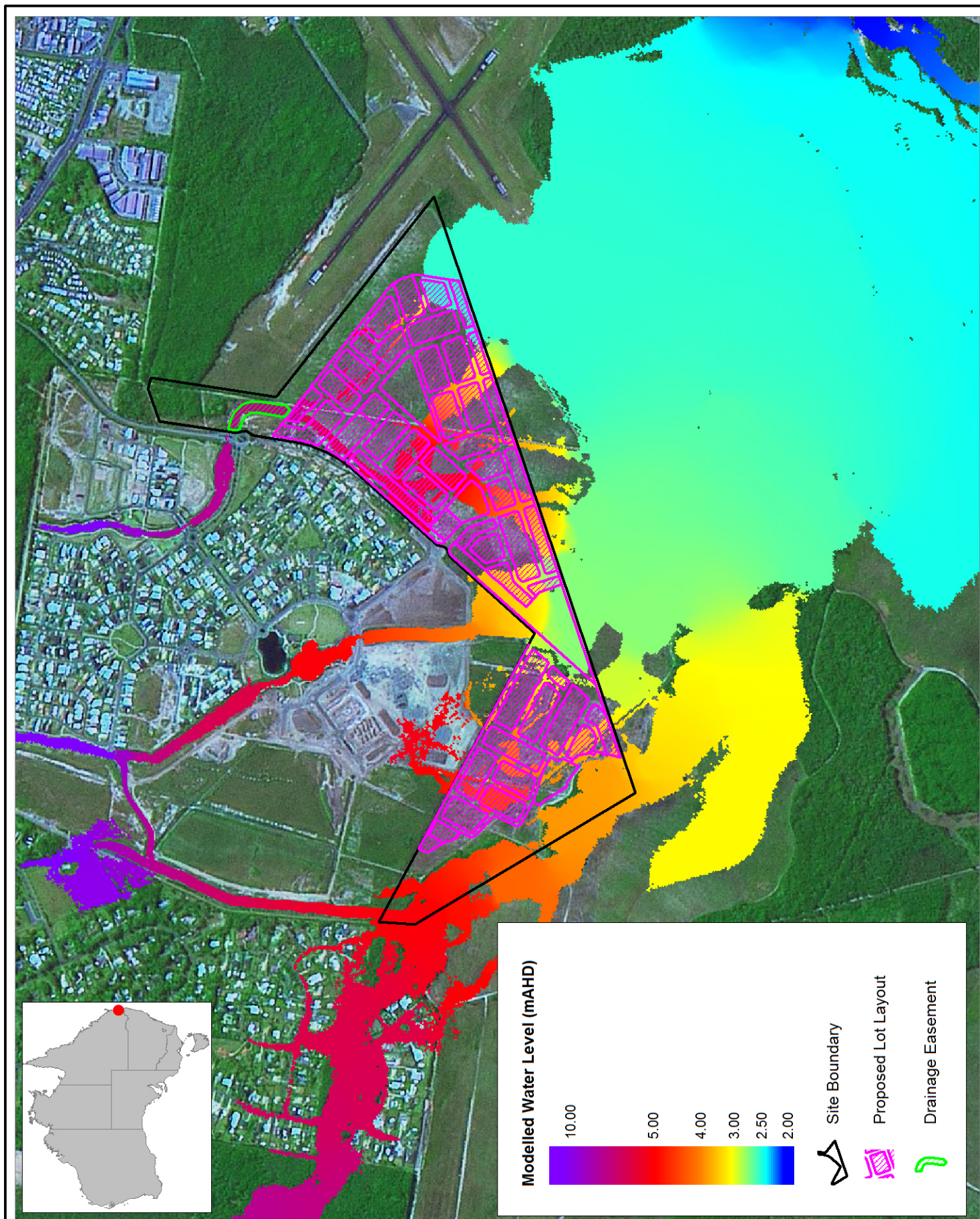
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0 250 500m
Approx. Scale





Title:
50 year ARI Peak Flood Levels for Base Case

Figure:
5-2

Rev:
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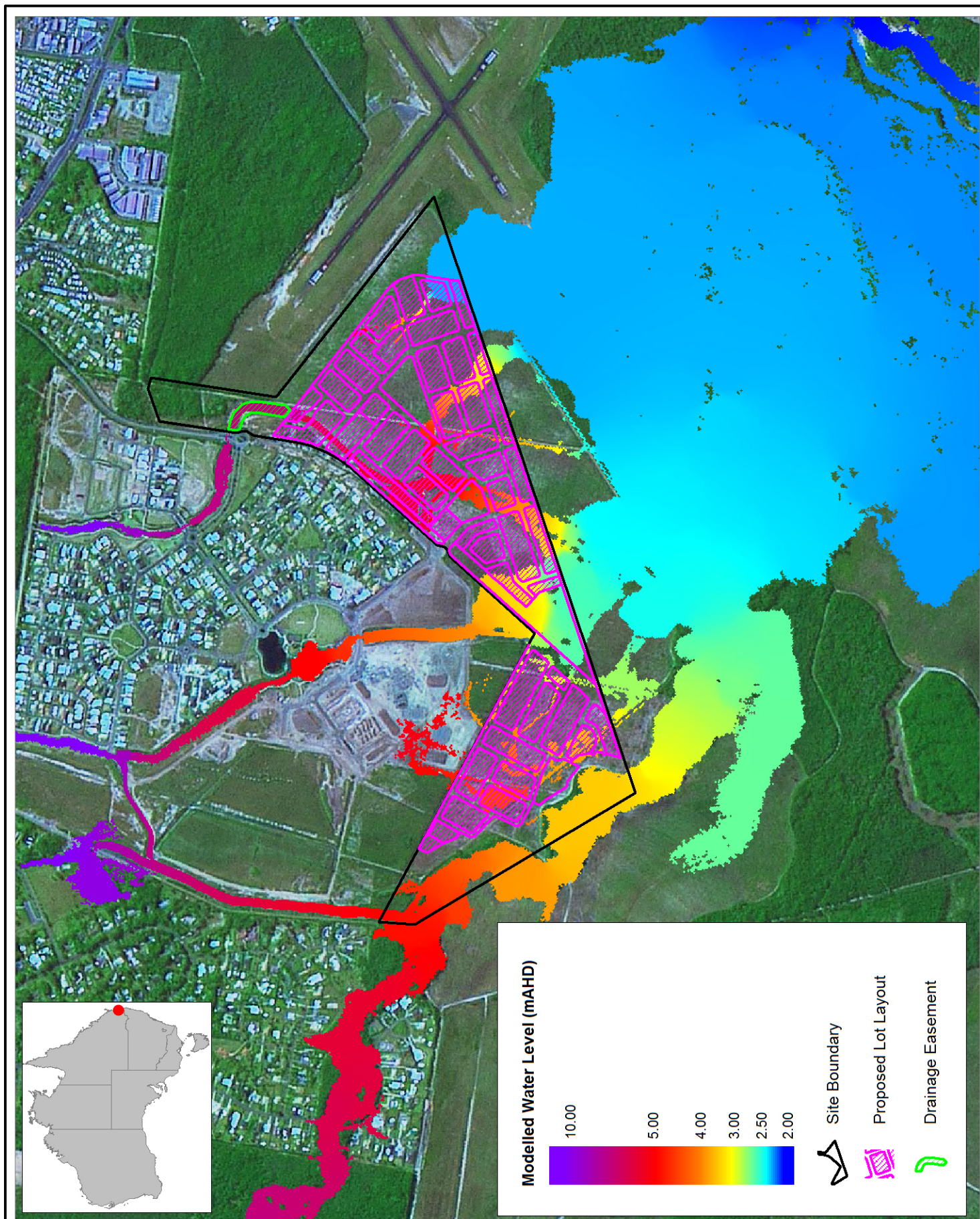
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Title:
5 year ARI Peak Flood Levels for Base Case

Figure:
5-3

Rev:
A

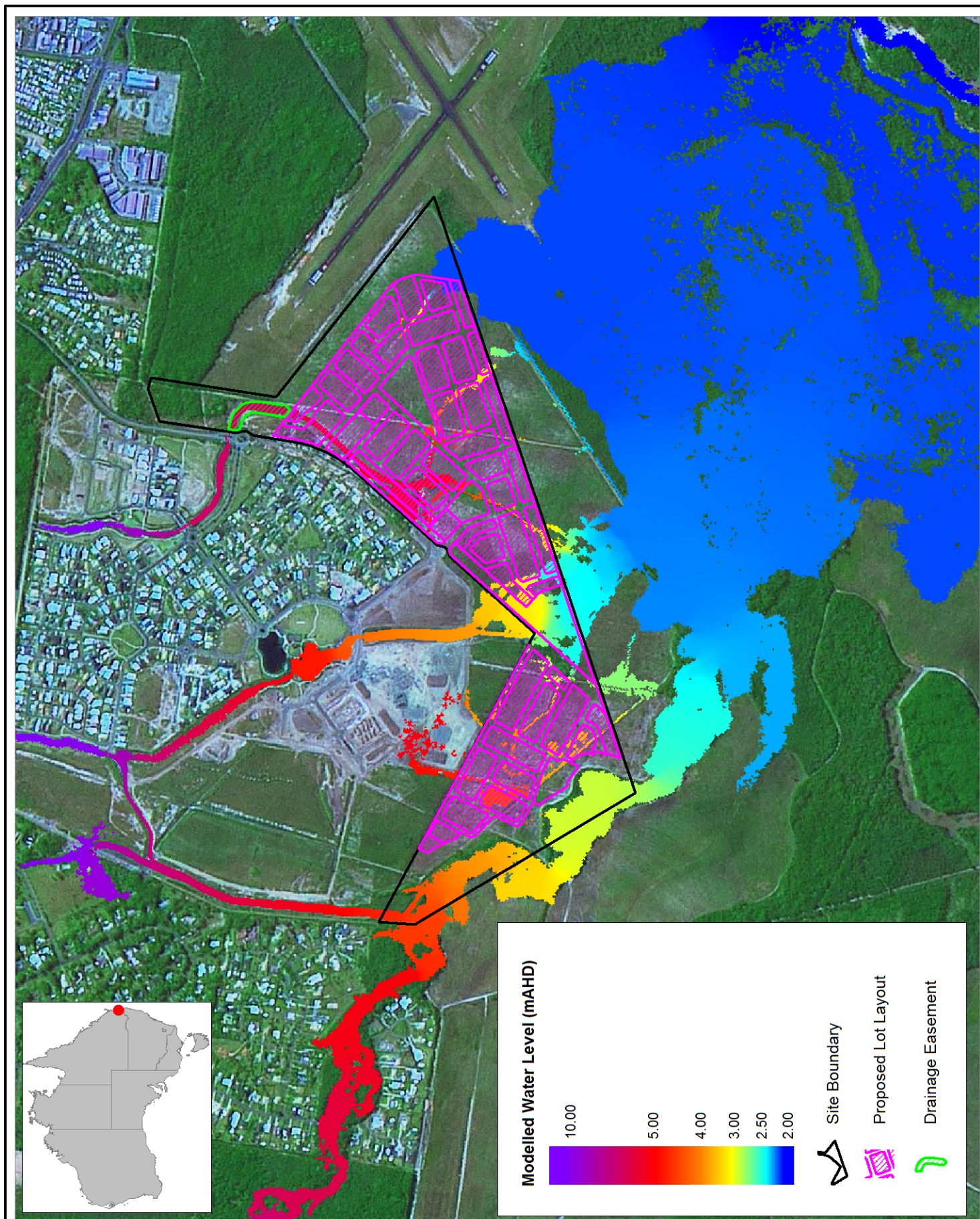
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Title:
1 year ARI Peak Flood Levels for Base Case

Figure:
5-4

Rev:
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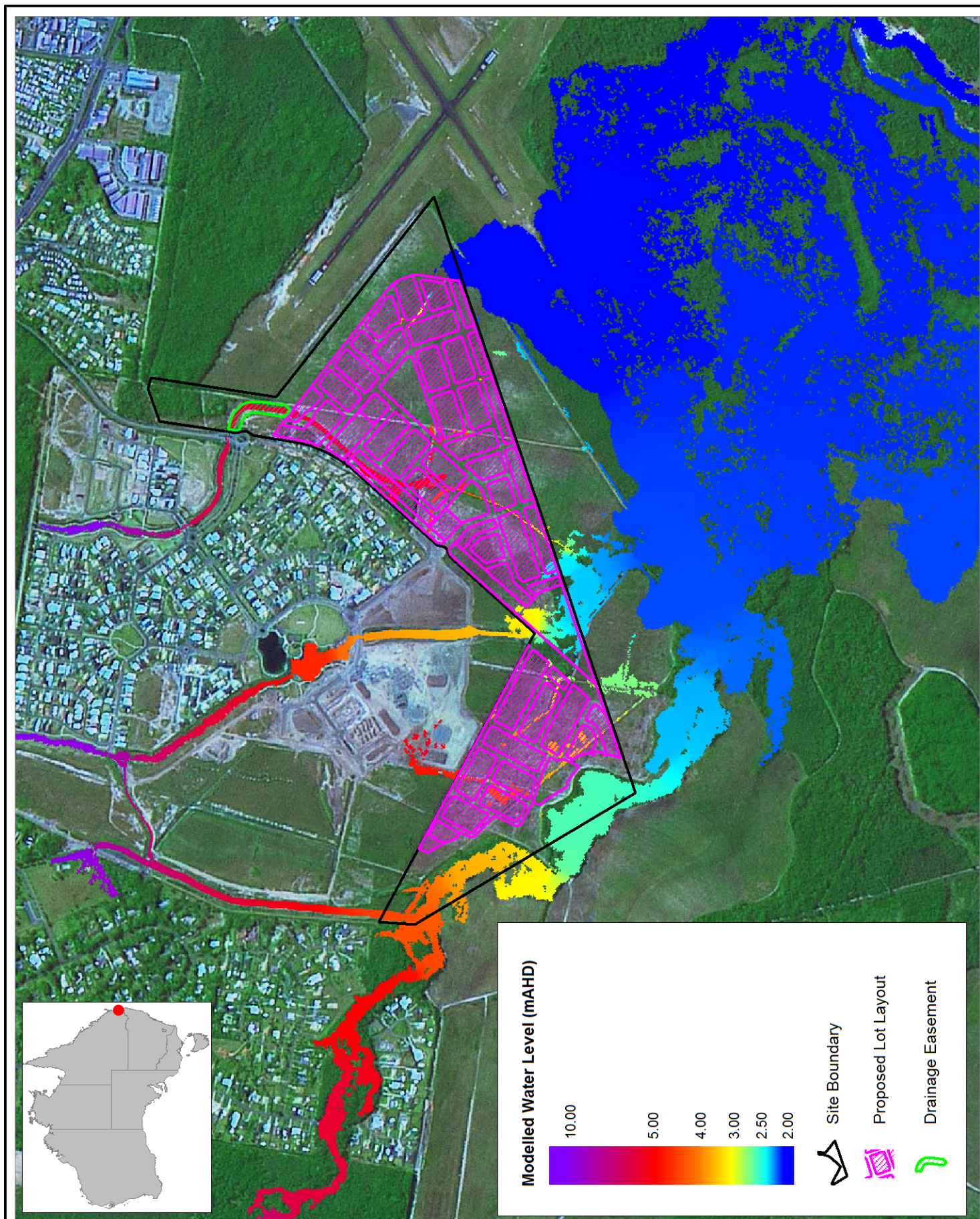
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Title:
3 month ARI Peak Flood Levels for Base Case

Figure:
5-5

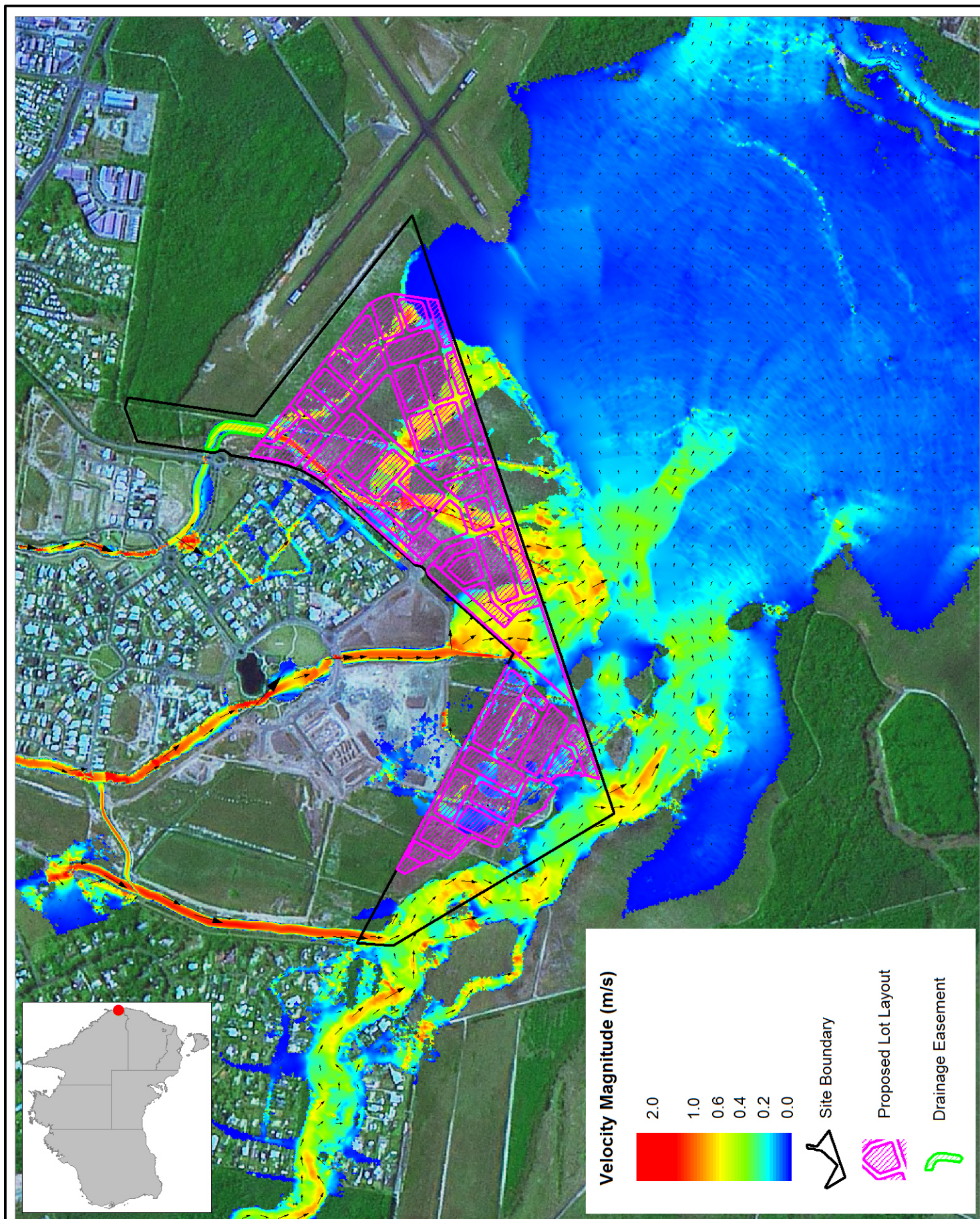
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Title:
100 year ARI Peak Flood Velocities for Base Case

Figure:
5-6

Rev:
A

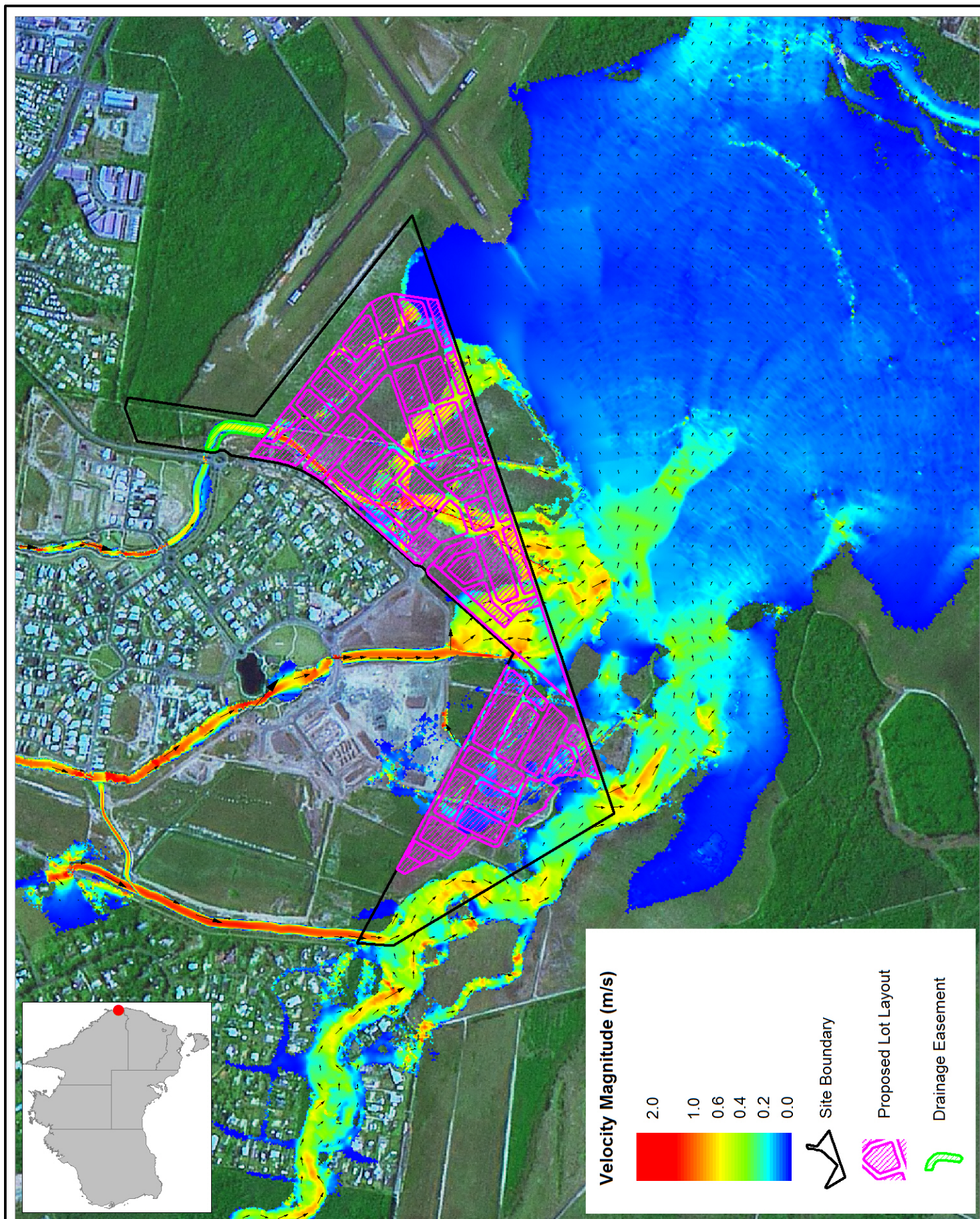
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Title:
50 year ARI Peak Flood Velocities for Base Case

Figure:
5-7

Rev:
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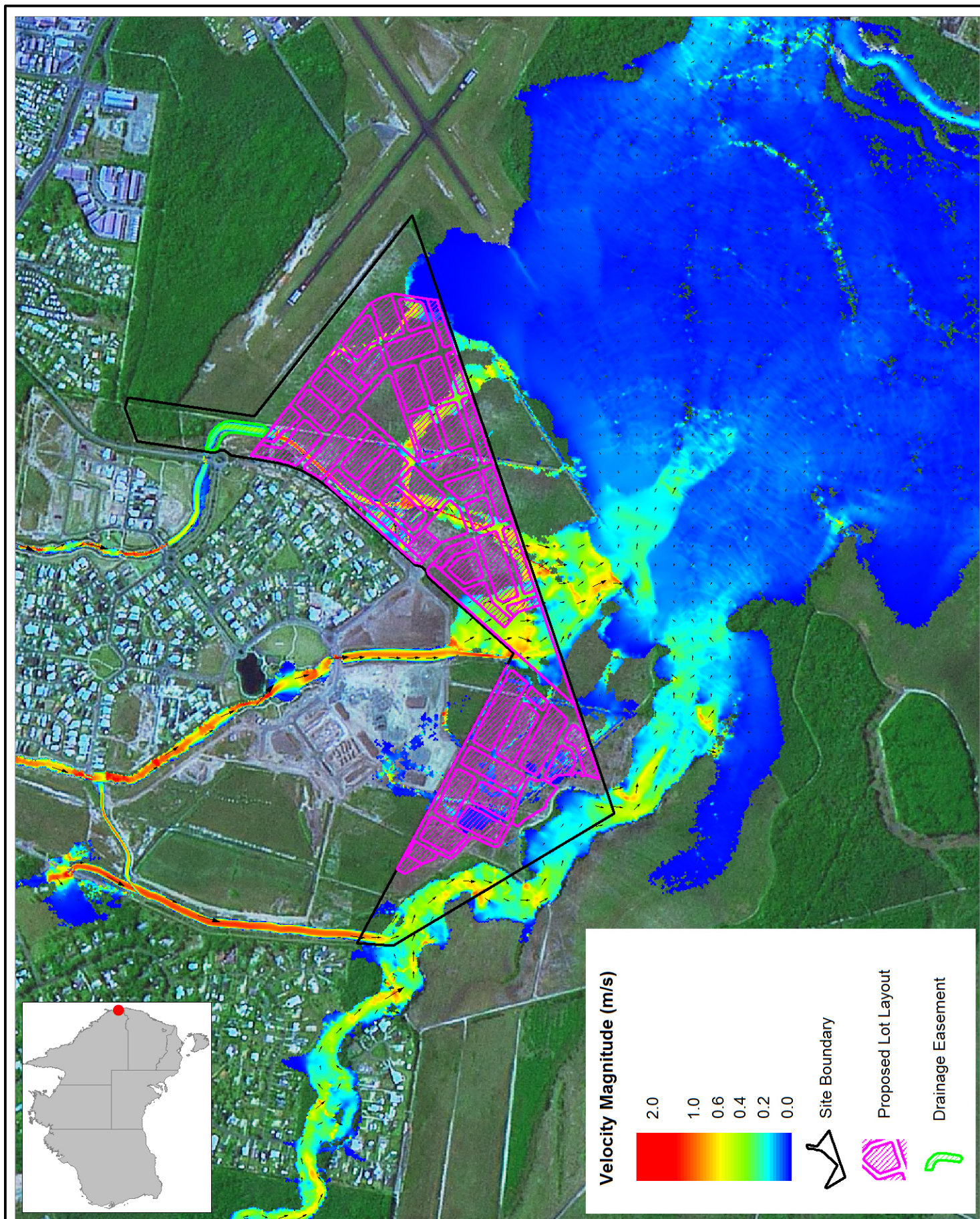
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Title:
5 year ARI Peak Flood Velocities for Base Case

Figure:
5-8

Rev:
A

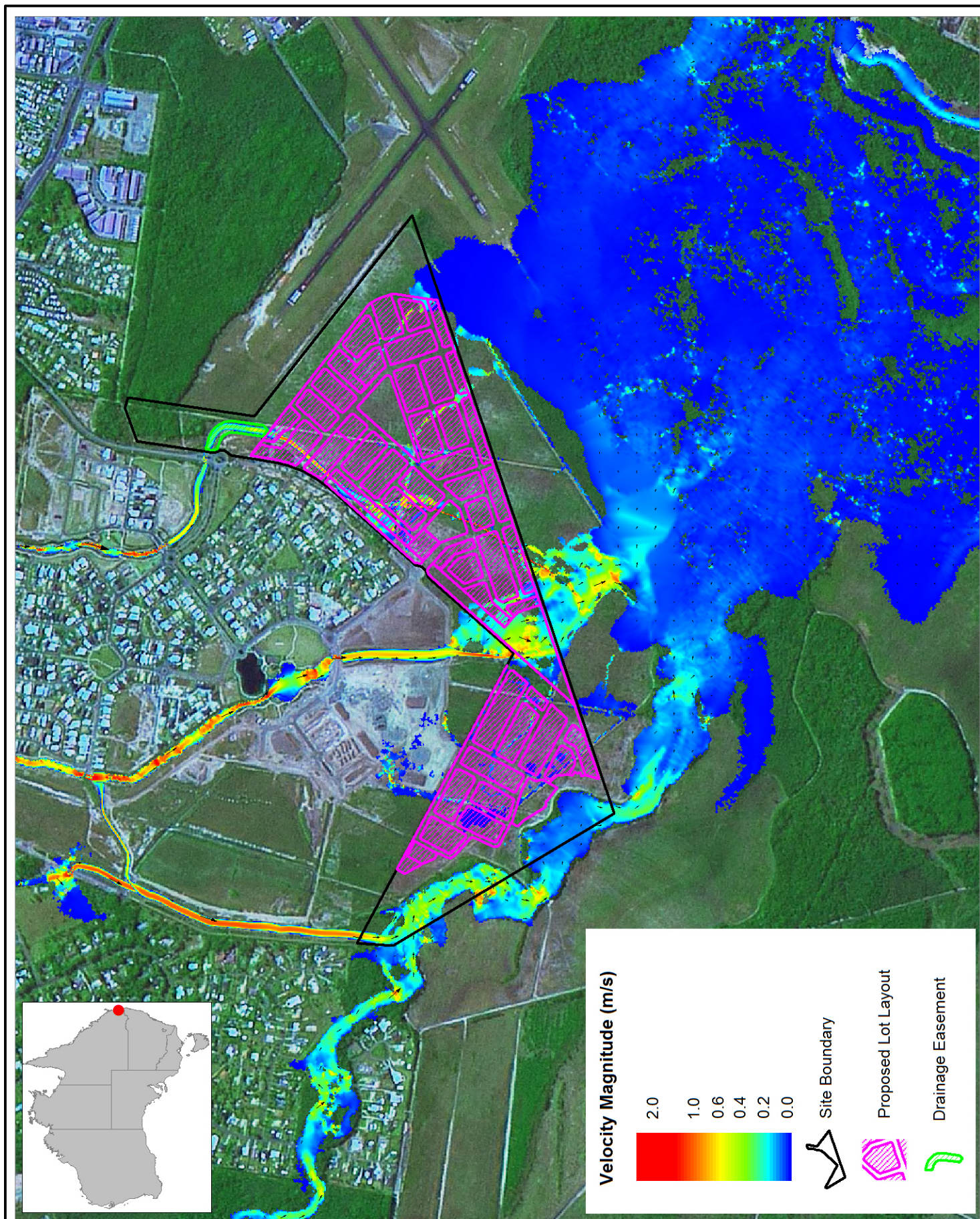
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Title:
1 year ARI Peak Flood Velocities for Base Case

Figure:
5-9

Rev:
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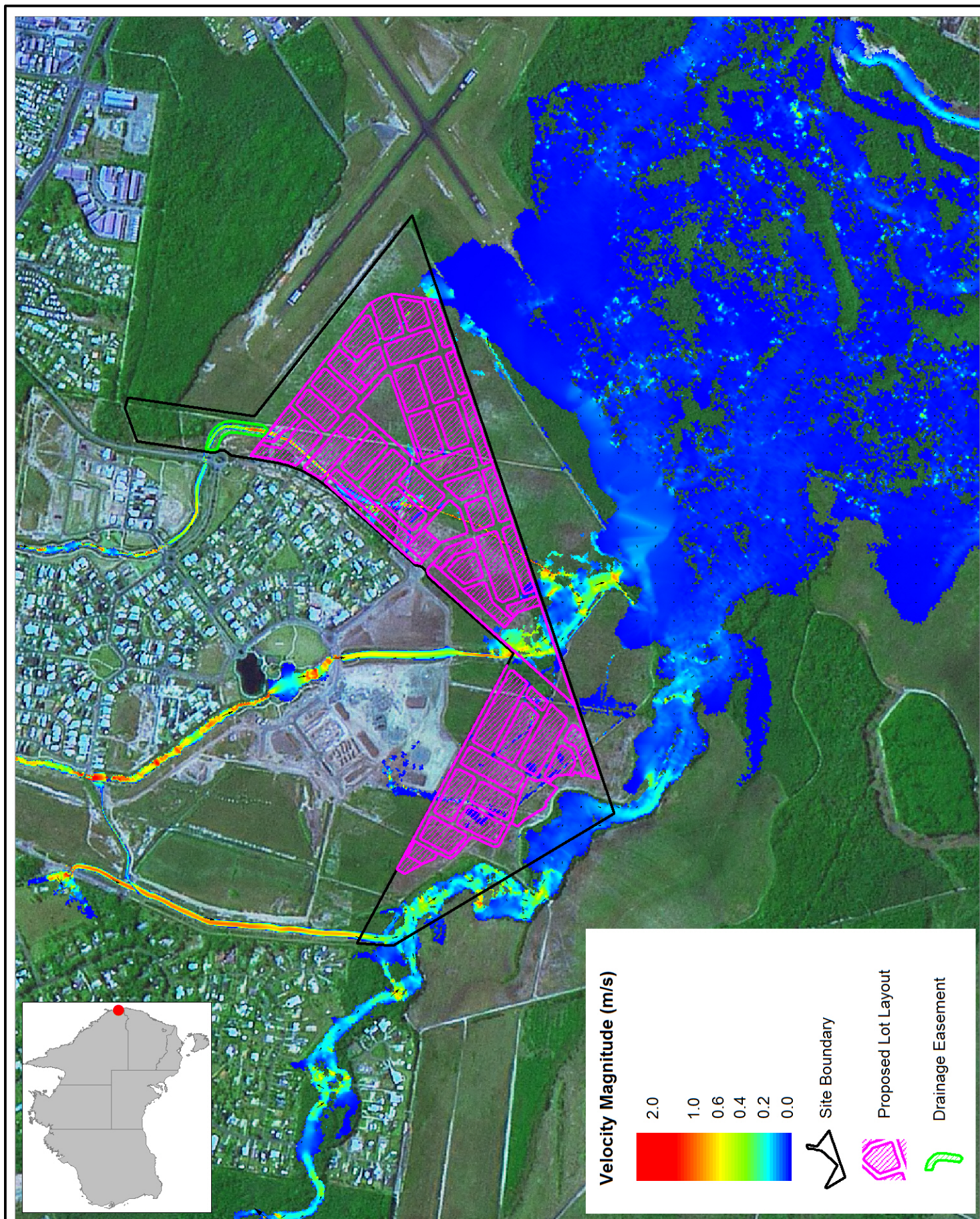
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Title:
3 month ARI Peak Flood Velocities for Base Case

Figure:
5-10

Rev:
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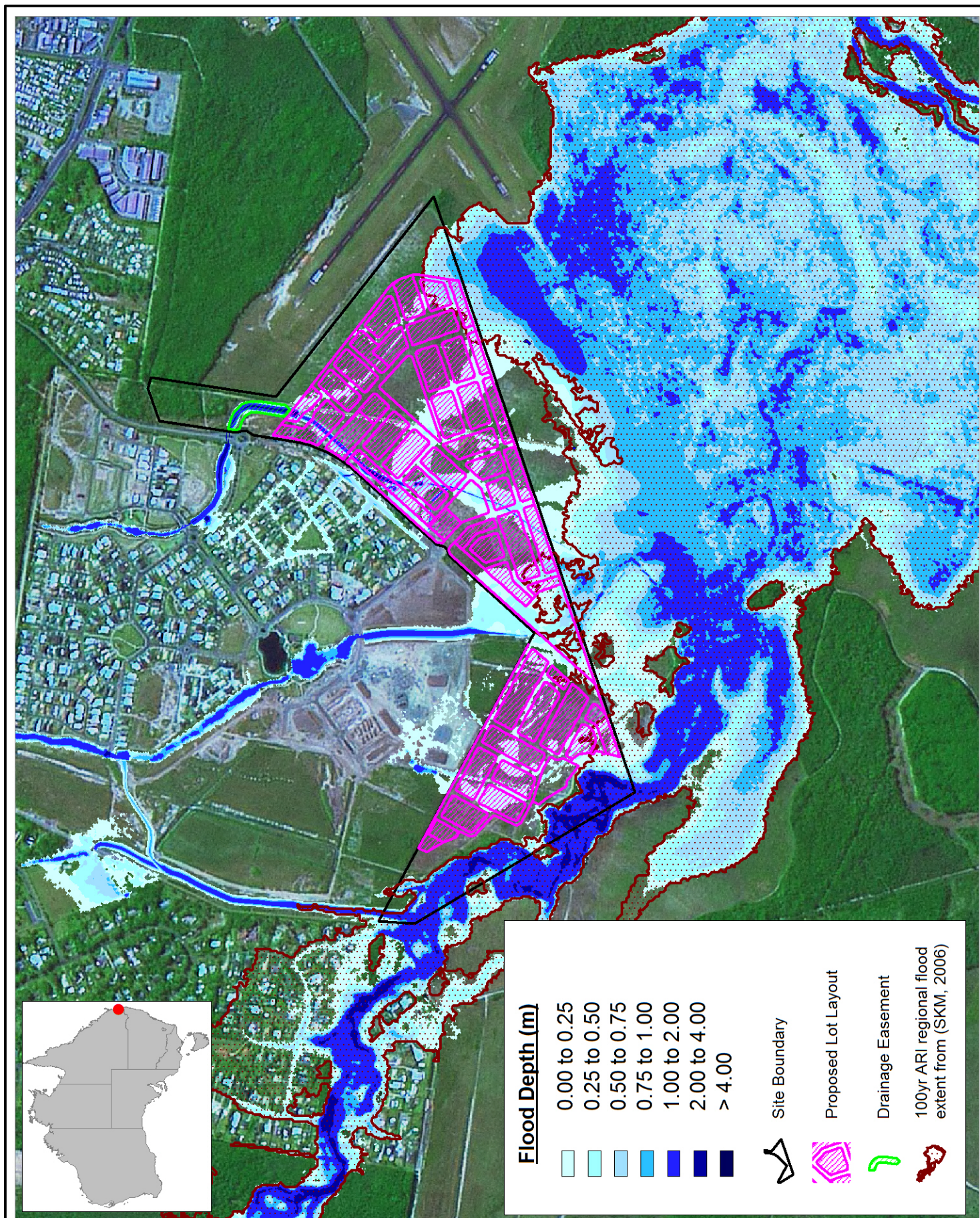
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Title:
100 year ARI Peak Flood Depth for Base Case

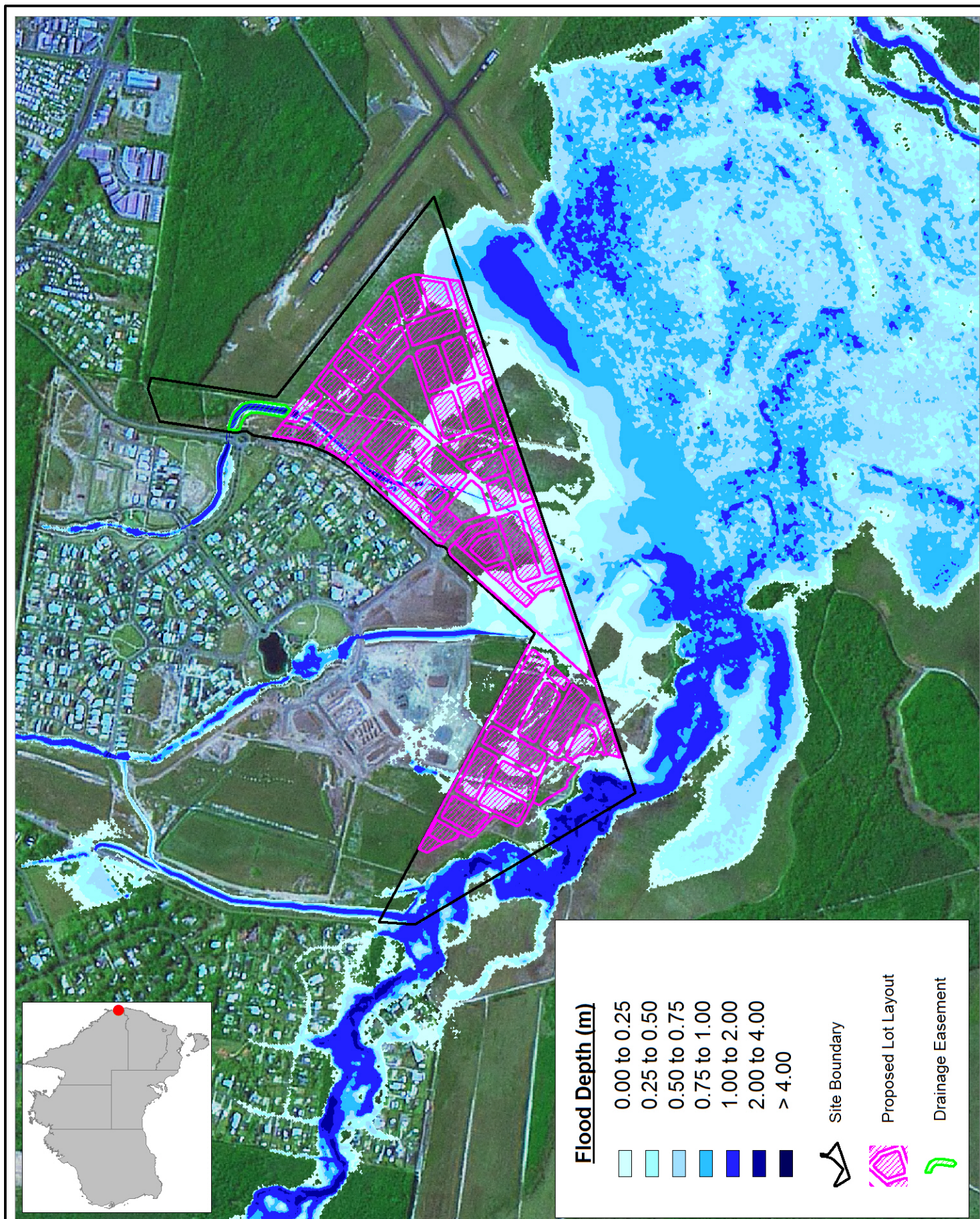
Figure:
5-11

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0 250 500m
Approx. Scale



Title:
50 year ARI Peak Flood Depth for Base Case

Figure:
5-12

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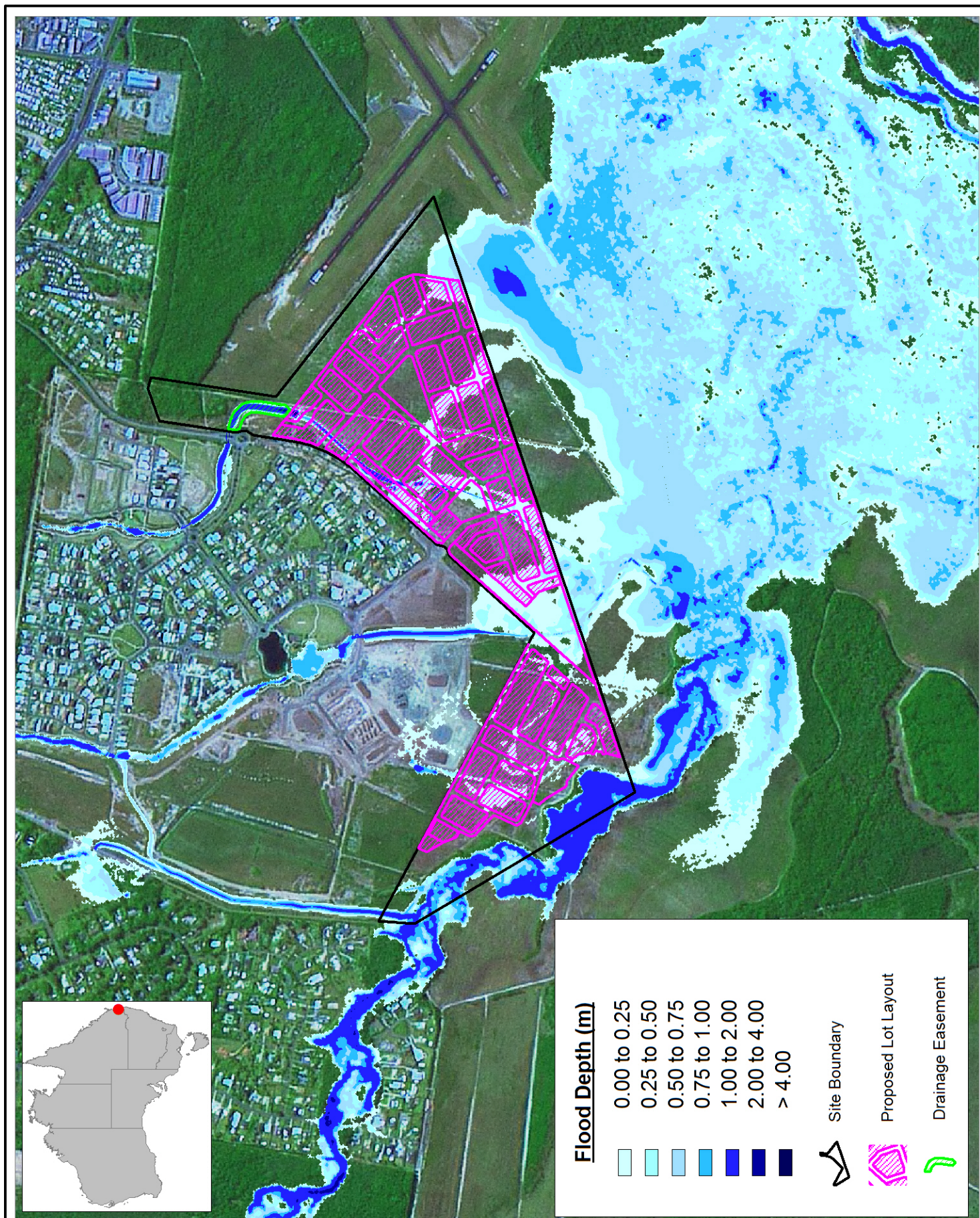
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Title:
5 year ARI Peak Flood Depth for Base Case

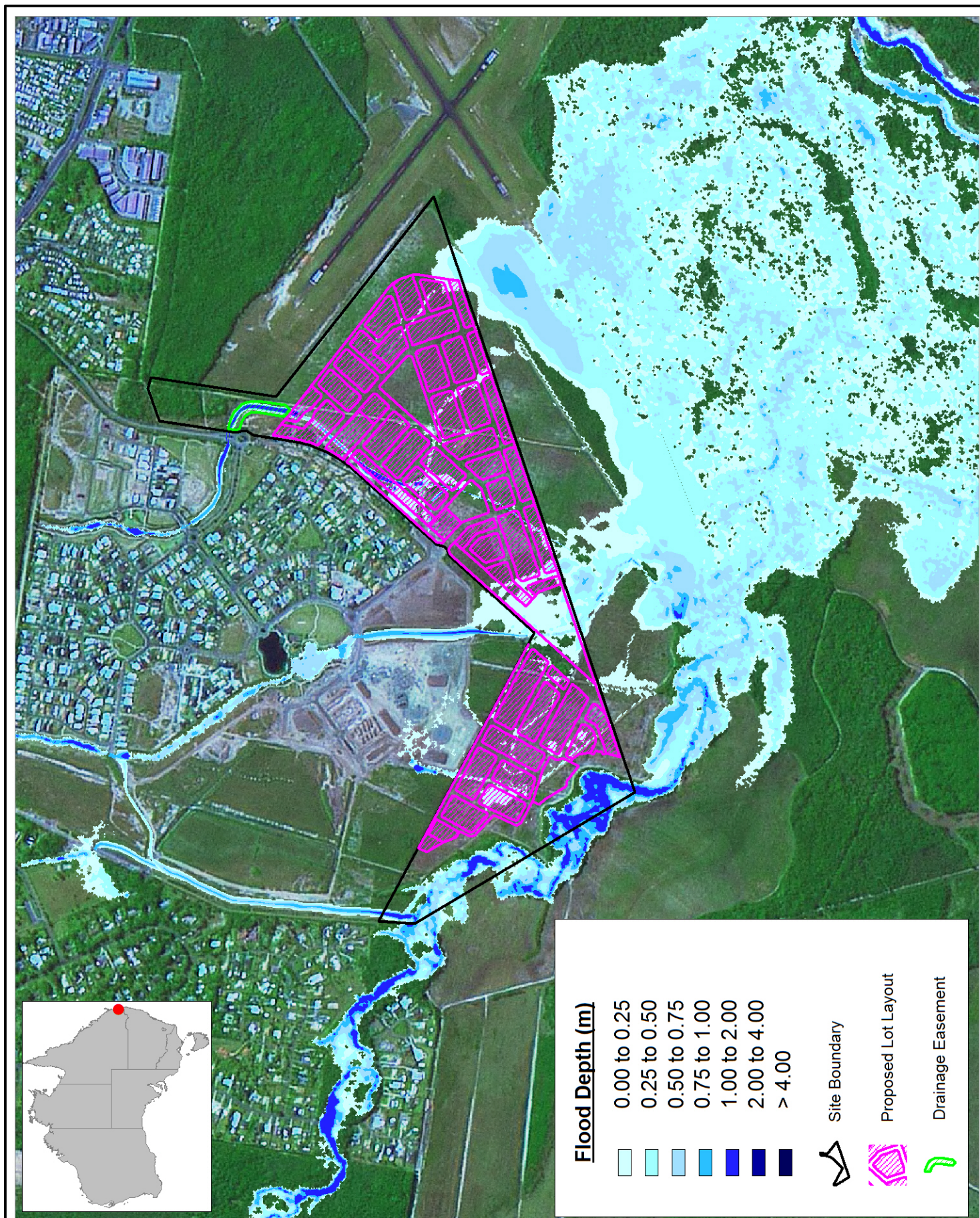
Figure:
5-13

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Title:
1 year ARI Peak Flood Depth for Base Case

Figure:
5-14

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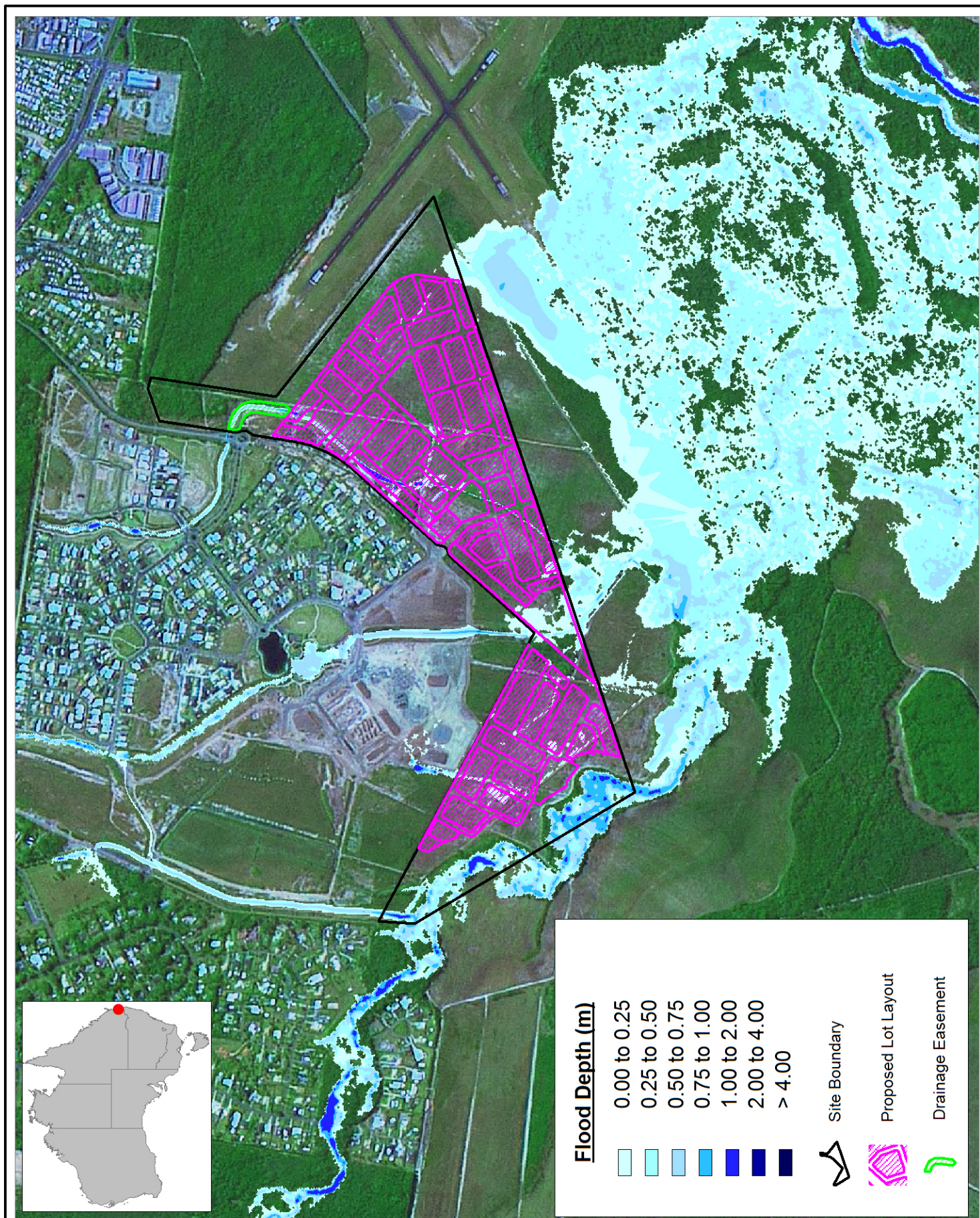
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Title:
3 month ARI Peak Flood Depth for Base Case

Figure:
5-15

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6 FLOOD IMPACT ASSESSMENT

6.1 Introduction

To assess flood impacts associated with the proposed development, hydrological and hydraulic modelling has been undertaken and a comparison between the Base Case (pre-development scenario) and Developed Case (post-development scenario) completed.

The development proposal includes filling over parts of the site to provide a minimum 100 year ARI flood immunity for all proposed urban areas including roads. This filling will be complemented with provision of a number of hydraulic features for stormwater and flood risk management.

6.2 Features of Proposed Development

The key features of the Development Case are presented in Figure 6-1 and include the following general elements:

- All urban areas (i.e. residential and commercial lots and roads) are assumed to be filled above the 100 year ARI design flood including an allowance for climate change impacts plus a 500mm allowance for freeboard;
- A change in Manning's 'n' roughness coefficients in accordance with the land use delineation presented in Figure 3-3 and the information provided by Brown Consulting (2011);
- A drainage corridor (the 'Eastern Drain') along the eastern edge of Precinct 1 connecting the existing drain along Dumbarton Drive and discharging to the wetland to the south of the site. The Eastern Drain corridor has a width of approximately 40m and includes a 15m wide, 2m deep open channel;
- A drainage corridor along the northern edge of Precinct 1, parallel to Bellvista Boulevard. This corridor consists of a set of underground pipes with a high-flow swale that extends between Killbride Court and Stornaway Avenue. West of Stornaway Avenue, there will be an open drainage channel;
- A culvert crossing underneath the proposed extension of Bellvista Boulevard discharging flows from the open space reserve near the Unity College. This culvert crossing consists of eight 2700mm by 1200mm box culverts;
- A minor open drain along the northern edge of Bellvista Boulevard, draining from the Unity College sports field to the proposed culvert crossing underneath Bellvista Boulevard;
- A 70m wide drainage corridor (the 'Central Drainage Corridor') between the Precinct 1 and Precinct 2. The topography of this drainage corridor will be similar to existing natural surface levels;
- Culverts draining the area to the north of Precinct 2 to Lamerough Creek. These culverts comprise of three 1500mm by 750mm box culverts; and
- Two compensatory floodplain storage areas within the site boundary; one to the south of the central drainage channel; and another to the south of the eastern drainage channel.

6.3 Flood Impacts of Proposed Development

The Base Case Bellvista II TUFLOW model was modified to represent the features of the proposed development for the Developed Case model configuration. The fill levels in the urban areas were derived from a ground model provided by Brown Consulting.

The proposed design was subsequently assessed for a range of flood events. Five design flood probabilities (3 month, 1, 5, 50 and 100 year ARI flood events) were simulated with the development features outlined in Section 6.2. For each design flood probability, four design storm durations have been investigated, namely the 1, 3, 6 and 12 hour storm events. Peak flood levels for the Developed Case are shown in Figure 6-2 to Figure 6-6 with peak flood velocities shown in Figure 6-7 to Figure 6-11 and peak flood depth shown in Figure 6-12 to Figure 6-16.

Peak flood levels for the Developed Case were subsequently compared with those of the Base Case to derive flood impact maps. Figure 6-17 to Figure 6-21 show the impacts of the proposed works on the peak flood levels for the range of design events.

6.3.1 100 Year ARI Flood Level Impacts

The impacts of the proposed works on peak flood levels for the 100 year ARI flood event are presented in Figure 6-17. The impacts depicted were derived from a difference between the peak flood envelopes of the four design storm durations considered for the Base Case and Developed Case conditions.

Based on the results of the hydrological and hydraulic modelling undertaken for this assessment, the following is noted regarding the flood level impacts for the 100 year ARI flood event:

- The proposed development will have no significant effect on peak flood levels on the Lamerough Creek floodplain outside of the land in the control of the applicant. Upstream and downstream of the property boundary, peak flood levels will not increase by more than 10mm with the exception of one small area adjacent to Precinct 2.
- Immediately to the north of the proposed development, on the open space reserve that is located between Bellvista Boulevard and the Unity College, flood levels are predicted to increase by up to approximately 550mm. These impacts will be confined to the reserve and no flood level impacts are predicted to the north of the reserve.
- There are localised flood level increases in the Central Drainage Channel and where the Central Drainage Channel discharges to the south of Bellvista Boulevard, but these increases are quickly dissipated. To the south of these localised increases is an area of minor decreases in water level due to the change in the Central Drainage channel in the Developed Case.
- Due to the proposed drainage system of the Bellvista II development, drainage of parts of the existing Bellvista I development (i.e. areas around the road corridors of Kilbride Court and Rosslare Street) are predicted to improve.

6.3.2 50 Year ARI Flood Level Impacts

The impacts of the proposed works on peak flood levels for the 50 year ARI flood event are presented in Figure 6-18.

Based on the results of the hydrological and hydraulic modelling undertaken for this assessment, the following is noted regarding the flood level impacts for the 50 year ARI flood event:

- The proposed development will have no significant effect on peak flood levels on the Lamerough Creek floodplain outside of the land in the control of the applicant. Upstream and downstream of the property boundary, peak flood levels will not increase by more than 10mm with the exception of one small area adjacent to Precinct 2.
- Immediately to the north of the proposed development, on the open space reserve that is located between Bellvista Boulevard and the Unity College, flood levels are predicted to increase by up to approximately 500mm. These impacts will be confined to the reserve and no flood level impacts are predicted to the north of the reserve.
- Flood levels within the drainage corridor along Dumbarton Drive (an existing drain to the northeast of the proposed development) will decrease. Immediately upstream of the development, flood level decreases of up to approximate 1m will be experienced.

6.3.3 5 Year ARI Flood Level Impacts

The impacts of the proposed works on peak flood levels for the 5 year ARI flood event are presented in Figure 6-19.

Based on the results of the hydrological and hydraulic modelling undertaken for this assessment, the following is noted regarding the flood level impacts for the 5 year ARI flood event:

- The proposed development will have no significant effect on peak flood levels on the Lamerough Creek floodplain. Upstream and downstream of the property boundary, peak flood levels do not increase by more than 10mm.
- Immediately to the north of the proposed development, on the open space reserve that is located between Bellvista Boulevard and the Unity College, flood levels are predicted to increase by up to approximately 415mm. These impacts will be confined to the reserve and no flood level impacts are predicted to the north of the reserve.
- Flood levels within the drainage corridor along Dumbarton Drive (an existing drain to the northeast of the proposed development) will decrease. Immediately upstream of the development, flood level decreases of up to approximate 1m will be experienced.

6.3.4 Impacts of Proposed Works on Flood Flow Patterns

The peak flow velocities for the Developed Case (i.e. flow velocities at the peak of the combined design flood events for the case with the proposed development) are presented in Figure 6-7 to Figure 6-11. Comparing these results with those for the Base Case (Refer to Figure 5-6 to Figure 5-10), it can be concluded that flow velocities on the floodplain surrounding the development site will generally not significantly change due to the proposed development.

Of particular interest are the mapped wetlands and PMAV areas on the Caloundra Aerodrome site, immediately to the south of the development site. Potential flood impacts on these wetlands are discussed in section 6.3.5.

6.3.5 Impacts on Wetland

The development proposals include formalising the drainage at the site to primarily be conveyed by three drainage channels which has the potential to impact on the mapped wetlands downstream of the development site. Potential impacts from increased flood levels, increased flood velocities and increased retention times have been assessed for the 3 month, 1, 5, 50 and 100 year ARI design flood events.

Reference to Figure 6-21, the flood level impact map for the 3 month events indicates there are minor impacts on flood levels. In the 3 month design flood events, there are some small areas of minor increases in flood levels to the south of the western channel although these are generally less than 30mm. There are other minor impacts, however, these are generally immediately downstream of the flow discharge points and the increased flood levels dissipate rapidly. Elsewhere there are no increases in flood levels in the wetlands within a tolerance of +/- 10mm with some exceptions.

Impacts on flood flow velocities were also considered. Immediately adjacent to flow discharge points, flow velocities are locally increased due to the formalisation of the stormwater drainage across the site. However, these increases rapidly dissipate. It is of note that flood velocities in the wetlands are low during all flood events considered; flow velocities are typically around 0.2m/s for flood events up to and including the 100 year ARI flood events. The velocity results indicate that there is no significant increase in flood flow velocities throughout the mapped wetlands.

Changes in retention times have been evaluated at a number of points throughout the wetland. Plots of flood level with time for the 1 year and 3 month 6 hour events respectively are displayed in Figure 6-22 and Figure 6-23 for the Base Case and the Developed Case. These figures indicate there is no significant change in the shape of the water level verses time curves although there is a slight alteration of in the timing of the onset of inundation. Overall there are no significant changes in Retention Time.

6.4 Floodwater Storage Volume Assessment

The predicted impacts of the proposed development on the flood behaviour have been comprehensively assessed using the hydraulic model (see above). The modelling analysis included the assessment of the dynamic effects of changes to floodplain storage, flood conveyance capacity and runoff characteristics that will result from the proposed development.

However, in order to isolate and quantify the effects of the proposed development on floodwater storage capacity of the Lamerough Creek river system, a floodwater storage volume assessment was undertaken, based on the impacts on regional flooding only.

To assess the change in floodwater storage volume of the Lamerough Creek floodplain, the peak floodwater volume contained on the subject site under pre-development and post-development conditions for the 100 year ARI regional flood event¹ was calculated by Brown Consulting.

Details of these calculations are contained in Appendix E. The results of these calculations are presented in Table 6-1.

¹ Based on 100 year ARI flood level from (SKM, 2006)

Table 6-1 Changes to Floodwater Storage Volume on Site

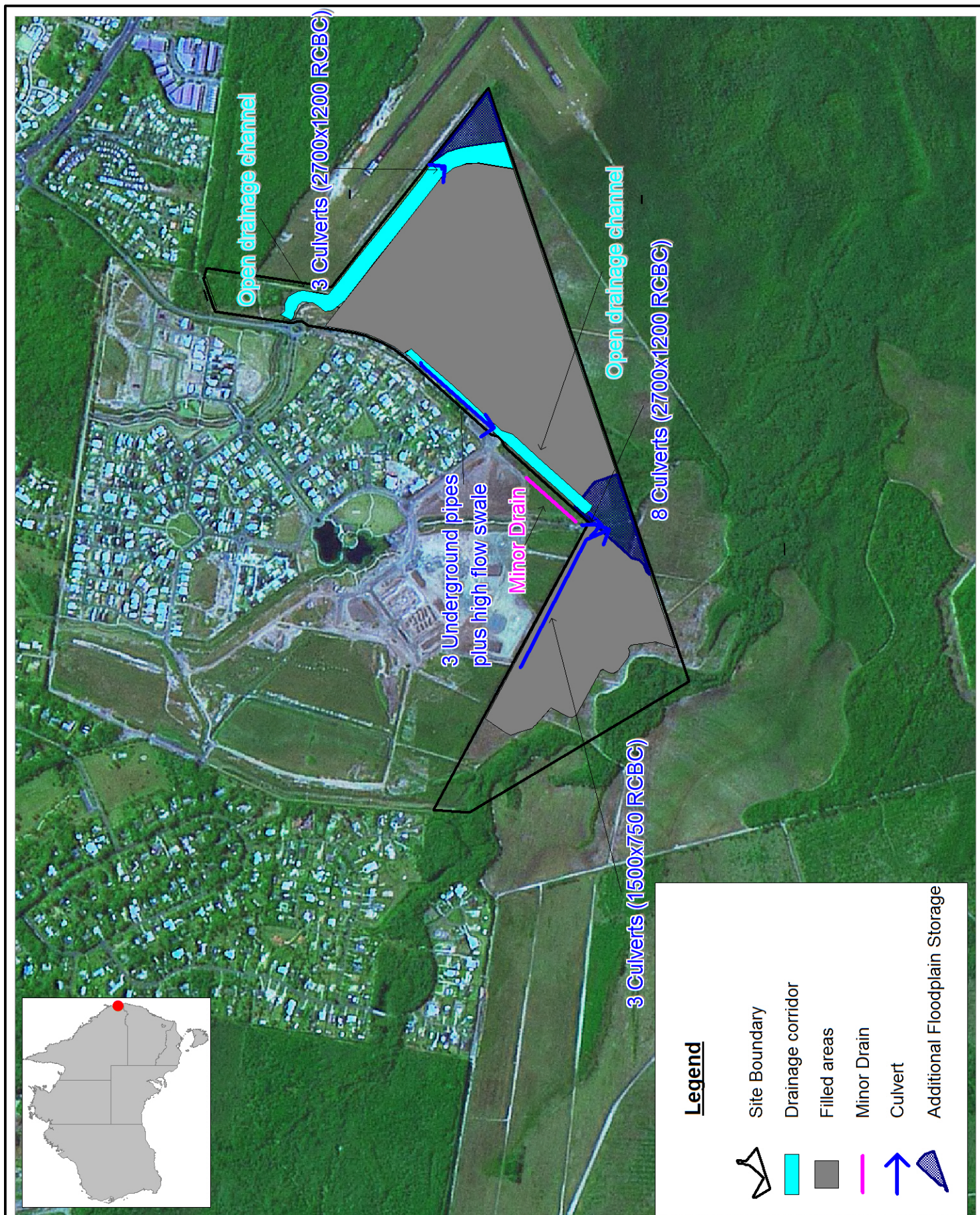
Design Flood Event (Regional Flooding¹)	Existing Floodplain Storage Volume (m³)	Post- Development Floodplain Storage Volume (m³)	Net Floodplain Gain (m³)
100 yr ARI	27,700	28,300	+600

Table 6-1 indicates that there is a net gain in floodplain storage.

6.5 Conclusions

Based on the flood impact assessment undertaken, the following can be concluded regarding the flood impacts associated with the proposed development:

- The proposed development will have no significant effect on peak flood levels on the Lamerough Creek floodplain. Upstream and downstream of the property boundary, peak flood levels will not increase by more than 10mm during the 100 year ARI, 50 year ARI and 5 year ARI flood events with the exception of a one small area.
- Immediately to the north of the proposed development, localised flood level impacts are predicted to occur on the open space reserve that is located between Bellvista Boulevard and the Unity College. These flood level impacts will, however, be confined to the reserve only (no significant flood level impacts are predicted upstream of the reserve). Due to the absence of development on the affected land, there will be no impact on existing properties.
- Due to the proposed drainage system of the Bellvista II development, drainage of parts of the existing Bellvista Estate (i.e. areas around the road corridors of Killbride Court and Rosslare Street) are predicted to improve.
- The proposed development will generally not significantly alter the flood flow patterns on the Lamerough Creek floodplain surrounding the development site. Peak velocities on the mapped wetlands and the PMAV areas on the existing Caloundra Aerodrome site will not significantly change due to the development and remain low (generally less than 0.2m/s). Such low flow velocities are considered not to damage vegetation in the area
- There is a net gain in floodplain storage.



Title:

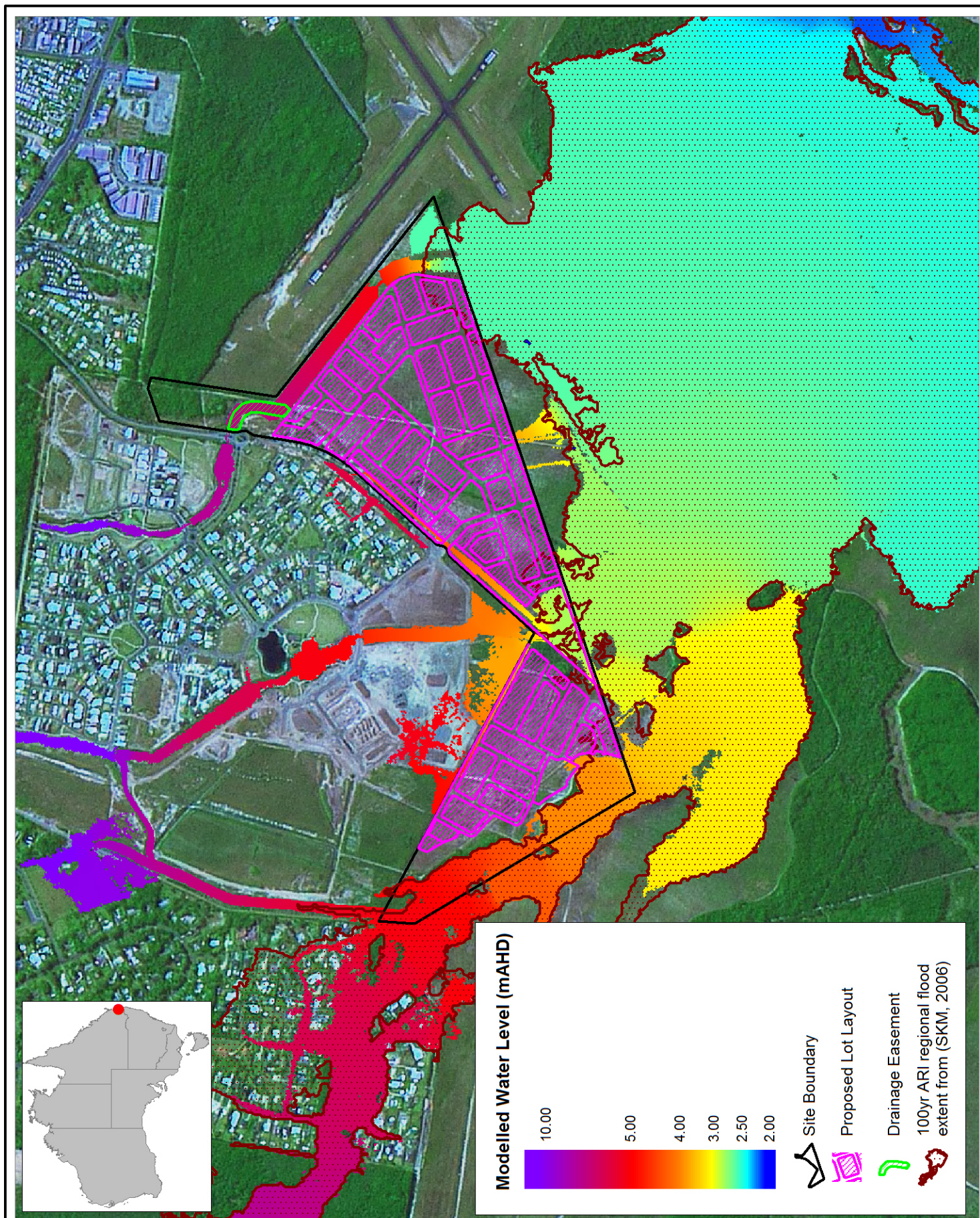
Key Features of the Ultimate Development Case

Figure:
6-1

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Title:
100 year ARI Peak Flood Levels for Developed Case

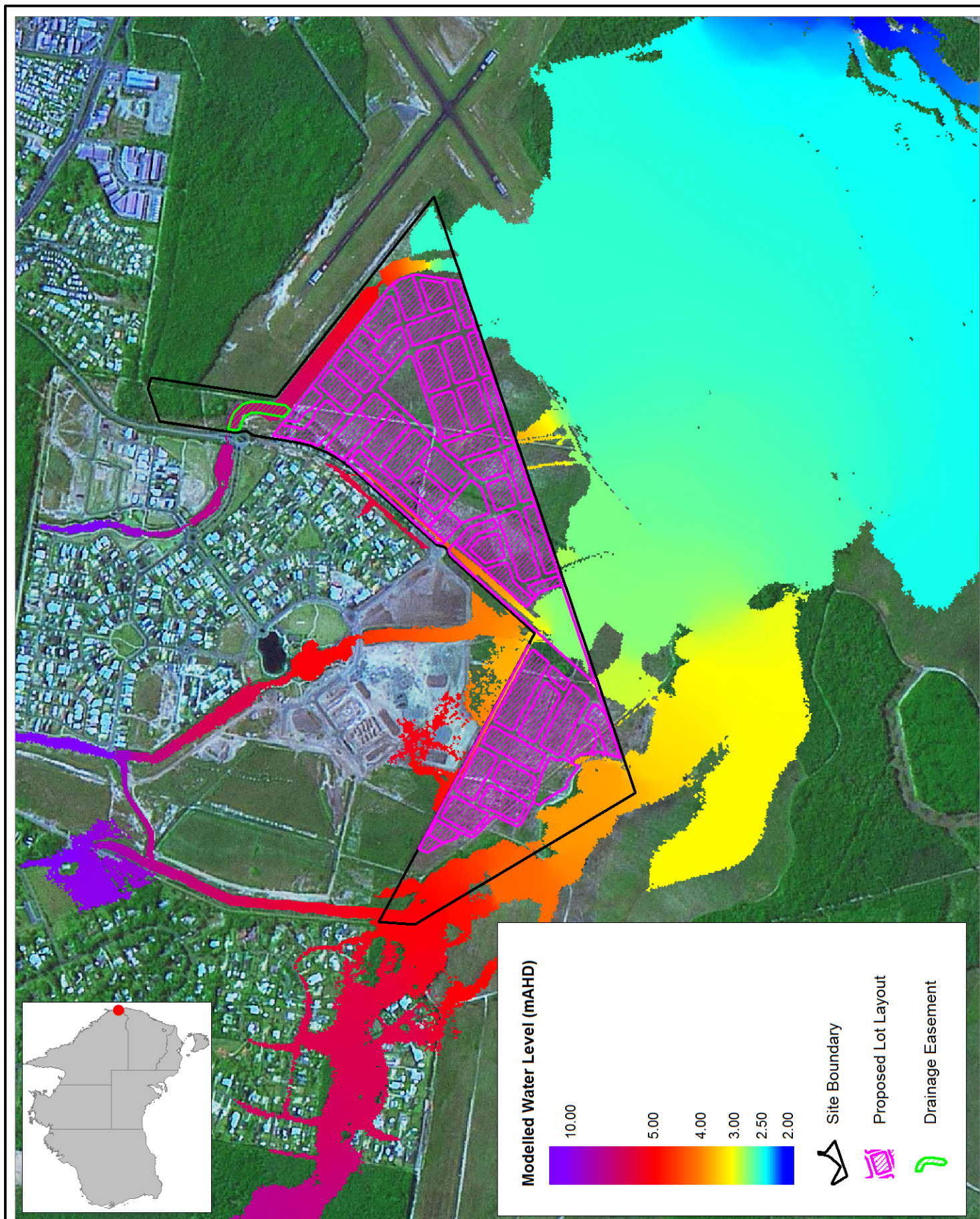
Figure:
6-2

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0 250 500m
Approx. Scale



Title:
50 year ARI Peak Flood Levels for Developed Case

Figure:
6-3

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A

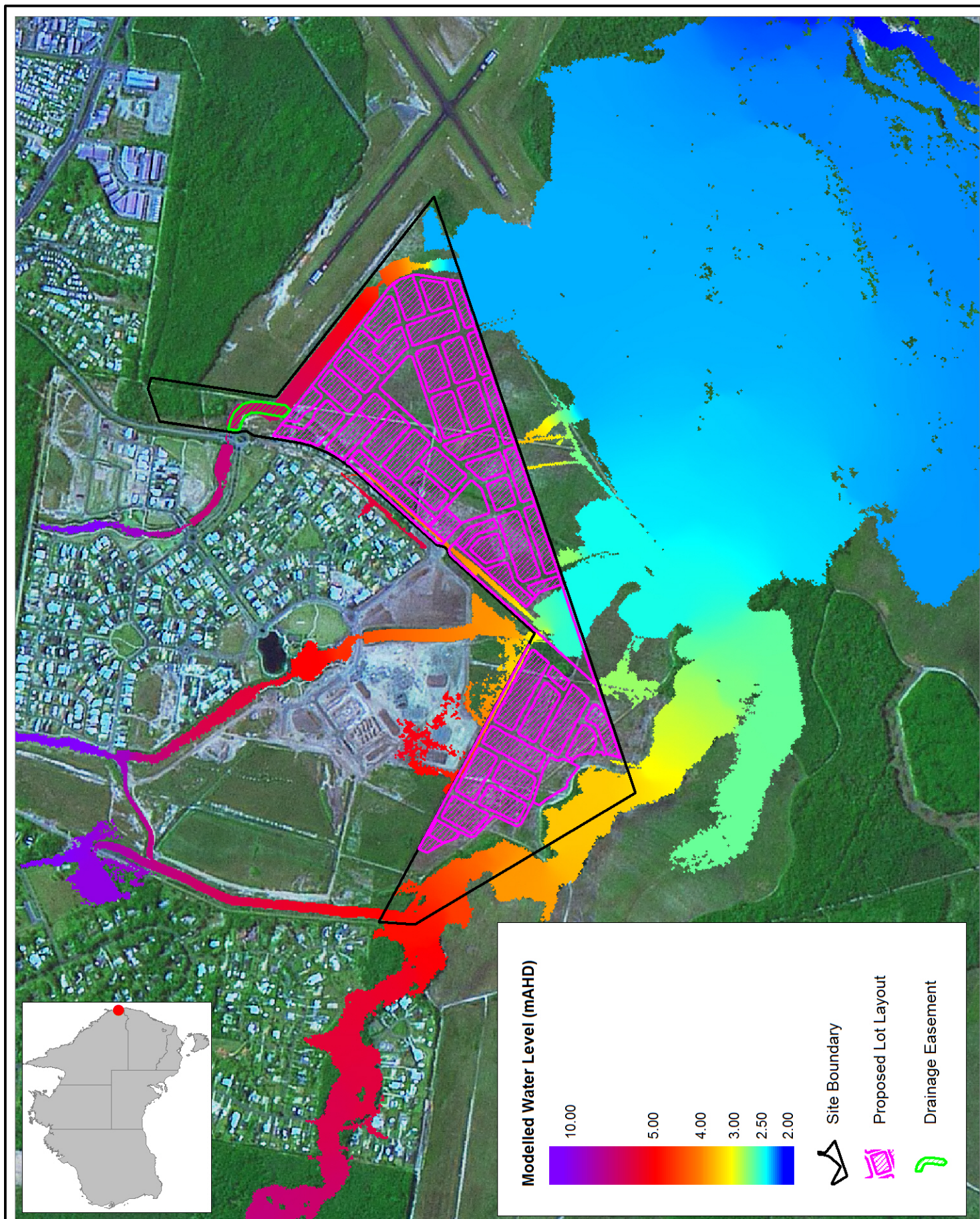
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Title:
5 year ARI Peak Flood Levels for Developed Case

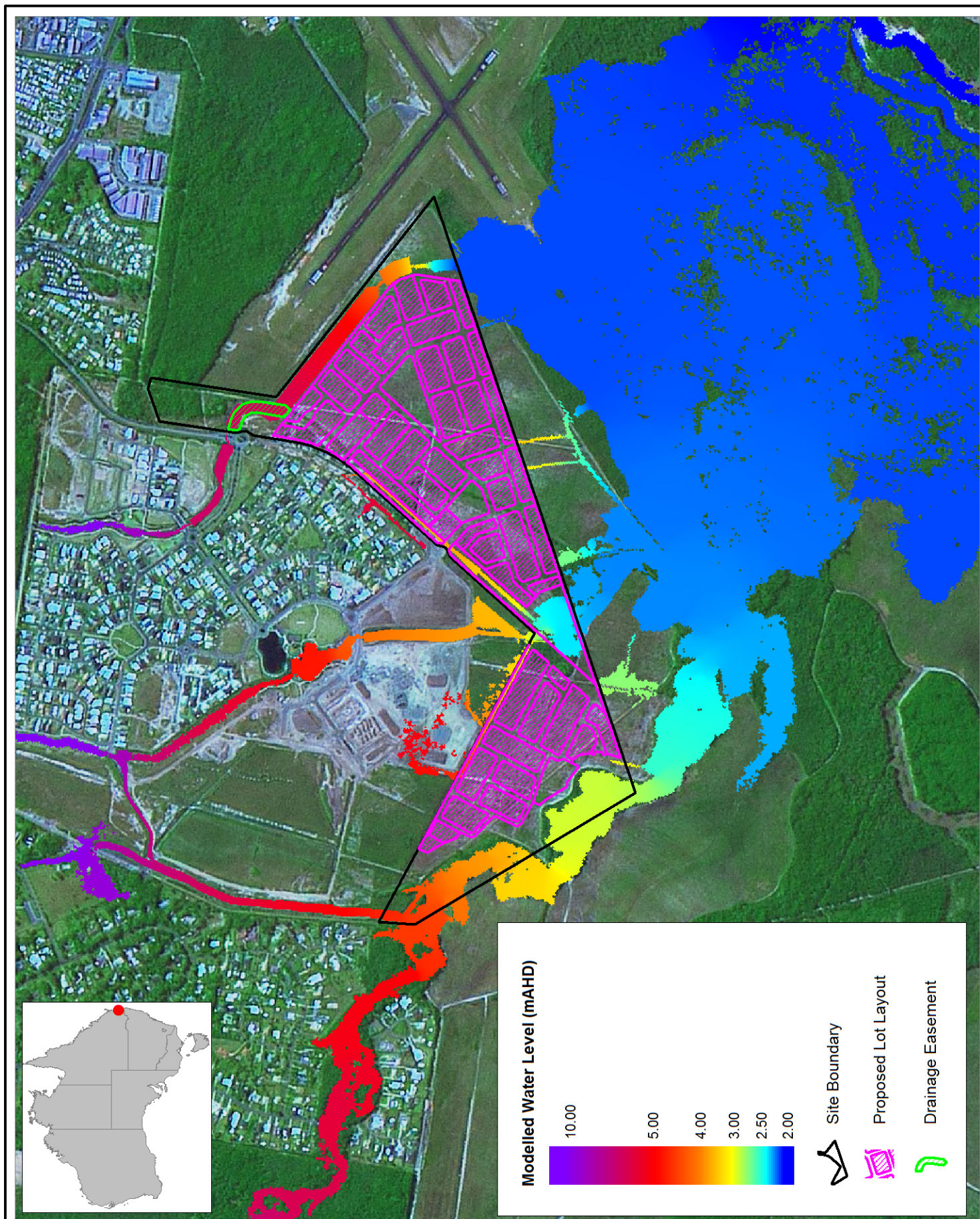
Figure:
6-4

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0 250 500m
Approx. Scale



Title:
1 year ARI Peak Flood Levels for Developed Case

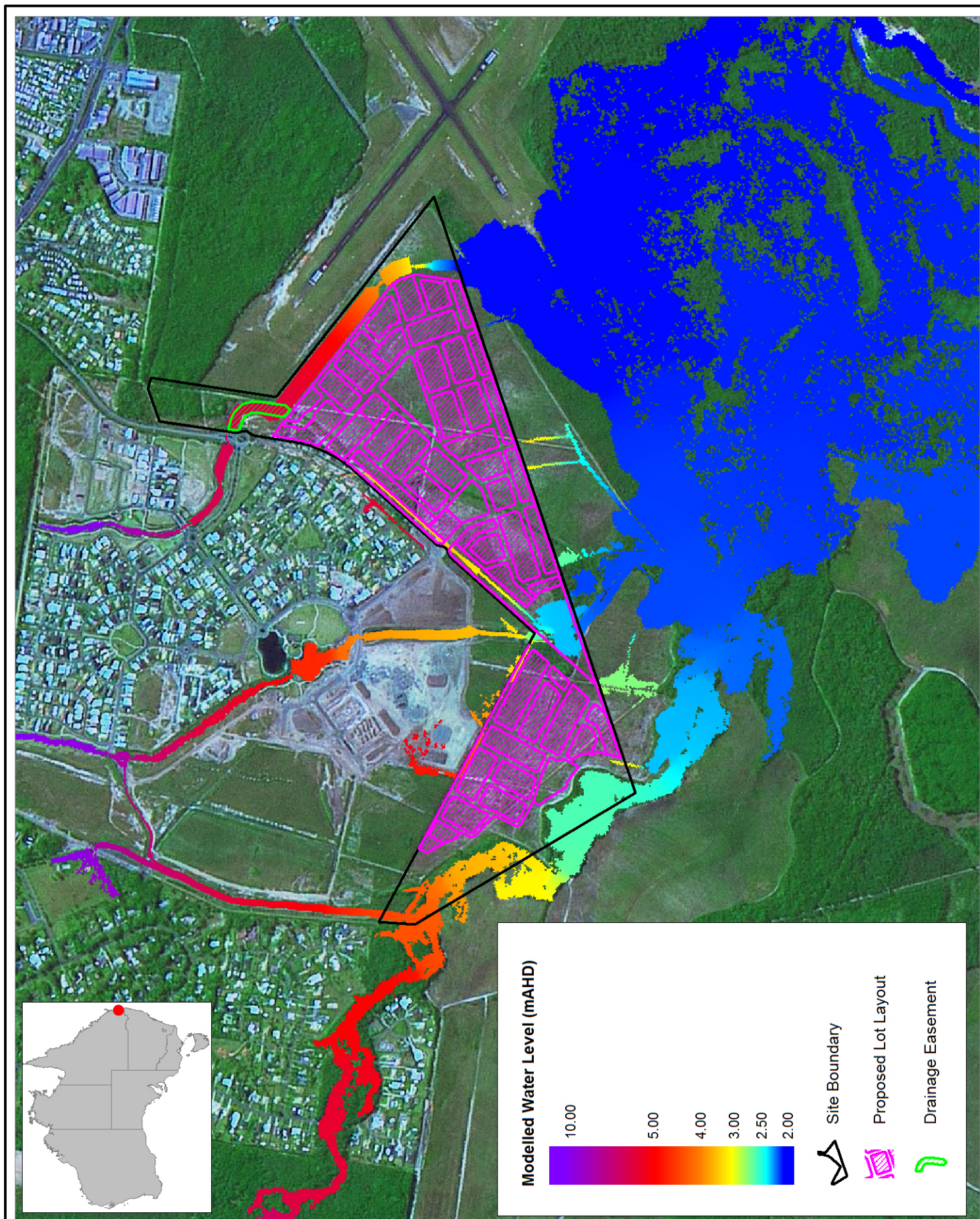
Figure:
6-5

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0 250 500m
Approx. Scale



Title:
3 month ARI Peak Flood Levels for Developed Case

Figure:
6-6

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A

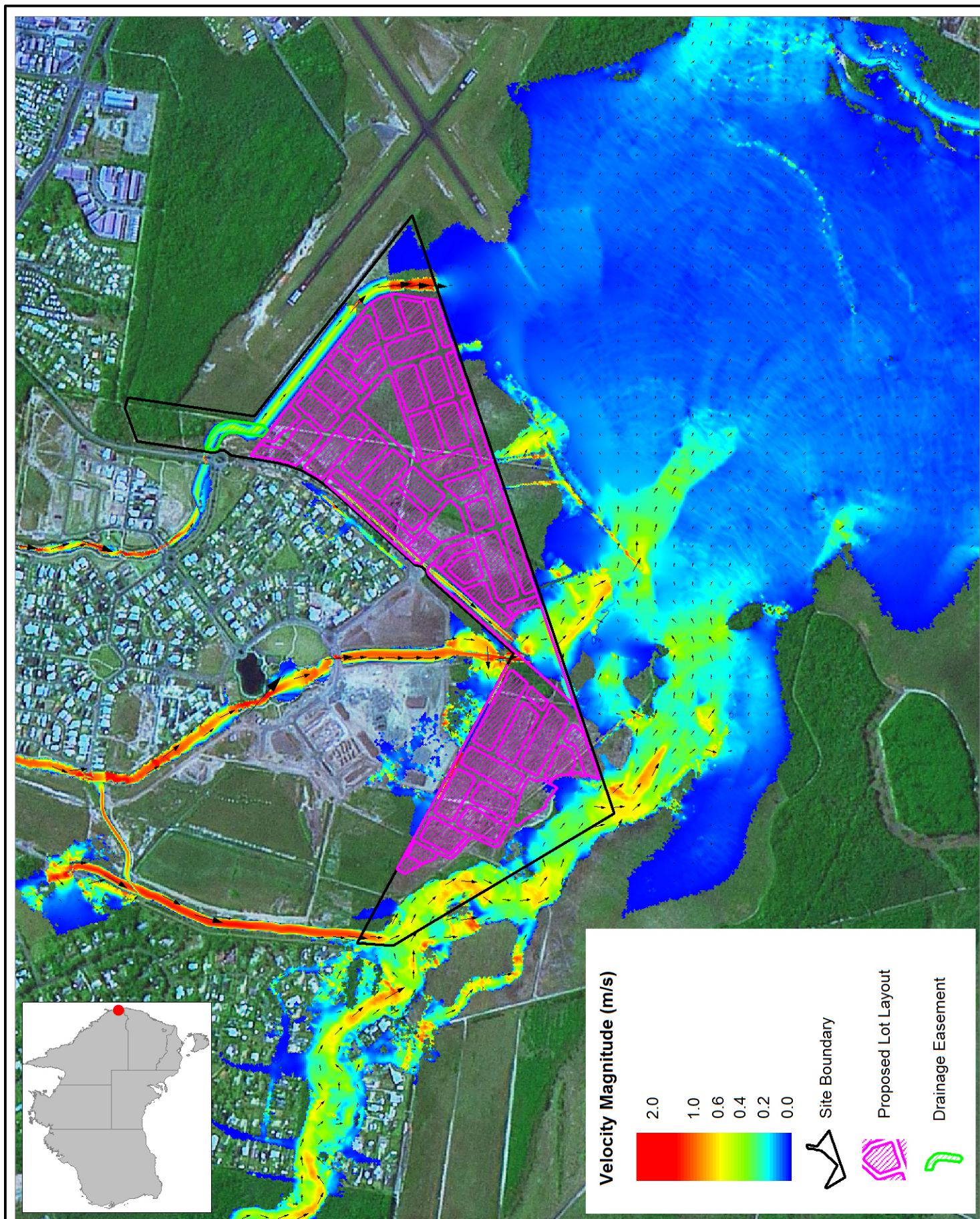
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Title:
100 year ARI Peak Flood Velocities for Developed Case

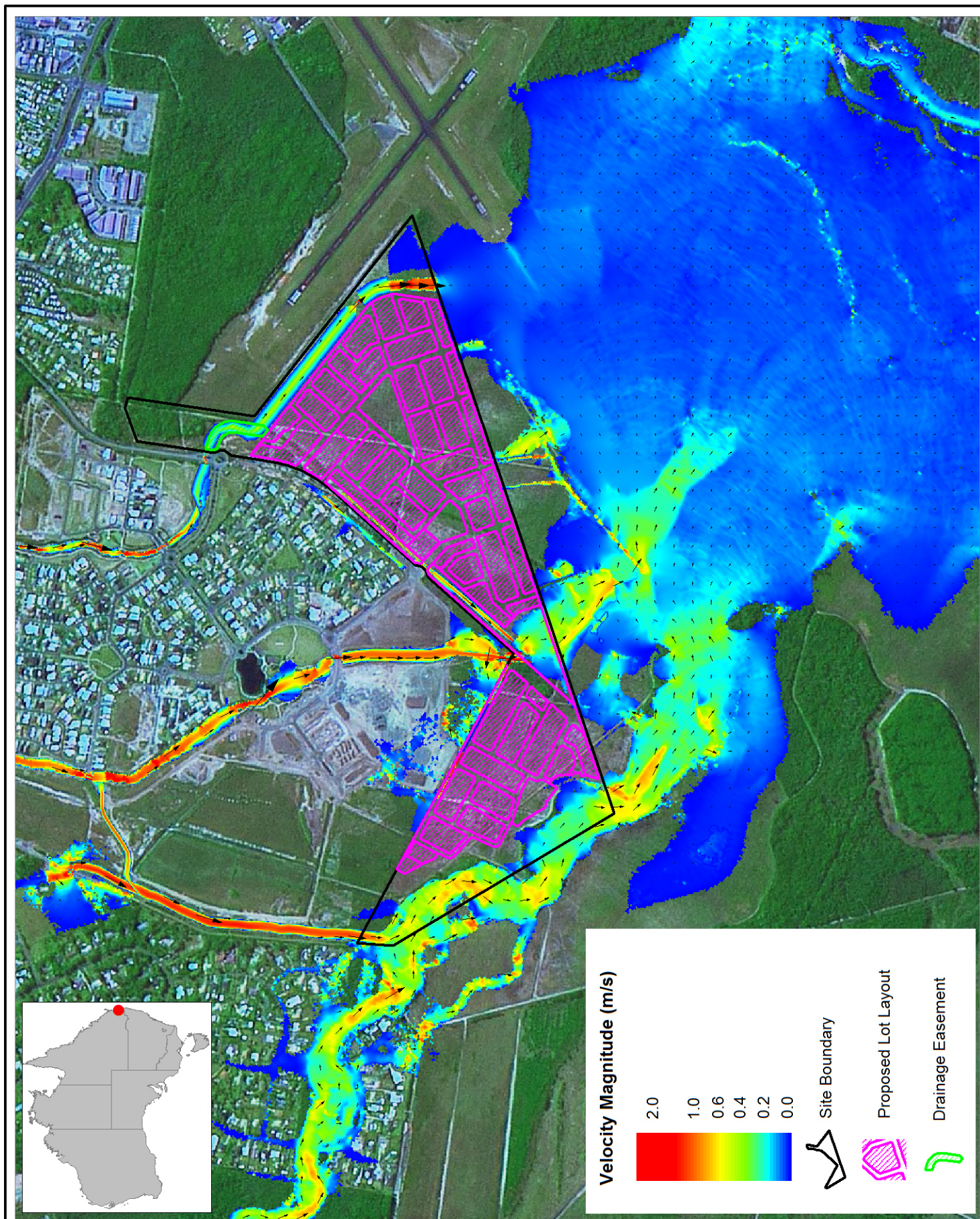
Figure:
6-7

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Title:
50 year ARI Peak Flood Velocities for Developed Case

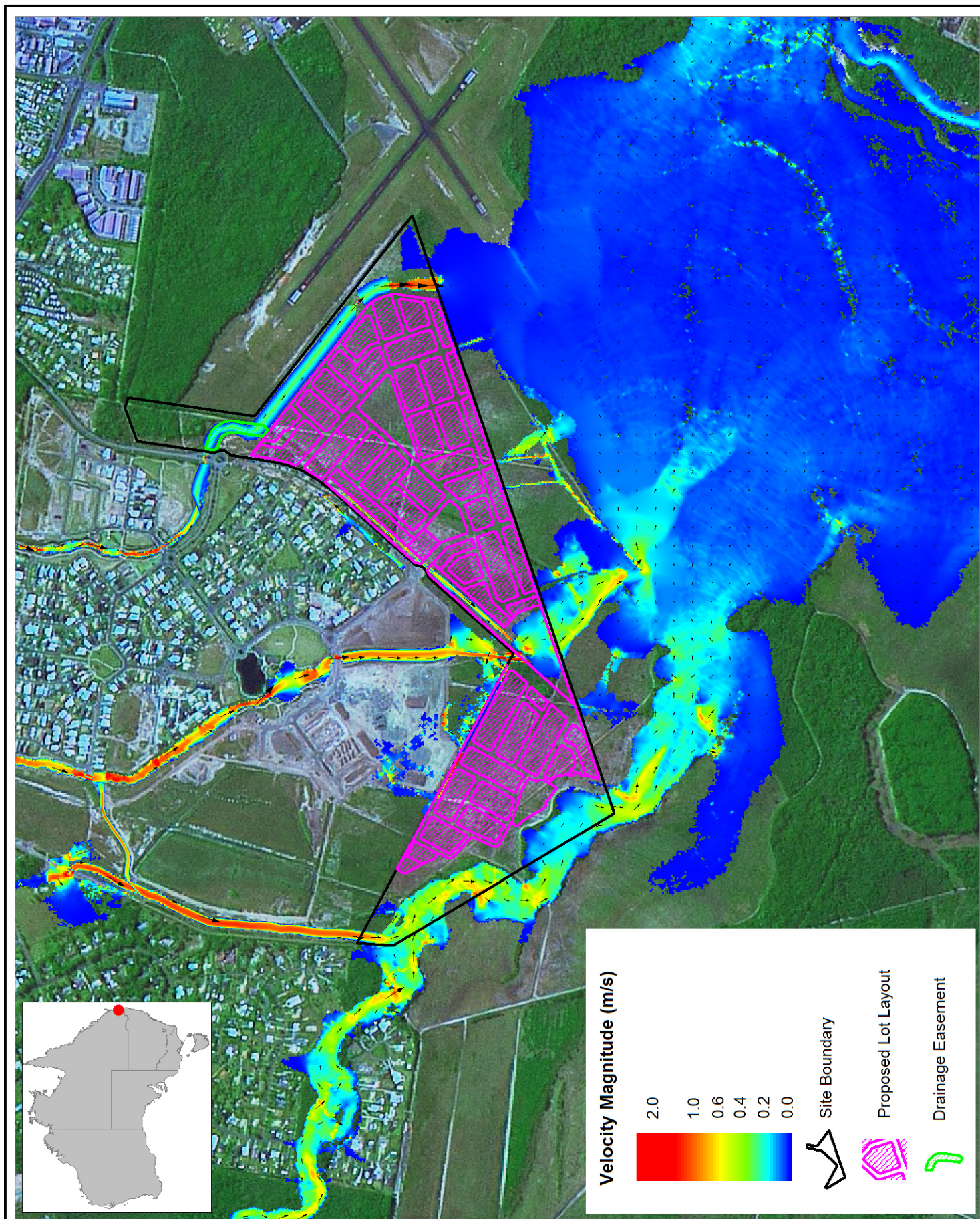
Figure:
6-8

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0 250 500m
Approx. Scale



Title:
5 year ARI Peak Flood Velocities for Developed Case

Figure:
6-9

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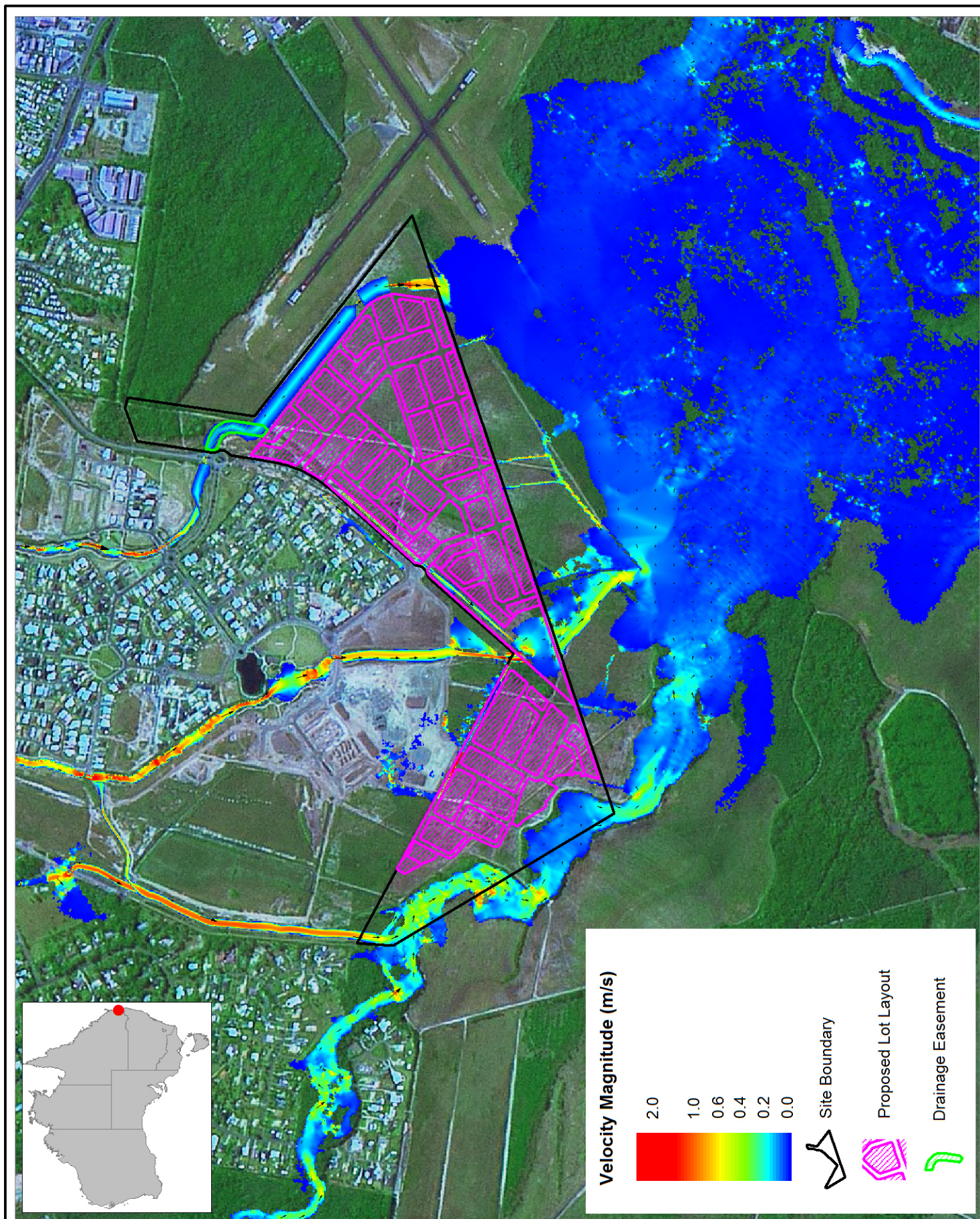
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Approx. Scale



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Title:
1 year ARI Peak Flood Velocities for Developed Case

Figure:
6-10

Rev:
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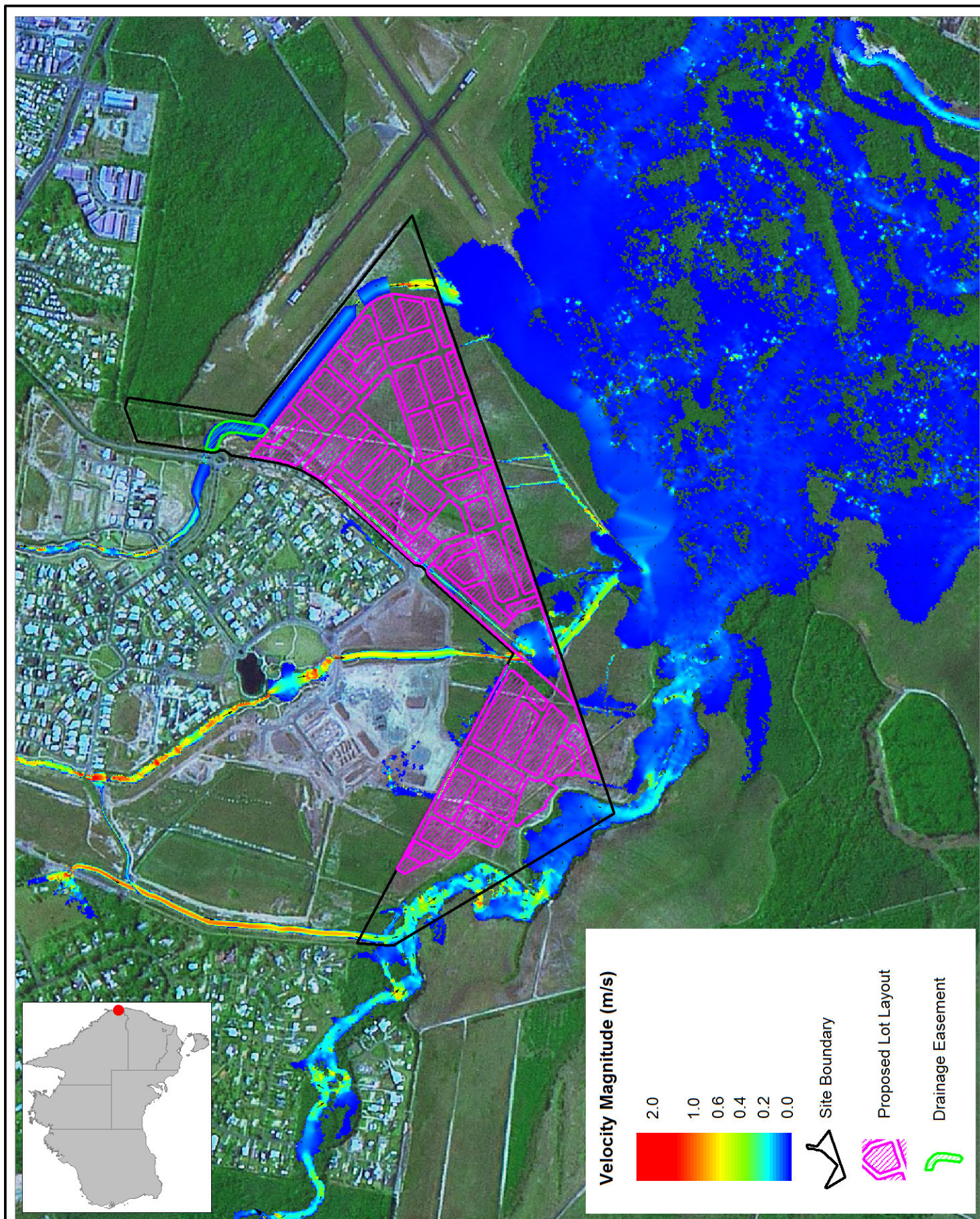
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Title:
3 month ARI Peak Flood Velocities for Developed Case

Figure:
6-11

Rev:
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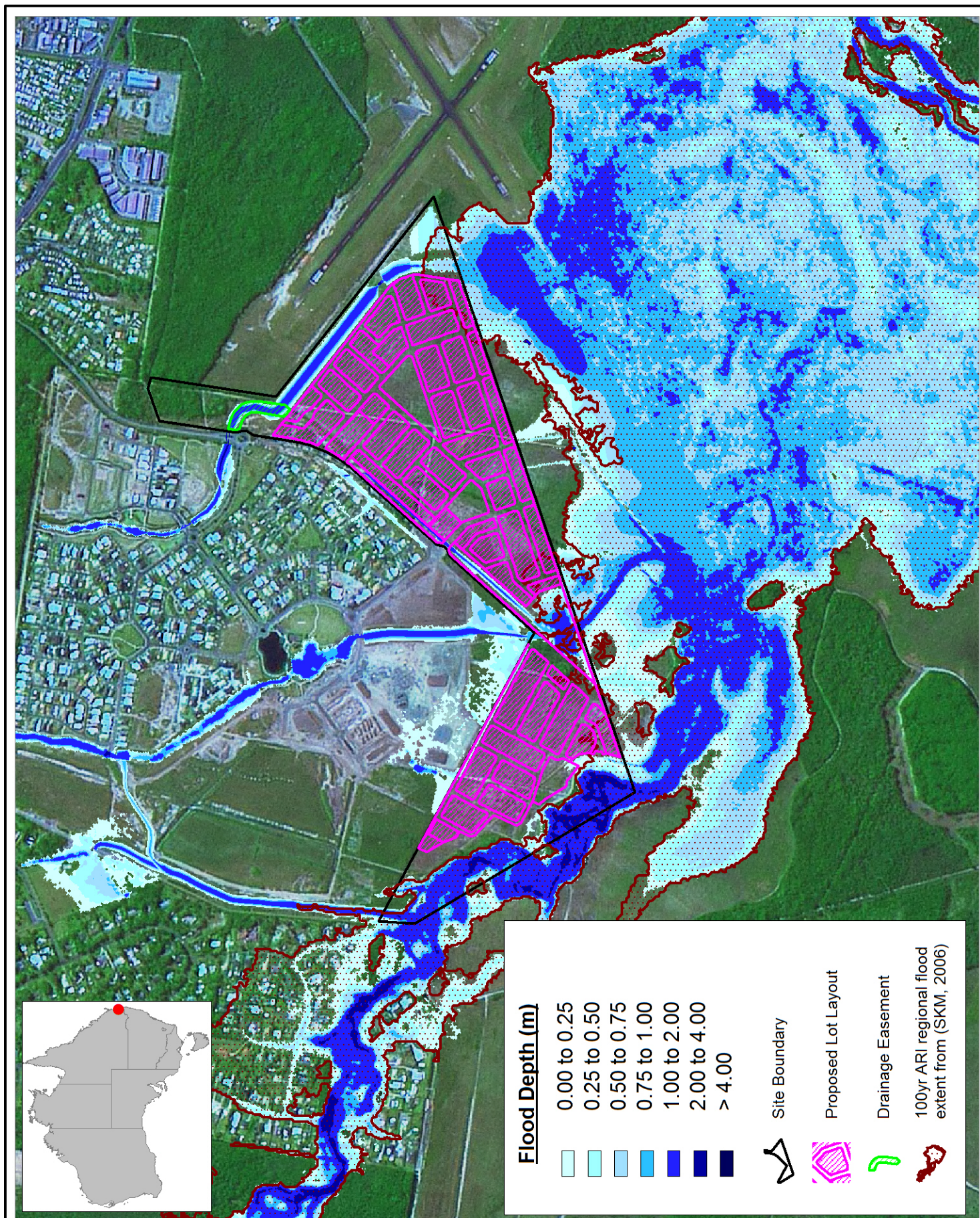
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Title:
100 year ARI Peak Flood Depth for Developed Case

Figure:
6-12

Rev:
A

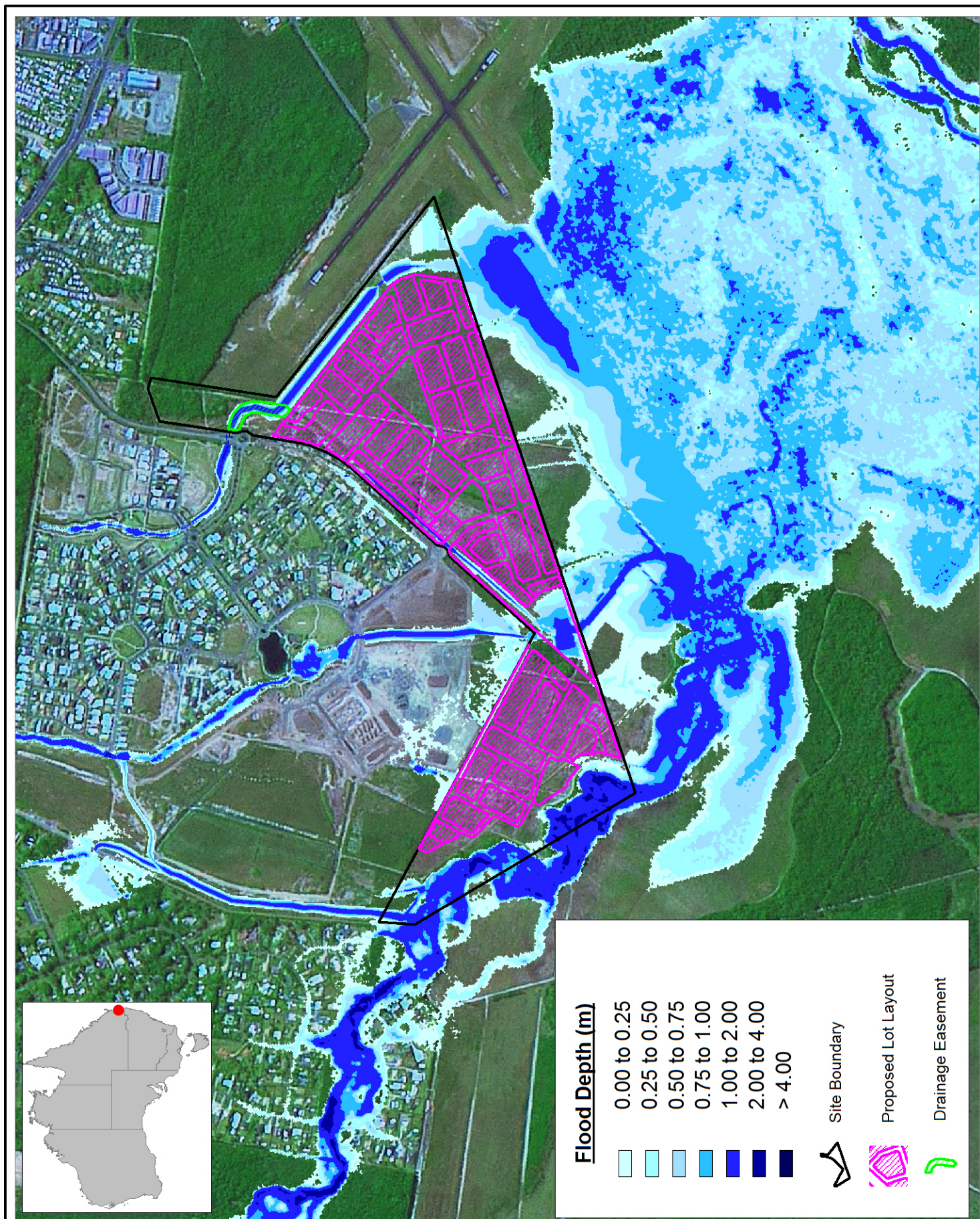
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Title:
50 year ARI Peak Flood Depth for Developed Case

Figure:
6-13

Rev:
A

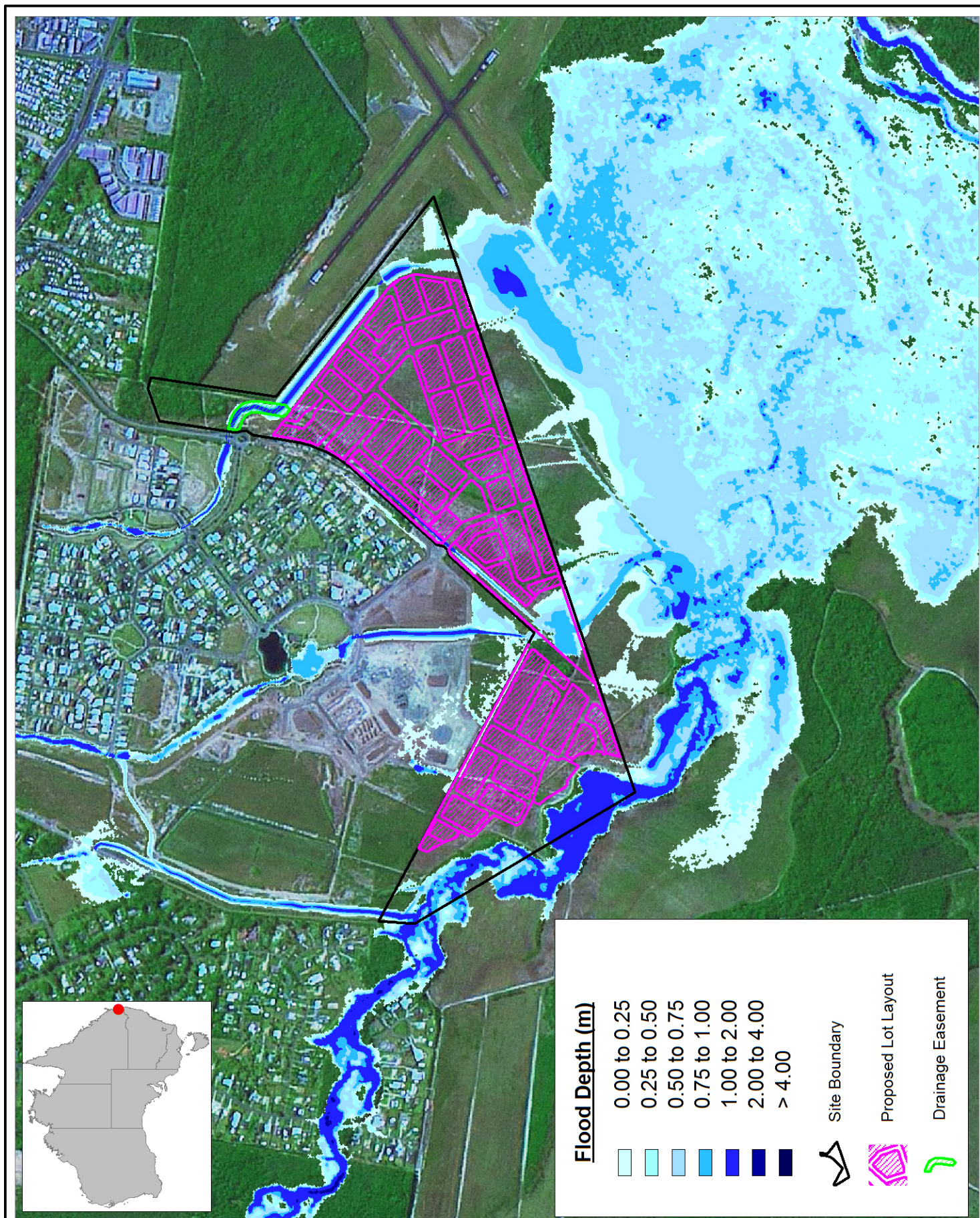
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Title:
5 year ARI Peak Flood Depth for Developed Case

Figure:
6-14

Rev:
A

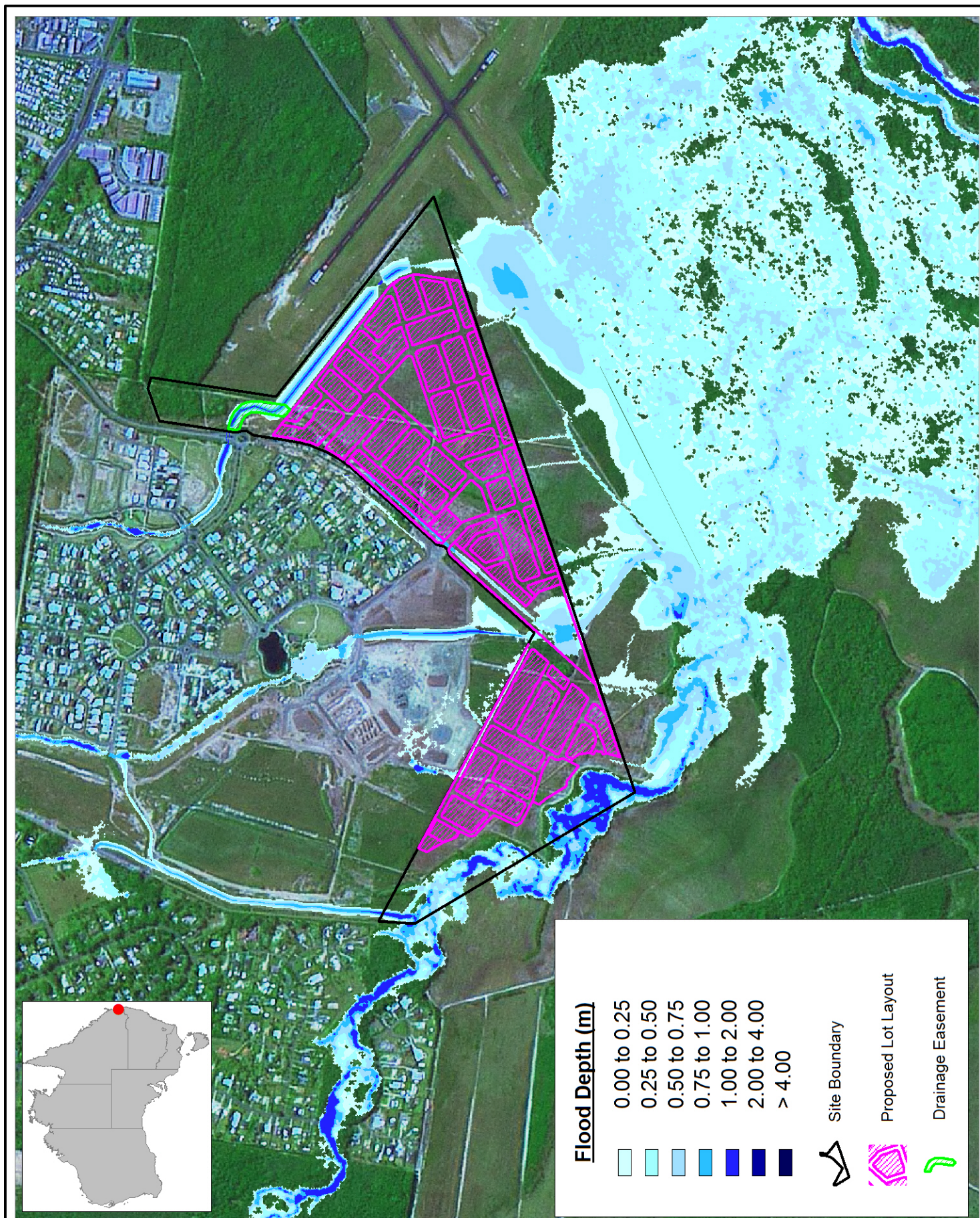
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Title:
1 year ARI Peak Flood Depth for Developed Case

Figure:
6-15

Rev:
A

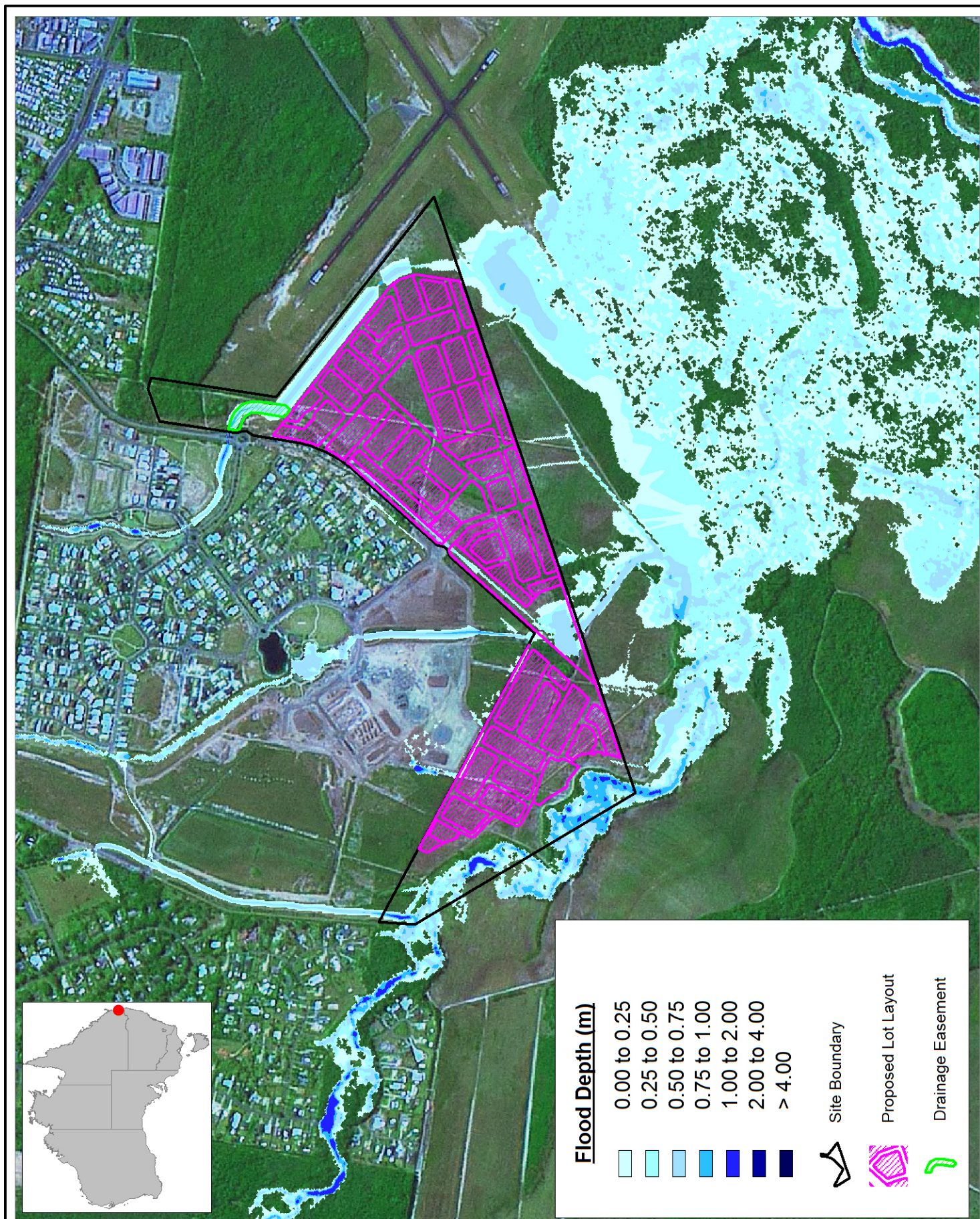
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Title:
3 month ARI Peak Flood Depth for Developed Case

Figure:
6-16

Rev:
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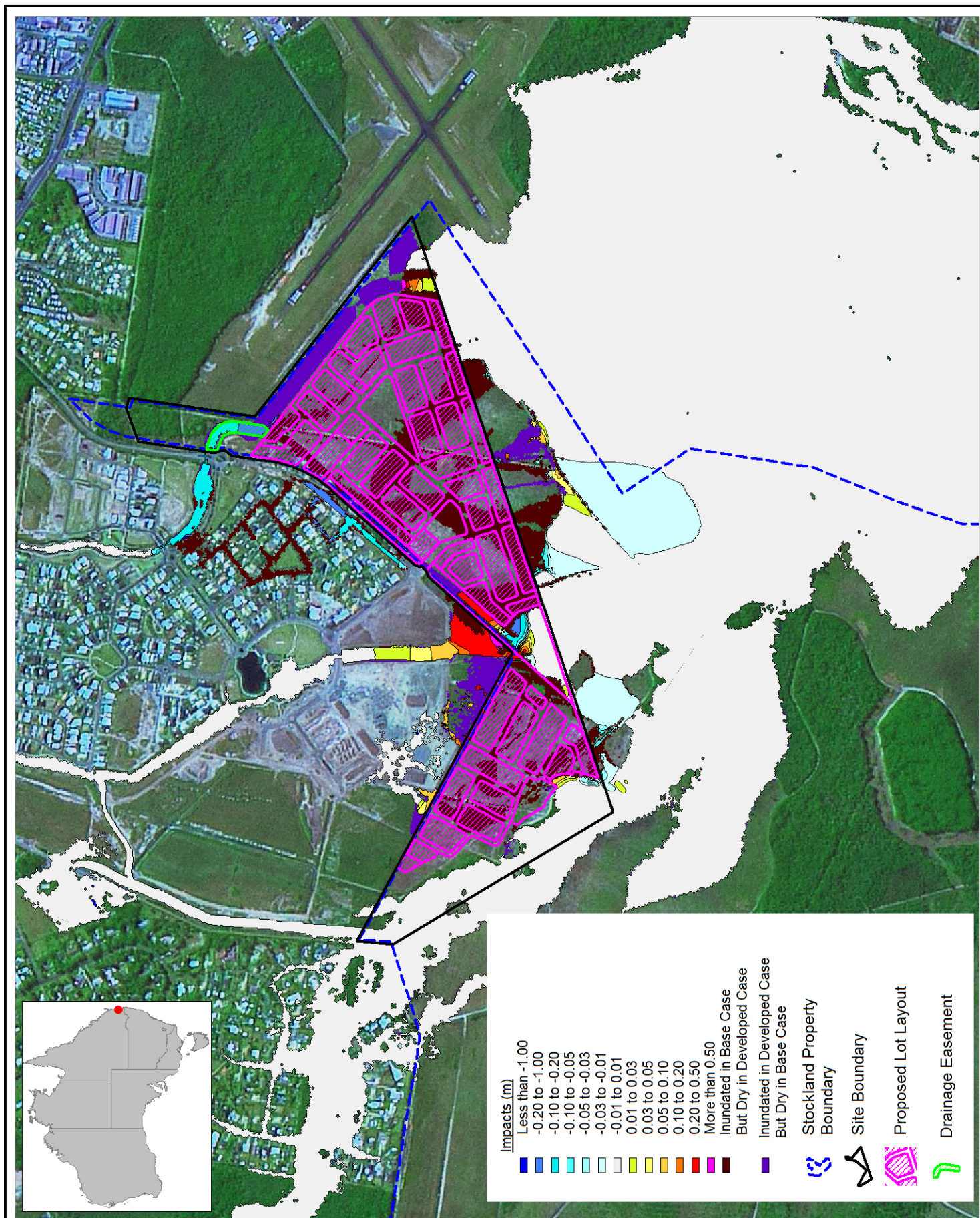
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Title:
100 year ARI Peak Flood Level Impacts

Figure:
6-17

Rev:
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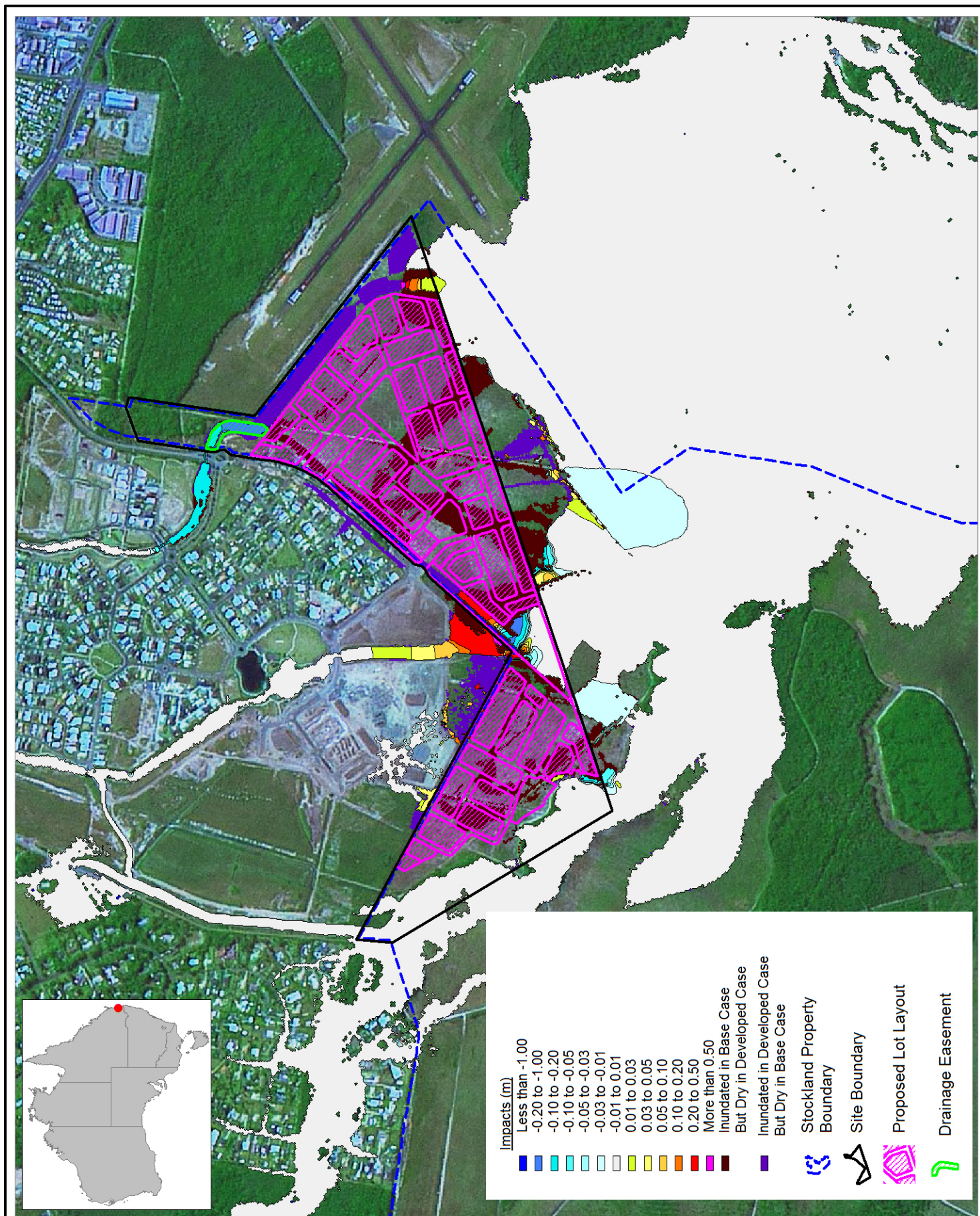
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Title:
50 year ARI Peak Flood Level Impacts

Figure:
6-18

Rev:
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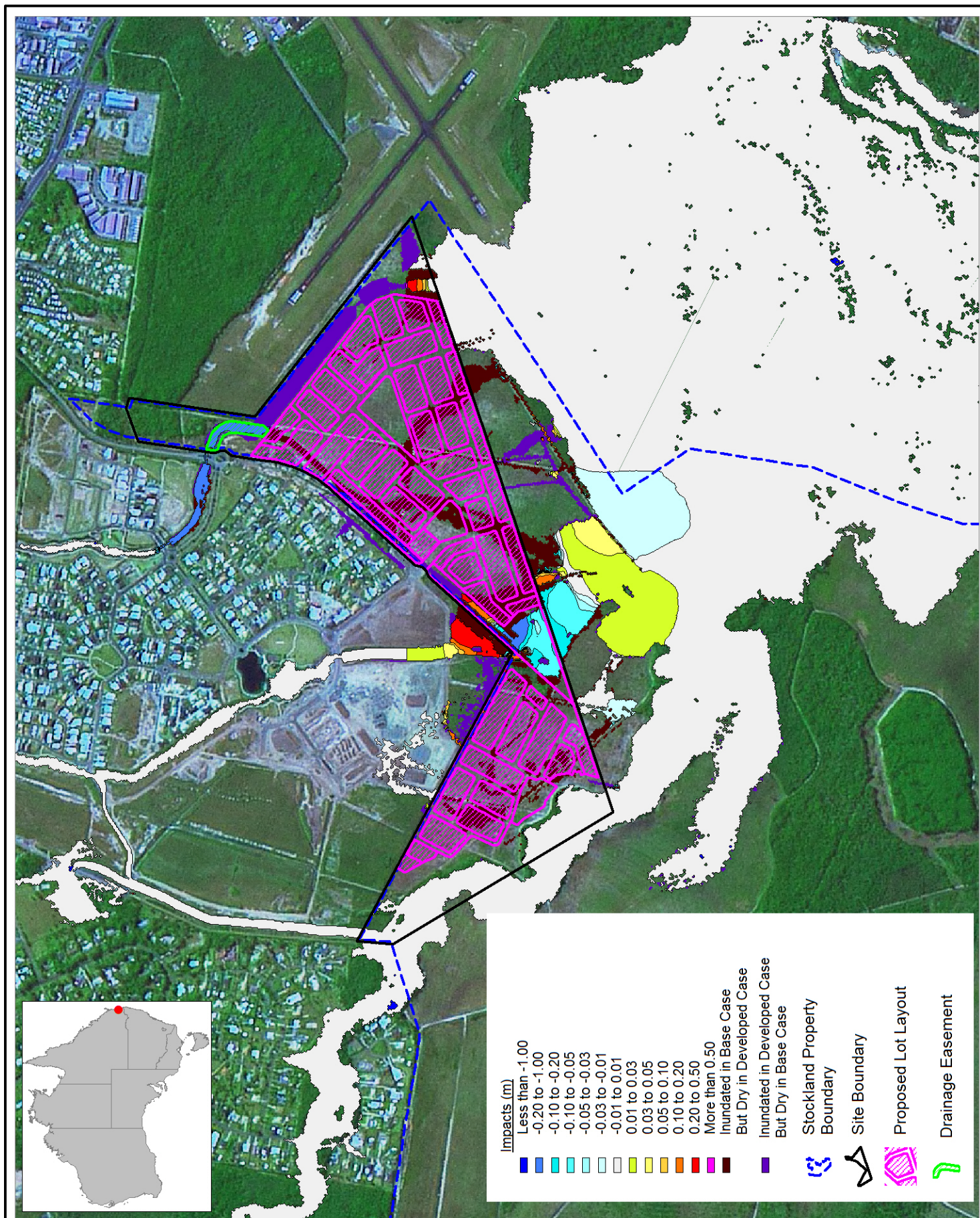
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Title:
5 year ARI Peak Flood Level Impacts

Figure:
6-19

Rev:
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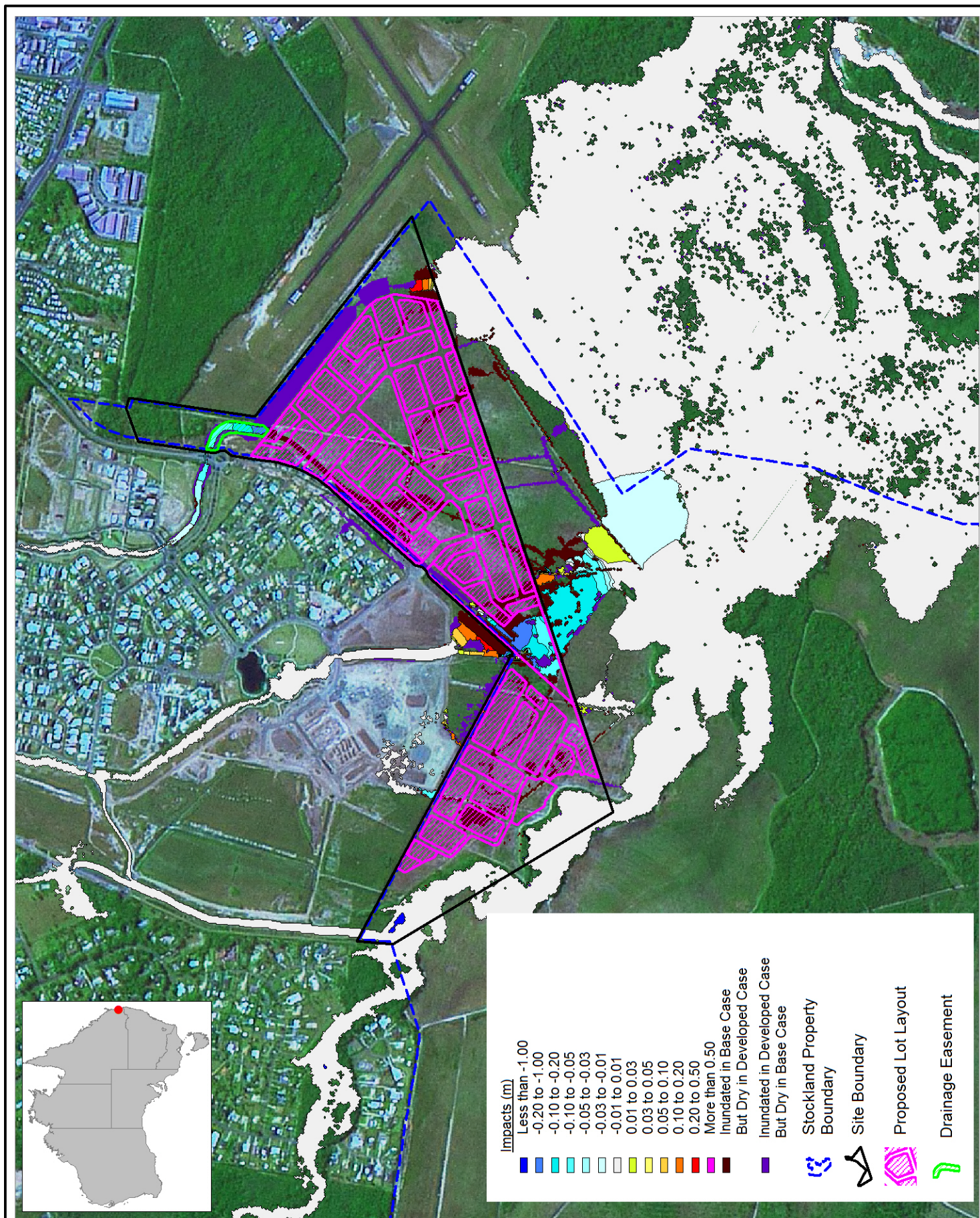
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Title:
1 year ARI Peak Flood Level Impacts

Figure:
6-20

Rev:
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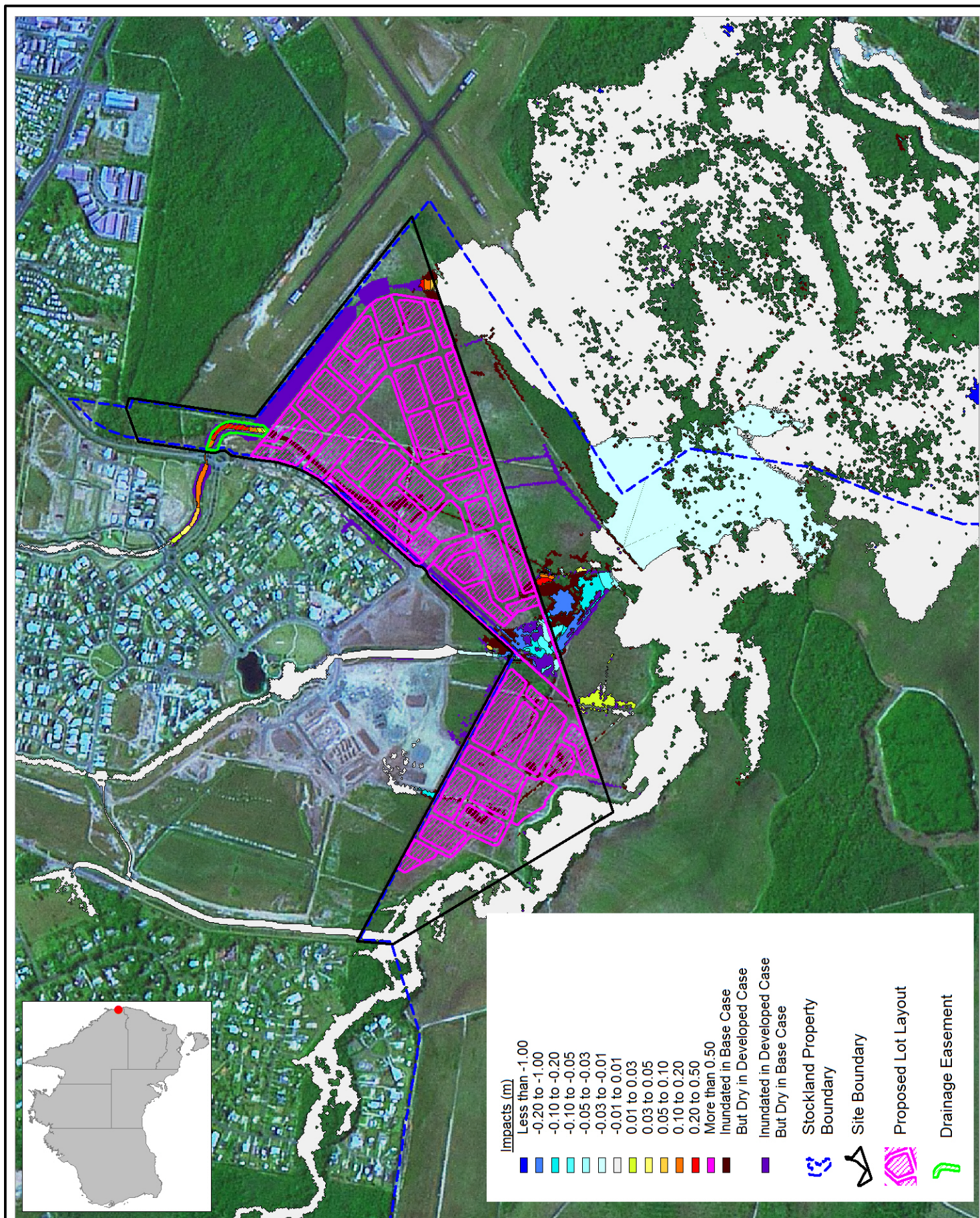
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Filepath : T:\M7908.JJ.BellVista2_FIA\GIS\DRG\report_110330\FIG6-20_110330_Q001_Impacts_A4.wor



Title:
3 month ARI Peak Flood Level Impacts

Figure:
6-21

Rev:
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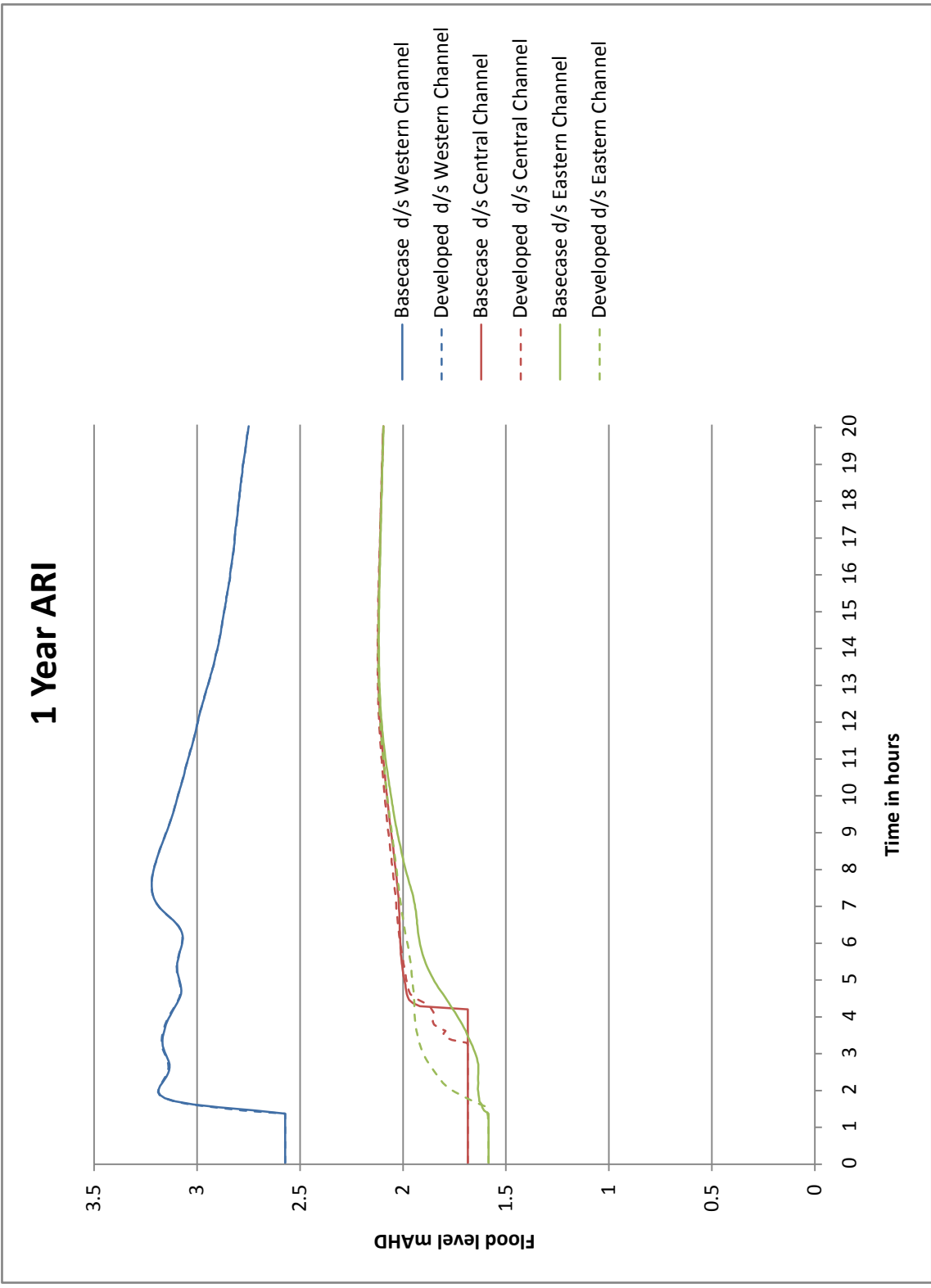


Figure 6-22 Comparison of Retention Time for the 1 Year ARI

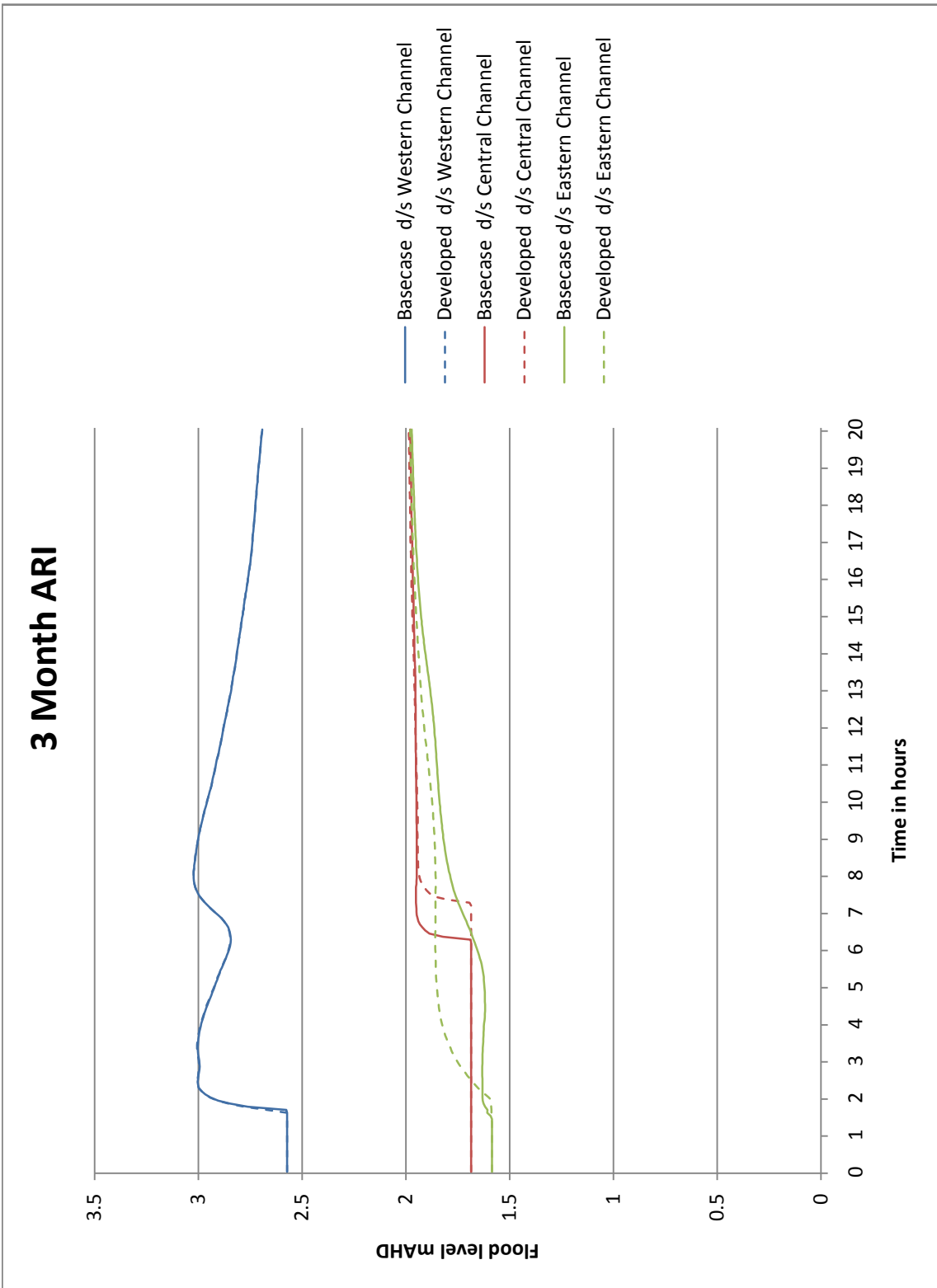


Figure 6-23 Comparison of Retention Time for the 3 Month ARI

7 CLIMATE CHANGE IMPACT ASSESSMENT

To ensure that the proposed development has appropriate flood immunity both now and in the future, the ground elevations of the proposed urban areas (i.e. roads, commercial lots and residential allotments) will be set to a minimum level that incorporates an allowance for climate change impacts.

In order to determine design flood levels, the potential impacts of climate change on the flood risk of the Bellvista II site have been assessed.

7.1 Potential Impacts of Climate Change

Current scientific research documented by the Intergovernmental Panel on Climate Change (IPCC), (IPCC, 2007) indicates that future climate change resulting from global warming is likely to result in:

- Changes in extreme rainfall intensity;
- Changes to storm occurrences and storm wind intensity, affecting storm surge levels; and
- Sea level rise.

Based on global and regional climate change assessments undertaken by IPCC (IPCC, 2007), CSIRO (CSIRO, 2007 and CSIRO, 2008), and James Cook University (JCU, 2004) estimates of the likely impacts of climate change have been established for the Bellvista II area. The predicted changes in extreme rainfall intensity, sea level rise and storm surge levels have been documented below.

7.1.1 Extreme Rainfall Intensity

Rainfall intensity is likely to vary as a result of global warming. The most detailed assessment outlining predicted increases in extreme rainfall intensity in the South East Queensland region was documented by Abbs and Rafter (Abbs and Rafter, 2008). Based on the A2 emission scenario (the second most extreme emission scenario), Abbs and Rafter downscaled output from the CSIRO Global Climate model to predict the likely impact of global warming on extreme rainfall intensity to 2030 and 2070. Results were documented for various duration events, including the 2, 12 and 72 hour events.

For the 2070 planning horizon timeframes, Abbs and Rafter estimated that the Caloundra region will experience an increase in extreme rainfall intensity by +5% and +15% for 2 hour and 12 hour duration events respectively. The 12 hour duration event has been identified as the critical duration event for most of the Bellvista II site. To adopt the precautionary approach, the projected increase in extreme rainfall intensity corresponding to the 12 hour event (i.e. 15% by 2070) was adopted for all storm durations considered. That is, for the assessment of potential climate change impacts, the design rainfall intensity in the Bellvista II hydrological models was increased by 15%.

7.1.2 Future Sea Level Rise

Global-average temperatures increased at about 0.7 degrees Celsius since 1900 and the global-average sea-level has risen 1.7 mm per year since 1900 (Church and White, 2006). Due to anthropogenic greenhouse gas emissions the rates of both temperature increase and Sea Level Rise

(SLR) are likely to be presently increasing and are expected to further accelerate in the future (IPCC, 2001; IPCC, 2007).

There are uncertainties as to the actual magnitude and rate of future sea level rise. This has led to various scenarios being adopted by the Intergovernmental Panel on Climate Change (IPCC), based on the range of model results available and dependent upon the amount of future emissions assumed.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) reports that global sea level rise is projected to be 18–59 cm by year 2100 relative to 1990 levels. These projections do not include a contribution from ice flow rates, however if these were to continue to grow linearly with global warming, then the upper ranges of sea level rise would increase by a further 10 to 20 cm (by year 2100 relative to 1990) (IPCC, 2007). There is an acknowledged risk that the contribution of ice sheets to sea level rise this century may be substantially higher than this.

The climate models predict that there will be a not-insignificant regional variation in future sea level rise, predominantly due to spatial variations in the contribution made by ocean thermal expansion. Predictions reported by the CSIRO (2007) indicate that future sea level rise along the eastern Australian coastline may be up to 4 cm greater than the global average due to the greater efficiency in South Pacific Ocean currents (such as the East Australian Current) to disperse thermal energy.

In summary the total mean sea level rise along the eastern Australian coastline is estimated to be in the range 28–83 cm to the year 2100. This will occur gradually at first as we continue to accelerate from the historic rate of 1.7 mm per year and then more rapidly as the year 2100 is approached.

For planning purposes, an allowance of 0.8 m for global warming induced mean sea level rise is recommended. This allowance is consistent with recommendations by DERM and Policy 1.4 of the Draft State Planning Policy Coastal Protection. To assess potential climate change impacts, a mean sea level rise of 0.8m was adopted in this assessment.

7.1.3 Changes to Storm Occurrences and Storm Intensities

The potential impacts of increased frequency and intensity of tropical cyclones at Golden Beach due to climate change were investigated in the Oceans Hazard Assessment Stage 2 Report (JCU, 2004). The JCU study assessed the likely impact of a 10% increase in cyclone intensity and frequency including a poleward shift in cyclone track by 1.3 degrees. This is in agreement with draft State Planning Policy Coastal Protection which recommends an increase in cyclone intensity of 10%. The JCU results indicate these changes to cyclone intensity, frequency and path may increase the 100 year ARI storm tide level around Bribie Island by approximately 0.15 m. This would be in addition to the mean sea level rise.

7.1.4 Summary

A climate change assessment has been undertaken for the Bellvista II site. The assessment accounted for a predicted increase in extreme rainfall intensity, global and regional sea level rise, and changes to storm occurrences and storm intensities (storm surge). The adopted values are presented in Table 7-1.

Table 7-1 Adopted Climate Change Variation Estimates

Environmental Forcing	Adopted Climate Change Variation Estimate
Extreme rainfall intensity / depth	+15%
Mean sea level rise	+0.8m
Increase in design storm tide levels	+0.95m

7.2 Potential Impacts on Flood Risk

To establish the minimum ground elevations of the development, the flood impacts of the potential climate change variations have been determined on the basis of:

- Assessment of affected design storm tide levels; and
- Flood modelling of increased rainfall intensities.

7.2.1 Design Storm Tide Levels with Climate Change Allowance

The present-day 100 year ARI design storm tide level at Pumicestone Passage from Connell Wagner (2003) is 1.95 mAHD (also refer to SKM, 2006). The assessment of the potential climate change impacts has indicated that the 100 year ARI design storm tide level may increase by 0.95m (approximately 0.15m due to changes to cyclone intensity, frequency and path and approximately 0.8m due to mean sea level rise).

For this assessment, a 100 year ARI design storm tide level of 2.9mAHD has been adopted.

7.2.2 Flood Modelling of Increased Rainfall Intensities

To investigate the impacts of increased extreme rainfall intensities due to Climate Change, the RAFTS-XP hydrological model was run with increased rainfall intensities. The design rainfall depths as determined by CRC-FORGE (refer to Table 3-2) were increased by an additional 15%.

The RAFTS-XP model results for the developed case with climate change allowance (refer to Table B-2 in Appendix B) suggest that the peak inflows are estimated to increase by approximately 20% as a result of these potential climate change impacts.

The revised RAFTS-XP inflow hydrographs were used to derive boundary conditions for the Bellvista II TUFLOW model and the Regional TUFLOW model was also re-run for the same potential climate change scenario to derive upstream and downstream boundary conditions (A tail water level of 1.25mAHD² was applied at the downstream boundary.) These tail water levels represents a high water springs in Pumistone Passage plus 0.8m sea level rise

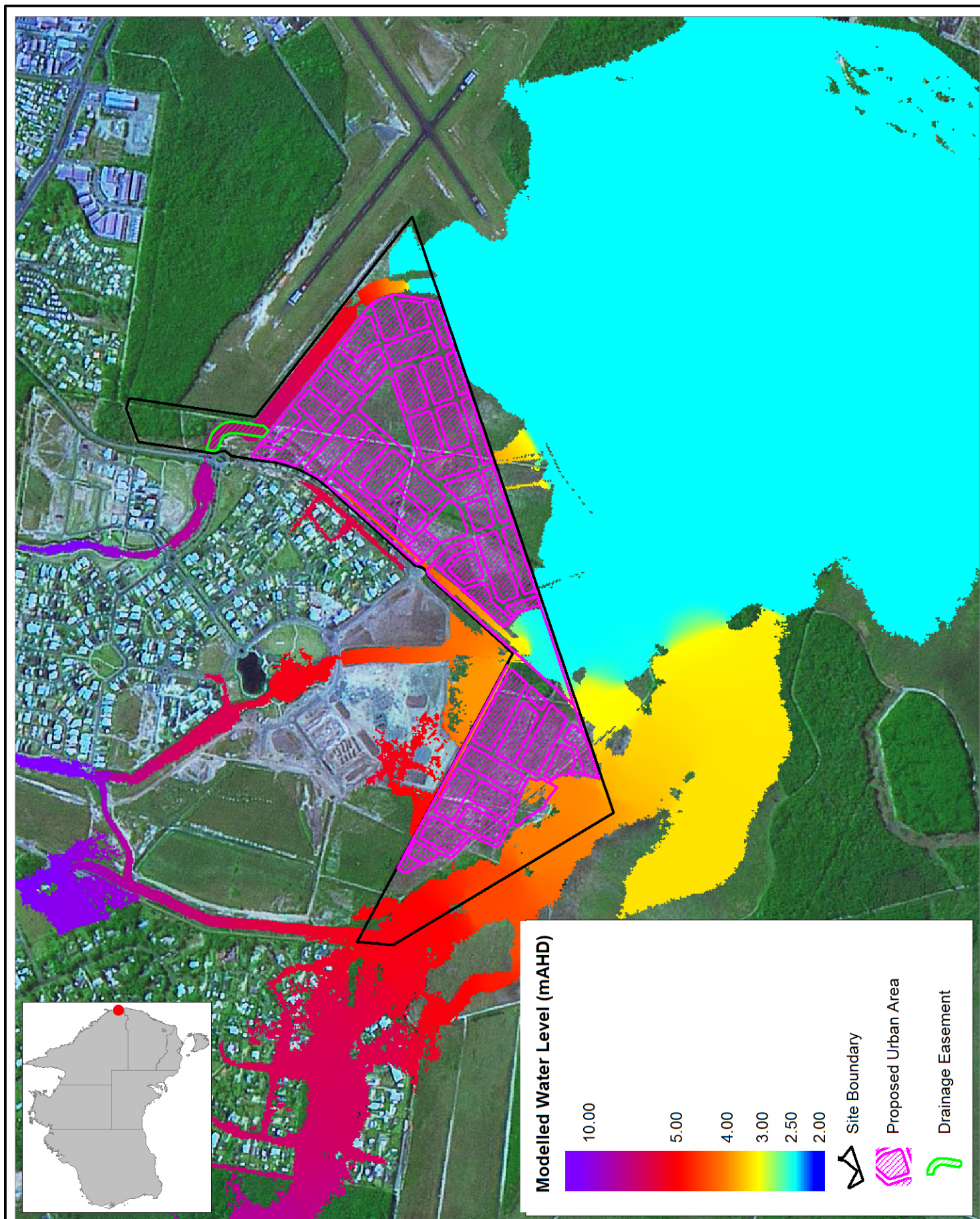
The modelled peak flood levels for the 100 year ARI flood event with inclusion of the recommended allowance for potential impacts of climate change is presented in Figure 7-1. The flood levels depicted in Figure 7-1 were derived from a compilation of 1 in 100 year ARI design flood events, including the 1, 3, 6 and 12 hour duration flood events and future storm tide events. The modelled peak flow velocities for the simulations with climate change impacts are presented in Figure 7-2 and the modelled peak flood depths in Figure 7-3.

7.3 Fill Levels

To ensure that the urban areas of the proposed development have an appropriate flood immunity now and in the future, the urban areas will be filled to a minimum level that incorporates an appropriate allowance for climate change impacts. In order to enable a quantified assessment of potential climate change impacts on the flood risk of the Bellvista II site, a climate change impact assessment was undertaken and design flood levels were assessed with recommended climate change allowances.

The planning levels for the development have been based on modelled peak design flood levels with inclusion of the recommended climate change allowances outlined in Section 7.1.

The urban areas of the proposed development will be filled to a minimum of the modelled 100 year ARI flood levels plus 500mm. The 100 year ARI design flood levels that include recommended climate change allowances are presented in Figure 7-1.



Title:
**100 year ARI Peak Flood Levels for Developed Case
 with Climate Change Allowance**

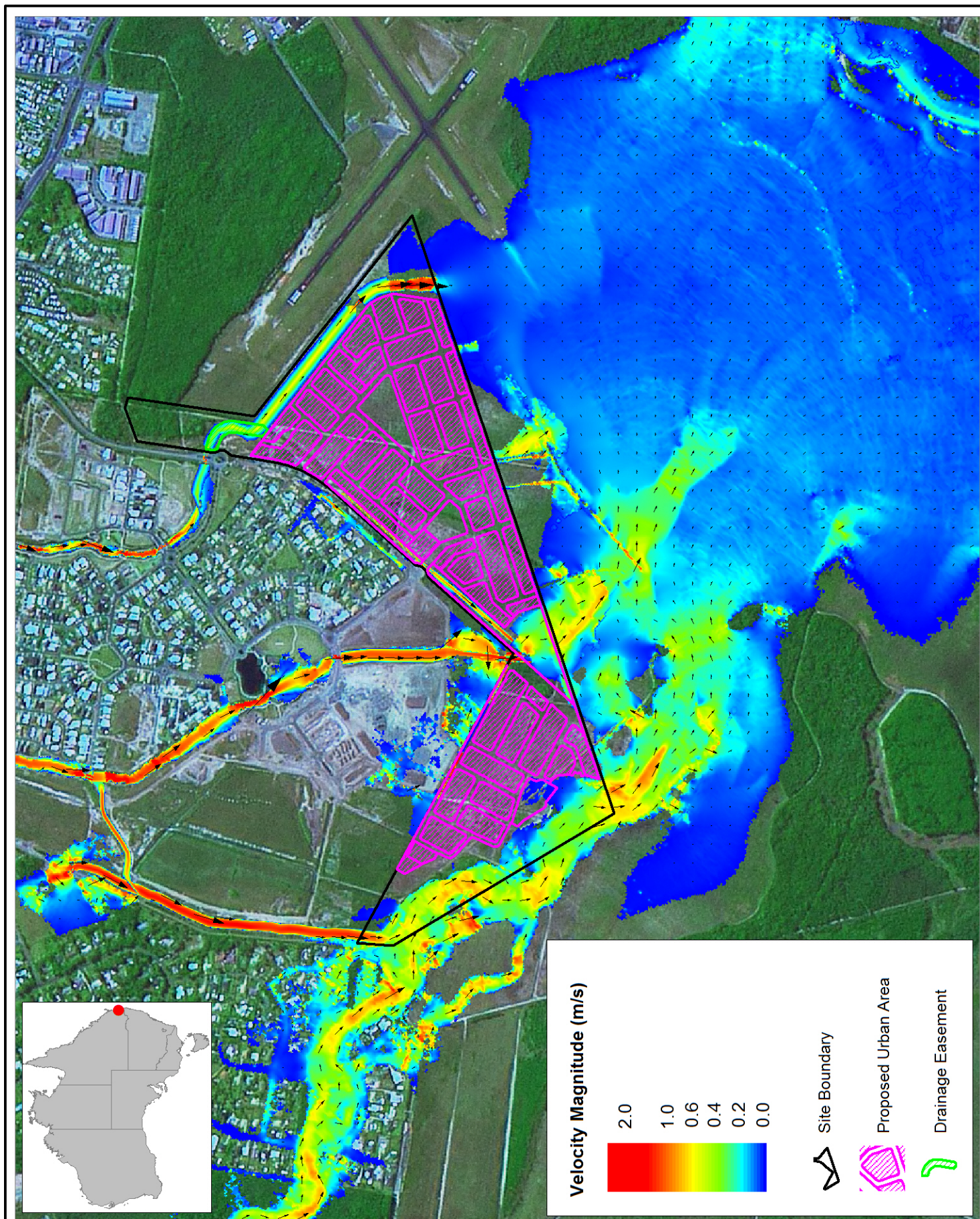
Figure:
7-1

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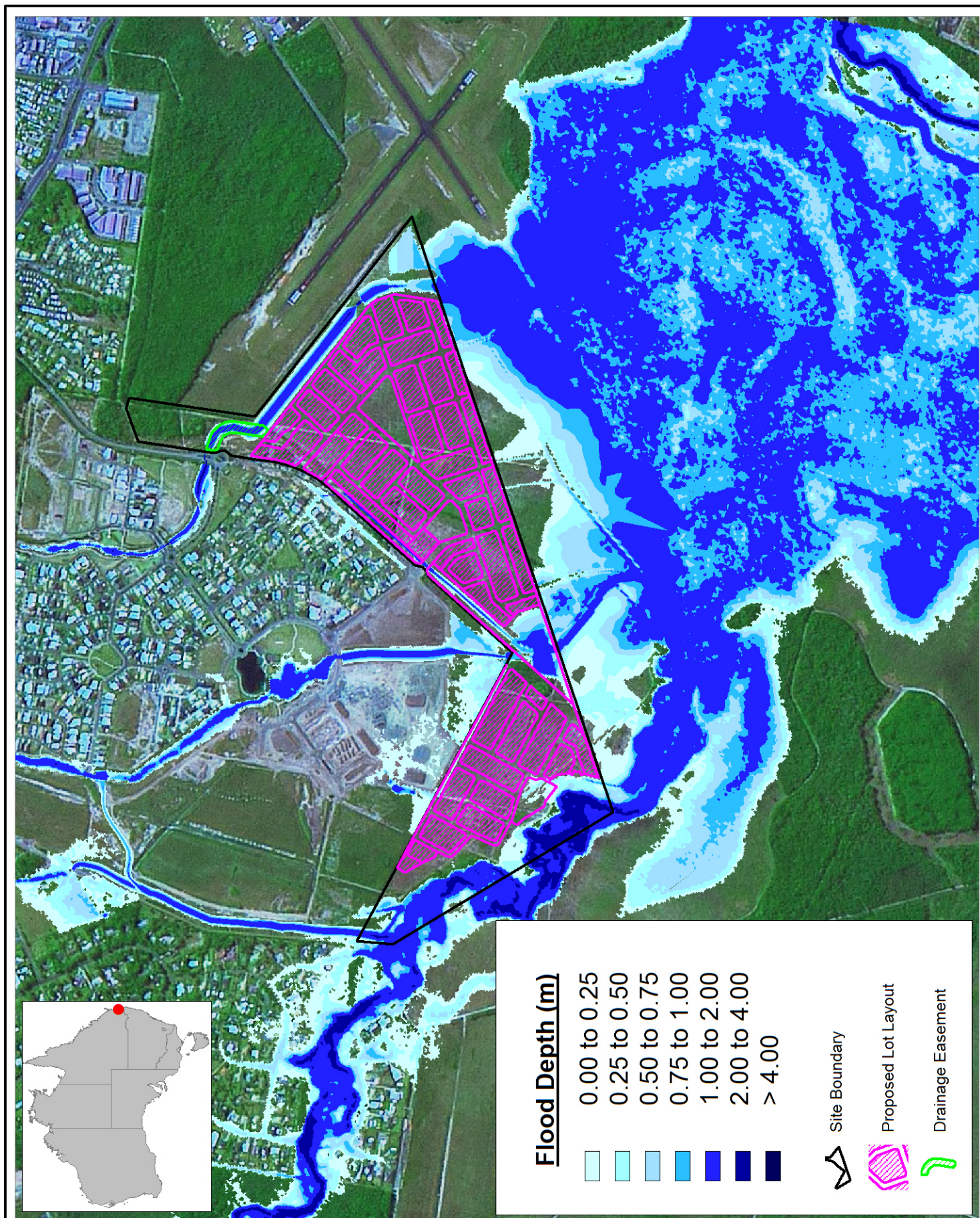
Title:
100 year ARI Peak Flood Velocities for Developed Case with Climate Change Allowance

Figure:
7-2

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Title:
**100 year ARI Peak Flood Depth for Developed Case
with Climate Change Allowance**

Figure:
7-3

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0 250 500m
Approx. Scale



Filepath : T:\M7908.JJ.BellVista2_FIA\GIS\DRG\report_110330\FIG7-03_110330_DEV_Q100_CC_Depth_ocean_A4.wor

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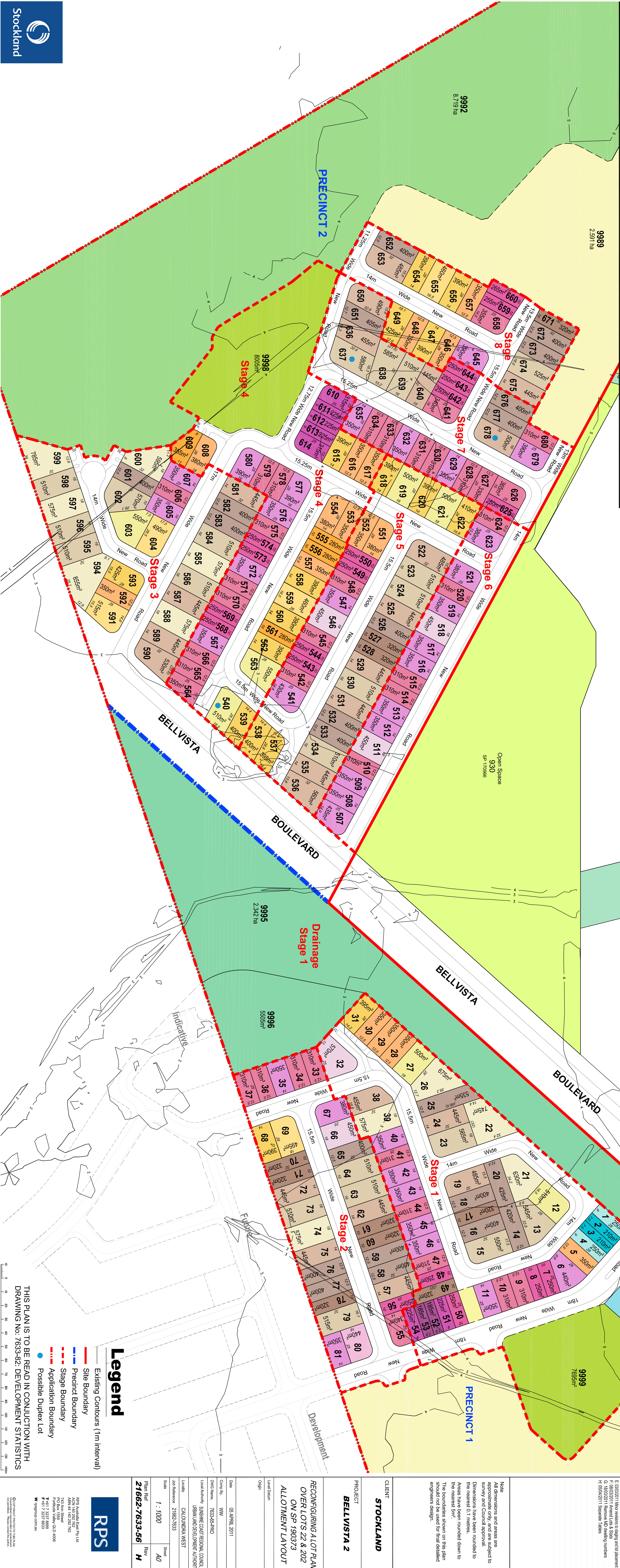
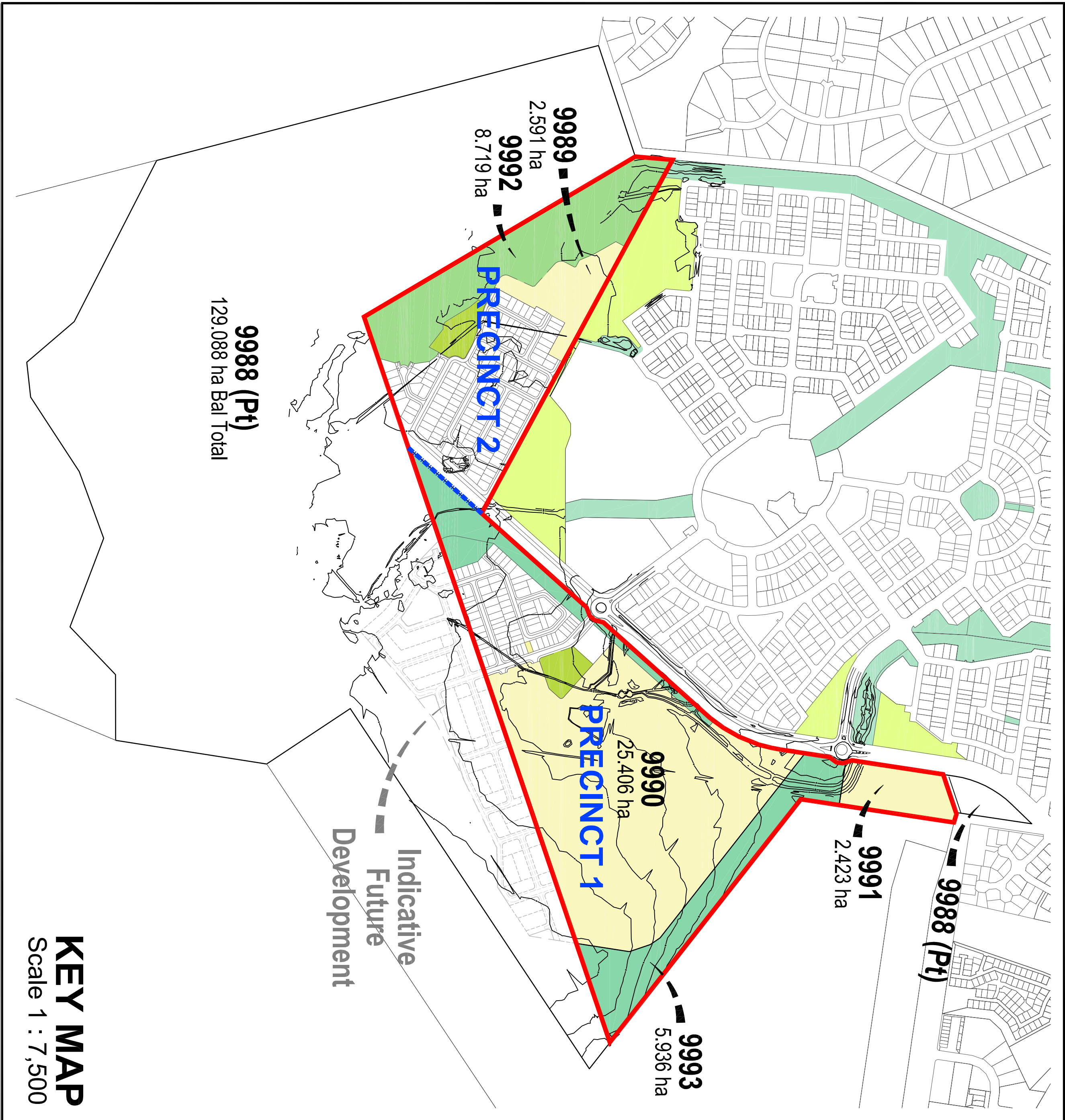
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APPENDIX A: PROPOSED BELLVISTA II LAYOUT PLAN



REVISION

- A: 26/11/2010 Amend Medium Density and Stats
- B: 26/11/2010 Amend lots and Parking and Stats
- C: 23/02/2011 Amend Layout
- D: 23/02/2011 Add Stats
- E: 03/03/2011 Minor revisions to staging and lot placement
- F: 08/03/2011 Amend Lots & Stats
- G: 18/03/2011 Remove MD dwelling numbers
- H: 05/04/2011 Separate Tables

Note
All dimensions and areas are approximate only, and are subject to survey and Council approval. Dimensions have been rounded to the nearest 0.1 metres. Areas have been rounded down to the nearest 5m².
The boundaries shown on this plan should not be used for final detailed engineers' design.

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APPENDIX B: RAFTS-XP SUBCATCHMENT INPUTS

Table B-1 Areas and Pervious Manning's 'n' Values of Regional RAFTS-XP Model

Subcatchment ID	Pervious Area	Impervious Area	Pervious N
BC01	288.7	58.1	0.078
BC02	390.4	30.3	0.082
BCN1	98.2	17.6	0.088
BCN2	78.9	2.3	0.091
BCN3	638.3	0.0	0.092
BCN4	356.5	0.0	0.098
BCN5	224.0	0.0	0.100
BCN6	550.0	0.0	0.099
BCN7	497.5	0.0	0.096
BCS1	54.2	1.2	0.093
BCS2	345.4	0.0	0.099
BCS3	605.3	0.0	0.098
BCS4	419.4	0.0	0.100
BCS5	478.2	0.0	0.100
BCS6	139.1	0.0	0.100
DC01	226.0	67.2	0.057
DC02	70.6	24.6	0.061
DC03	59.2	63.9	0.022
HC01	733.2	0.0	0.093
HC02	314.9	0.0	0.087
HC03	305.4	0.0	0.096
HC04	396.0	0.0	0.099
LC01	189.1	218.7	0.038
LC02	223.7	8.3	0.090
LC03	180.1	0.0	0.095
LC04	123.9	0.0	0.067
LC05	126.8	0.1	0.070
LC06	199.8	115.8	0.043
LC07	158.3	91.7	0.051
LC08	112.6	0.0	0.085
LC09	112.8	0.0	0.086
LC10	271.5	0.0	0.087
LC11	96.8	0.0	0.100
TOTAL	9064.7	699.9	

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Table B-2 Areas and Pervious Manning's 'n' Values of Local RAFTS-XP Model

Subcatchment ID	Base Case Model				Developed Case Model			
	Impervious Area	Pervious Area	Pervious N	Impervious N	Impervious Area	Pervious Area	Pervious N	Impervious N
LC05	0.00	128.05	0.04	0.015	0.00	128.05	0.04	0.015
LC04	0.00	88.32	0.04	0.015	0.00	88.32	0.04	0.015
LC07_01	41.64	97.16	0.04	0.015	41.64	97.16	0.04	0.015
LC07_05	0.00	3.00	0.04	0.015	0.00	3.00	0.04	0.015
LC6_6_01_b	0.00	2.20	0.12	0.015	0.00	2.20	0.12	0.015
LC6_6_01_a	0.00	2.17	0.12	0.015	1.60	0.56	0.12	0.015
LC6_6_1_d3	0.00	2.79	0.12	0.015	2.07	0.73	0.12	0.015
LC6_6_1_d2	0.00	1.62	0.04	0.015	0.00	1.62	0.04	0.015
LC6_6_02_a	0.00	3.33	0.04	0.015	0.00	3.33	0.04	0.015
LC6_7_2_b3	0.00	4.80	0.04	0.015	3.55	1.25	0.04	0.015
LC6_7_06_b	0.00	2.49	0.04	0.015	0.00	2.49	0.04	0.015
LC6_7_2_b2	0.00	4.25	0.04	0.015	2.76	1.49	0.04	0.015
LC6_7_05_d	0.00	4.21	0.04	0.015	0.00	4.21	0.04	0.015
LC6_7_2_b1	0.00	9.32	0.04	0.015	6.53	2.80	0.04	0.015
LC6_7_4_b	0.00	4.18	0.04	0.015	2.63	1.55	0.04	0.015
LC6_7_05_b	0.00	2.01	0.04	0.015	1.51	0.50	0.04	0.015
LC6_7_05_c	0.00	5.58	0.04	0.015	0.00	5.58	0.04	0.015
LC6_7_05_a	0.00	4.40	0.04	0.015	0.00	4.40	0.04	0.015
LC6_7_4_a4	0.00	3.42	0.04	0.015	0.00	3.42	0.04	0.015
LC06_03_09	0.00	3.35	0.04	0.015	0.00	3.35	0.04	0.015
LC06_03_08	2.24	0.75	0.04	0.015	2.24	0.75	0.04	0.015
LC06_03_10	0.00	18.25	0.04	0.015	0.00	18.25	0.04	0.015
LC07_04	5.02	4.64	0.04	0.015	5.02	4.64	0.04	0.015
LC06_03_04	5.70	3.96	0.04	0.015	5.70	3.96	0.04	0.015
LC06_03_07	0.00	2.43	0.04	0.015	0.00	2.43	0.04	0.015
LC06_03_05	0.00	0.79	0.04	0.015	0.00	0.79	0.04	0.015
LC06_03_06	2.20	2.48	0.04	0.015	2.20	2.48	0.04	0.015
LC06_03_02	9.22	4.14	0.04	0.015	9.22	4.14	0.04	0.015
LC07_03	3.54	3.02	0.04	0.015	3.54	3.02	0.04	0.015
LC07_02	3.64	1.21	0.04	0.015	3.64	1.21	0.04	0.015
LC06_03_03	6.99	5.49	0.04	0.015	6.99	5.49	0.04	0.015
LC06_03_01	8.68	2.89	0.04	0.015	8.68	2.89	0.04	0.015
LC12_04	9.12	16.93	0.04	0.015	9.12	16.93	0.04	0.015
LC12_03	18.57	15.82	0.04	0.015	18.57	15.82	0.04	0.015
LC12_02	4.16	2.24	0.04	0.015	4.16	2.24	0.04	0.015
LC12_01	17.64	9.50	0.05	0.015	17.64	9.50	0.05	0.015
LC06_01_01	15.07	8.12	0.05	0.015	15.07	8.12	0.05	0.015
LC06_01_03	5.33	9.48	0.04	0.015	5.33	9.48	0.04	0.015
LC06_01_02	13.31	9.64	0.04	0.015	13.31	9.64	0.04	0.015
LC06_02	7.28	31.03	0.12	0.015	7.28	31.03	0.12	0.015

	Base Case Model				Developed Case Model			
Subcatchment ID	Impervious Area	Pervious Area	Pervious N	Impervious N	Impervious Area	Pervious Area	Pervious N	Impervious N
LC06_04_01	13.53	6.97	0.04	0.015	13.53	6.97	0.04	0.015
LC06_04_03	1.53	2.72	0.04	0.015	1.53	2.72	0.04	0.015
LC06_04_02	1.69	2.33	0.04	0.015	1.69	2.33	0.04	0.015
LC06_04_04	0.00	1.66	0.04	0.015	0.00	1.66	0.04	0.015
LC06_05	8.94	18.99	0.04	0.015	8.94	18.99	0.04	0.015
LC6_6_02_b	0.00	12.75	0.04	0.015	0.00	12.75	0.04	0.015
LC06_03_11	1.81	0.60	0.04	0.015	1.81	0.60	0.04	0.015
LC06_04_05	10.48	4.49	0.04	0.015	10.48	4.49	0.04	0.015
LC6_6_1_e1	0.00	1.96	0.04	0.015	0.00	1.96	0.04	0.015
LC6_6_1_e2	0.00	1.60	0.04	0.015	1.23	0.37	0.04	0.015
LC6_6_1_e3	0.00	3.99	0.04	0.015	3.07	0.92	0.04	0.015
LC6_6_1_d1	0.00	2.12	0.04	0.015	1.61	0.51	0.04	0.015
LC6_7_4_a2	0.00	3.37	0.04	0.015	0.00	3.37	0.04	0.015
LC6_7_4_a1	0.00	0.88	0.04	0.015	0.66	0.22	0.04	0.015
LC6_7_4_a3	0.00	4.09	0.04	0.015	3.06	1.02	0.04	0.015
LC6_7_4_a5	0.00	1.86	0.04	0.015	1.39	0.46	0.04	0.015
TOTAL	217.35	599.84			249.03	568.16		

APPENDIX C: RAFTS-XP PEAK FLOW SUMMARY

Table C-1 Q100 RAFTS-XP Peak Inflows without Climate Change Allowance (m³/s)

Event Magnitude	100 Year ARI							
Event Duration	1 Hour		3 Hour		6 Hour		12 Hour	
Subcatchment ID	EXG	DEV	EXG	DEV	EXG	DEV	EXG	DEV
LC04	2.3	2.3	4.4	4.4	5.9	5.9	6.2	6.2
LC05	12.1	12.1	60.2	60.3	91.1	92.1	16.6	16.6
LC06_01_01	13.4	13.4	8.6	8.6	6.7	6.7	7.0	7.0
LC06_01_02	12.7	12.7	8.4	8.4	6.7	6.7	7.0	7.0
LC06_01_03	6.4	6.4	4.9	4.9	4.2	4.2	4.3	4.3
LC06_02	7.3	7.3	5.5	5.5	5.4	5.4	6.2	6.2
LC06_03_01	7.2	7.2	4.3	4.3	3.2	3.2	3.4	3.4
LC06_03_02	7.8	7.8	4.7	4.7	3.6	3.6	3.7	3.7
LC06_03_03	6.1	6.1	3.8	3.8	3.1	3.1	3.1	3.1
LC06_03_04	4.9	4.9	3.1	3.1	2.5	2.5	2.6	2.6
LC06_03_05	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
LC06_03_06	2.0	2.0	1.4	1.4	1.2	1.2	1.2	1.2
LC06_03_07	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
LC06_03_08	1.9	1.9	1.2	1.2	0.9	0.9	0.9	0.9
LC06_03_09	1.9	1.9	1.2	0.7	0.9	0.7	0.9	0.7
LC06_03_10	2.6	2.6	3.1	3.1	2.6	2.6	2.7	2.7
LC06_03_11	1.6	1.6	1.0	1.0	0.7	0.7	0.7	0.7
LC06_04_01	11.6	11.6	7.2	7.2	5.6	5.6	5.8	5.8
LC06_04_02	1.7	1.7	1.3	1.3	1.1	1.1	1.1	1.1
LC06_04_03	1.6	1.6	1.3	1.3	1.1	1.1	1.2	1.2
LC06_04_04	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
LC06_04_05	9.0	9.0	5.5	5.5	4.2	4.2	4.4	4.4
LC06_05	9.9	9.9	7.8	7.8	7.2	7.2	7.2	7.2
LC07_01	37.2	37.2	23.9	23.9	20.5	20.5	23.1	23.1
LC07_02	3.1	3.1	1.9	1.9	1.4	1.4	1.5	1.5
LC07_03	3.2	3.2	2.1	2.1	1.7	1.7	1.8	1.8
LC07_04	4.5	4.5	2.9	2.9	2.5	2.5	2.5	2.5
LC07_05	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
LC12_01	15.1	15.1	9.3	9.3	7.3	7.3	7.5	7.5
LC12_02	3.8	3.8	2.5	2.5	1.9	1.9	2.0	2.0
LC12_03	16.6	16.6	10.7	10.7	8.9	8.9	9.0	9.0
LC12_04	9.2	9.2	6.7	6.7	6.2	6.2	6.1	6.1
LC6_6_01_a	0.1	1.3	0.2	0.8	0.2	0.5	0.2	0.6
LC6_6_01_b	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
LC6_6_02_a	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
LC6_6_02_b	1.4	1.4	1.9	1.9	1.8	1.8	1.9	1.9
LC6_6_1_d1	0.4	1.4	0.4	0.8	0.4	0.6	0.3	0.6

Event Magnitude	100 Year ARI							
Event Duration	1 Hour		3 Hour		6 Hour		12 Hour	
Subcatchment ID	EXG	DEV	EXG	DEV	EXG	DEV	EXG	DEV
LC6_6_1_d2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
LC6_6_1_d3	0.1	1.7	0.2	1.0	0.3	0.7	0.3	0.7
LC6_6_1_e1	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
LC6_6_1_e2	0.3	1.0	0.3	0.6	0.3	0.5	0.3	0.5
LC6_6_1_e3	0.6	2.6	0.7	1.5	0.6	1.1	0.6	1.2
LC6_7_05_a	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
LC6_7_05_b	0.6	1.3	0.5	0.8	0.5	0.6	0.5	0.6
LC6_7_05_c	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2
LC6_7_05_d	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9
LC6_7_06_b	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
LC6_7_2_b1	1.9	5.6	2.0	3.5	1.8	2.7	1.7	2.8
LC6_7_2_b2	1.1	2.4	1.0	1.6	1.0	1.2	0.9	1.3
LC6_7_2_b3	1.1	3.1	1.1	1.9	1.1	1.4	1.0	1.5
LC6_7_4_a1	0.3	0.6	0.3	0.4	0.2	0.3	0.2	0.3
LC6_7_4_a2	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
LC6_7_4_a3	1.0	2.6	1.0	1.6	0.9	1.2	0.9	1.3
LC6_7_4_a4	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
LC6_7_4_a5	0.5	1.2	0.5	0.8	0.5	0.6	0.5	0.6
LC6_7_4_b	1.0	2.3	1.0	1.0	0.9	1.0	0.9	1.0

Table C-2 Q50 RAFTS-XP Peak Inflows without Climate Change Allowance (m³/s)

Event Magnitude	50 Year ARI							
Event Duration	1 Hour		3 Hour		6 Hour		12 Hour	
Subcatchment ID	EXG	DEV	EXG	DEV	EXG	DEV	EXG	DEV
LC04	1.9	1.9	3.5	3.5	4.8	4.8	5.1	5.1
LC05	15.2	15.2	14.7	14.7	0.0	0.0	60.4	60.8
LC06_01_01	11.6	11.6	7.4	7.4	5.8	5.8	6.0	6.0
LC06_01_02	10.9	10.9	7.2	7.2	5.8	5.8	6.0	6.0
LC06_01_03	5.4	5.4	4.2	4.2	3.6	3.6	3.7	3.7
LC06_02	6.2	6.2	4.6	4.6	4.5	4.5	5.3	5.3
LC06_03_01	6.3	6.3	3.7	3.7	2.8	2.8	2.9	2.9
LC06_03_02	6.7	6.7	4.0	4.0	3.1	3.1	3.2	3.2
LC06_03_03	5.3	5.3	3.3	3.3	2.6	2.6	2.7	2.7
LC06_03_04	4.3	4.3	2.7	2.7	2.1	2.1	2.2	2.2
LC06_03_05	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
LC06_03_06	1.7	1.7	1.2	1.2	1.0	1.0	1.0	1.0
LC06_03_07	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
LC06_03_08	1.7	1.7	1.0	1.0	0.8	0.8	0.8	0.8
LC06_03_09	1.7	0.6	1.0	0.6	0.8	0.6	0.8	0.6
LC06_03_10	2.1	2.1	2.6	2.6	2.3	2.3	2.4	2.4
LC06_03_11	1.3	1.3	0.8	0.8	0.6	0.6	0.6	0.6
LC06_04_01	10.1	10.1	6.2	6.2	4.8	4.8	5.0	5.0
LC06_04_02	1.5	1.5	1.1	1.1	1.0	1.0	1.0	1.0
LC06_04_03	1.4	1.4	1.1	1.1	1.0	1.0	1.0	1.0
LC06_04_04	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
LC06_04_05	7.8	7.8	4.8	4.8	3.7	3.7	3.8	3.8
LC06_05	8.4	8.4	6.5	6.5	6.1	6.1	6.0	6.0
LC07_01	32.1	32.1	20.6	20.6	17.3	17.3	19.7	19.7
LC07_02	2.7	2.7	1.6	1.6	1.2	1.2	1.3	1.3
LC07_03	2.7	2.7	1.8	1.8	1.5	1.5	1.5	1.5
LC07_04	3.9	3.9	2.5	2.5	2.1	2.1	2.1	2.1
LC07_05	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5
LC12_01	13.1	13.1	8.0	8.0	6.2	6.2	6.4	6.4
LC12_02	3.3	3.3	2.1	2.1	1.6	1.6	1.7	1.7
LC12_03	14.3	14.3	9.2	9.2	7.6	7.6	7.8	7.8
LC12_04	7.8	7.8	5.7	5.7	5.2	5.2	5.2	5.2
LC6_6_01_a	0.1	1.1	0.2	0.7	0.2	0.5	0.2	0.5
LC6_6_01_b	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
LC6_6_02_a	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4
LC6_6_02_b	1.1	1.1	1.6	1.6	1.5	1.5	1.6	1.6
LC6_6_1_d1	0.3	1.2	0.3	0.7	0.3	0.5	0.3	0.6

Event Magnitude	50 Year ARI							
Event Duration	1 Hour		3 Hour		6 Hour		12 Hour	
Subcatchment ID	EXG	DEV	EXG	DEV	EXG	DEV	EXG	DEV
LC6_6_1_d2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
LC6_6_1_d3	0.1	1.5	0.2	0.8	0.2	0.6	0.2	0.7
LC6_6_1_e1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
LC6_6_1_e2	0.3	0.9	0.3	0.5	0.2	0.4	0.2	0.4
LC6_6_1_e3	0.5	2.2	0.6	1.3	0.5	1.0	0.5	1.0
LC6_7_05_a	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8
LC6_7_05_b	0.5	1.1	0.4	0.7	0.4	0.5	0.4	0.6
LC6_7_05_c	1.1	1.1	1.1	1.1	1.0	1.0	0.9	0.9
LC6_7_05_d	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8
LC6_7_06_b	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
LC6_7_2_b1	1.6	4.8	1.7	3.0	1.5	2.3	1.4	2.4
LC6_7_2_b2	0.9	2.1	0.8	1.3	0.8	1.1	0.8	1.1
LC6_7_2_b3	0.9	2.6	0.9	1.6	0.9	1.2	0.8	1.3
LC6_7_4_a1	0.2	0.5	0.2	0.3	0.2	0.2	0.2	0.2
LC6_7_4_a2	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6
LC6_7_4_a3	0.8	2.3	0.8	1.4	0.8	1.0	0.7	1.1
LC6_7_4_a4	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6
LC6_7_4_a5	0.4	1.1	0.4	0.7	0.4	0.5	0.4	0.5
LC6_7_4_b	0.8	0.9	0.8	0.9	0.8	0.8	0.8	0.8

Table C-3 Q5 RAFTS-XP Peak Inflows without Climate Change Allowance (m³/s)

Event Magnitude	5 Year ARI							
Event Duration	1 Hour		3 Hour		6 Hour		12 Hour	
Subcatchment ID	EXG	DEV	EXG	DEV	EXG	DEV	EXG	DEV
LC04	0.9	0.9	1.6	1.6	2.1	2.1	2.3	2.3
LC05	7.3	7.3	4.9	4.9	0.0	0.0	51.1	51.7
LC06_01_01	8.2	8.2	5.0	5.0	3.8	3.8	3.7	3.7
LC06_01_02	7.5	7.5	4.8	4.8	3.8	3.8	3.7	3.7
LC06_01_03	3.5	3.5	2.6	2.6	2.3	2.3	2.2	2.2
LC06_02	4.2	4.2	2.8	2.8	2.4	2.4	3.0	3.0
LC06_03_01	4.5	4.5	2.6	2.6	1.8	1.8	1.8	1.8
LC06_03_02	4.8	4.8	2.8	2.8	2.0	2.0	2.0	2.0
LC06_03_03	3.7	3.7	2.2	2.2	1.6	1.6	1.6	1.6
LC06_03_04	3.0	3.0	1.8	1.8	1.3	1.3	1.3	1.3
LC06_03_05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
LC06_03_06	1.2	1.2	0.8	0.8	0.6	0.6	0.6	0.6
LC06_03_07	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2
LC06_03_08	1.2	1.2	0.7	0.7	0.5	0.5	0.5	0.5
LC06_03_09	1.2	0.3	0.7	0.3	0.5	0.3	0.5	0.3
LC06_03_10	1.1	1.1	1.4	1.4	1.2	1.2	1.3	1.3
LC06_03_11	0.9	0.9	0.6	0.6	0.4	0.4	0.4	0.4
LC06_04_01	7.1	7.1	4.2	4.2	3.1	3.1	3.1	3.1
LC06_04_02	1.0	1.0	0.7	0.7	0.6	0.6	0.6	0.6
LC06_04_03	0.9	0.9	0.6	0.6	0.6	0.6	0.5	0.5
LC06_04_04	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
LC06_04_05	5.5	5.5	3.2	3.2	2.4	2.4	2.4	2.4
LC06_05	5.5	5.5	4.0	4.0	3.7	3.7	3.5	3.5
LC07_01	22.3	22.3	13.7	13.7	10.5	10.5	11.2	11.2
LC07_02	1.9	1.9	1.1	1.1	0.8	0.8	0.8	0.8
LC07_03	1.9	1.9	1.2	1.2	0.9	0.9	0.9	0.9
LC07_04	2.7	2.7	1.7	1.7	1.3	1.3	1.3	1.3
LC07_05	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
LC12_01	9.2	9.2	5.5	5.5	4.0	4.0	4.0	4.0
LC12_02	2.3	2.3	1.4	1.4	1.1	1.1	1.1	1.1
LC12_03	10.0	10.0	6.2	6.2	4.7	4.7	4.7	4.7
LC12_04	5.3	5.3	3.6	3.6	3.1	3.1	3.0	3.0
LC6_6_01_a	0.0	0.8	0.1	0.5	0.1	0.3	0.1	0.3
LC6_6_01_b	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
LC6_6_02_a	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2
LC6_6_02_b	0.6	0.6	0.8	0.8	0.8	0.8	0.9	0.9
LC6_6_1_d1	0.2	0.8	0.2	0.5	0.2	0.3	0.2	0.3
LC6_6_1_d2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1

Event Magnitude	5 Year ARI							
Event Duration	1 Hour		3 Hour		6 Hour		12 Hour	
Subcatchment ID	EXG	DEV	EXG	DEV	EXG	DEV	EXG	DEV
LC6_6_1_d3	0.0	1.0	0.1	0.6	0.1	0.4	0.1	0.4
LC6_6_1_e1	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2
LC6_6_1_e2	0.1	0.6	0.2	0.4	0.1	0.3	0.1	0.3
LC6_6_1_e3	0.2	1.6	0.3	0.9	0.3	0.6	0.3	0.7
LC6_7_05_a	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
LC6_7_05_b	0.3	0.8	0.3	0.5	0.2	0.3	0.2	0.3
LC6_7_05_c	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
LC6_7_05_d	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4
LC6_7_06_b	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
LC6_7_2_b1	0.8	3.4	0.9	2.0	0.7	1.5	0.7	1.5
LC6_7_2_b2	0.5	1.5	0.5	0.9	0.4	0.7	0.4	0.7
LC6_7_2_b3	0.5	1.9	0.5	1.1	0.5	0.8	0.4	0.8
LC6_7_4_a1	0.1	0.4	0.1	0.2	0.1	0.2	0.1	0.2
LC6_7_4_a2	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
LC6_7_4_a3	0.4	1.6	0.5	1.0	0.4	0.7	0.4	0.7
LC6_7_4_a4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
LC6_7_4_a5	0.2	0.7	0.2	0.4	0.2	0.3	0.2	0.3
LC6_7_4_b	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4

Table C-4 Q100 RAFTS-XP Peak Inflows with Climate Change Allowance (m³/s)

Subcatchment ID	1hr			3hr			6hr			12hr		
	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase
LC04	2.8	2.3	21	5.7	4.4	29	7.3	5.9	24	7.5	6.2	21
LC05	21.5	12.1	77	21.4	60.2	-64	75.3	92.1	-18	85.7	16.6	417
LC06_01_01	15.6	13.4	16	10.1	8.6	17	7.8	6.7	16	8.1	7.0	16
LC06_01_02	14.8	12.7	16	9.8	8.4	16	7.7	6.7	16	8.1	7.0	16
LC06_01_03	7.5	6.4	17	5.7	4.9	17	4.9	4.2	16	5.1	4.3	17
LC06_02	8.6	7.3	19	6.6	5.5	20	6.5	5.4	20	7.3	6.2	18
LC06_03_01	8.4	7.2	15	5.1	4.3	17	3.8	3.2	16	3.9	3.4	16
LC06_03_02	9.0	7.8	16	5.5	4.7	17	4.2	3.6	17	4.3	3.7	17
LC06_03_03	7.1	6.1	16	4.5	3.8	17	3.6	3.1	18	3.7	3.1	17
LC06_03_04	5.7	4.9	16	3.6	3.1	17	2.9	2.5	17	3.0	2.6	17
LC06_03_05	0.3	0.2	19	0.3	0.2	18	0.2	0.2	18	0.2	0.2	18
LC06_03_06	2.4	2.0	17	1.6	1.4	17	1.4	1.2	17	1.4	1.2	18
LC06_03_07	0.7	0.6	23	0.7	0.6	21	0.6	0.5	19	0.6	0.5	20
LC06_03_08	2.2	1.9	15	1.4	1.2	16	1.0	0.9	15	1.1	0.9	16
LC06_03_09	0.9	1.9	-53	0.9	1.2	-24	0.8	0.7	22	0.8	0.7	22
LC06_03_10	3.2	2.6	22	3.8	3.1	21	3.1	2.6	19	3.2	2.7	16
LC06_03_11	1.8	1.6	16	1.1	1.0	16	0.8	0.7	16	0.9	0.7	16
LC06_04_01	13.4	11.6	15	8.4	7.2	16	6.6	5.6	17	6.8	5.8	17
LC06_04_02	2.1	1.7	20	1.5	1.3	18	1.3	1.1	17	1.3	1.1	17
LC06_04_03	2.0	1.6	19	1.5	1.3	19	1.3	1.1	17	1.4	1.2	18
LC06_04_04	0.6	0.5	22	0.6	0.5	20	0.5	0.4	19	0.5	0.4	21
LC06_04_05	10.4	9.0	16	6.5	5.5	17	4.9	4.2	16	5.1	4.4	16

Subcatchment ID	1hr			3hr			6hr			12hr		
	Q100 with Allowance	Climate Change	Q100 without Allowance	% Increase	Q100 with Allowance	Climate Change	Q100 without Allowance	% Increase	Q100 with Allowance	Climate Change	Q100 without Allowance	% Increase
LC06_05	11.6	9.9	18	18	9.4	7.8	21	8.5	7.2	8.6	7.2	20
LC07_01	43.3	37.2	17	17	28.2	23.9	18	24.4	20.5	27.2	23.1	18
LC07_02	3.6	3.1	16	16	2.2	1.9	16	1.6	1.4	1.7	1.5	16
LC07_03	3.7	3.2	18	18	2.5	2.1	19	2.0	1.7	2.1	1.8	17
LC07_04	5.2	4.5	16	16	3.4	2.9	17	2.9	2.5	3.0	2.5	19
LC07_05	0.9	0.7	25	25	0.9	0.7	20	0.8	0.7	0.8	0.7	21
LC12_01	17.4	15.1	15	15	10.8	9.3	17	8.5	7.3	8.8	7.5	17
LC12_02	4.4	3.8	16	16	2.9	2.5	16	2.2	1.9	2.3	2.0	16
LC12_03	19.3	16.6	16	16	12.6	10.7	17	10.5	8.9	10.6	9.0	18
LC12_04	10.7	9.2	16	16	8.0	6.7	19	7.4	6.2	7.3	6.1	19
LC6_6_01_a	1.5	1.3	15	15	0.9	0.2	319	0.6	0.5	0.7	0.6	14
LC6_6_01_b	0.1	0.1	21	21	0.3	0.2	24	0.3	0.2	0.3	0.2	24
LC6_6_02_a	0.7	0.6	23	23	0.8	0.6	22	0.6	0.5	0.6	0.5	20
LC6_6_02_b	1.8	1.4	27	27	2.3	1.9	20	2.1	1.8	2.2	1.9	17
LC6_6_1_d1	1.6	1.4	15	15	1.0	0.4	131	0.7	0.6	0.7	0.6	15
LC6_6_1_d2	0.4	0.3	26	26	0.4	0.3	20	0.4	0.3	0.3	0.3	23
LC6_6_1_d3	1.9	1.7	15	15	1.1	0.2	352	0.8	0.7	0.9	0.7	15
LC6_6_1_e1	0.5	0.4	26	26	0.5	0.4	21	0.4	0.3	0.4	0.3	26
LC6_6_1_e2	1.2	1.0	15	15	0.7	0.3	124	0.5	0.5	0.6	0.5	17
LC6_6_1_e3	3.0	2.6	15	15	1.8	0.7	143	1.3	1.1	1.3	1.2	15
LC6_7_05_a	1.3	1.1	22	22	1.3	1.0	20	1.2	1.0	1.2	1.0	20
LC6_7_05_b	1.6	1.3	17	17	1.0	0.5	77	0.7	0.6	0.7	0.6	15
LC6_7_05_c	1.6	1.3	22	22	1.5	1.3	19	1.4	1.2	1.4	1.2	21
LC6_7_05_d	1.3	1.0	22	22	1.2	1.0	20	1.1	1.0	1.1	0.9	21

Subcatchment ID	1hr			3hr			6hr			12hr		
	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase	Q100 with Climate Change Allowance	Q100 without Climate Change Allowance	% Increase
LC6_7_06_b	0.8	0.7	23	0.8	0.6	20	0.7	0.6	19	0.7	0.6	19
LC6_7_2_b1	6.5	5.6	16	4.0	2.0	105	3.1	2.7	16	3.2	2.8	16
LC6_7_2_b2	2.8	2.4	17	1.8	1.0	80	1.4	1.2	17	1.5	1.3	17
LC6_7_2_b3	3.6	3.1	16	2.2	1.1	95	1.6	1.4	16	1.7	1.5	16
LC6_7_4_a1	0.7	0.6	19	0.4	0.3	64	0.3	0.3	16	0.3	0.3	16
LC6_7_4_a2	1.1	0.9	22	1.0	0.8	21	0.9	0.8	19	0.9	0.8	20
LC6_7_4_a3	3.1	2.6	16	1.9	1.0	92	1.4	1.2	16	1.5	1.3	15
LC6_7_4_a4	1.1	0.9	22	1.0	0.8	21	0.9	0.8	20	0.9	0.8	21
LC6_7_4_a5	1.4	1.2	17	0.9	0.5	74	0.6	0.6	15	0.7	0.6	15
LC6_7_4_b	1.3	2.3	-44	1.3	1.0	25	1.2	1.0	20	1.2	1.0	20

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APPENDIX D: STATE PLANNING POLICY 1/03 SPECIFIC OUTCOMES

Table D-1 outlines the proposed solutions for the Specific Outcomes of the State Planning Policy 1/03.

Table D-1 Proposed Solutions for Specific Outcomes of State Planning Policy 1/03

Specific Outcomes	Proposed Solution
1. Development maintains the safety of people on the development site from all floods up to and including the DFE (1% AEP Event)	This report is a Flood Impact Assessment of the proposed development. As part to this Flood Impact Assessment, detailed flood modelling was undertaken that investigates the dynamic effects of any changes to floodplain storage, flood conveyance capacity and runoff characteristics that will result from the proposed development. The modelling undertaken takes into account flooding from the Lamerough Creek/Bells Creek system, tidal sources and local catchments to the immediate north of the subject site. The urban areas of the proposed development will be filled to a minimum of the modelled 100 year ARI flood levels with climate change allowance plus 500mm. It demonstrates that the proposed development is flood free in the DFE (1% AEP event) and therefore the safety of people on the development site is maintained.
2. Development does not result in adverse impacts on people's safety or the capacity to use land within the floodplain. ..	The flood impact assessment demonstrates that the proposed development is does not result in significant flood impacts outside the applicant's property boundaries and will generally not significantly alter the flood flow patterns on the Lamerough Creek floodplain surrounding the development site for design flood events between the 3 month and the 100 year ARI events. The urban areas of the proposed development will be filled to a minimum of the modelled 100 year ARI flood levels with climate change allowance plus 500mm
3. Development minimises the potential damage from flooding to property on the development site.	The flood impact assessment demonstrates that the proposed development is flood free in the DFE (1% AEP event) and therefore the potential damage from flooding to the development site is minimised.
4. Public safety and the environment are not adversely affected by the detrimental impacts of floodwater on hazardous materials manufactured or stored in bulk.	No storage of floodwater or hazardous material on site are proposed.
5. Essential services infrastructure (e.g. on-site electricity, gas, water supply, sewerage and telecommunications) maintains its function during a DFE.	Essential services infrastructure will be located above the DFE (1% AEP) level.

APPENDIX E: FLOOD STORAGE VOLUMES

10 August 2010

BMT WBM
Level 5
99 King Street
MELBOURNE VIC 3000

Attention: Joris Jörissen

Dear Joris

**BELLVISTA 2, LITTLE MOUNTAIN
TECHNICAL MEMORANDUM
FLOOD STORAGE VOLUMES**

We refer to the abovementioned development and in particular regional Q100 flood storage volumes. We have undertaken an assessment of said storage volumes using the following information:

- Q100 Flood Surface (provided by Philip Pedruco of your office via email dated 30/7/2010).
- Natural Surface Level Survey (provided by the project surveyors, RPS Group).
- Preliminary Design Surface (prepared by Brown Consulting, refer drawings N08042-MCU05 and N08042-MCU06).

The preliminary design surface has been developed in accordance with the site drainage strategy, Council's policy with respect to allotments being above Q100 (plus 500mm freeboard) and with the objective of achieving no net loss of Q100 floodplain storage within the development footprint. This design surface is preliminary only and subject to change with detailed design. This analysis has yielded the following results:

- Q100 Flood Storage – Pre-Developed Volume: 27,670m³
- Q100 Flood Storage – Post-Developed Volume: 28,277m³

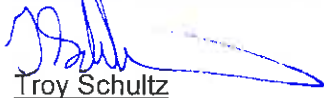
Therefore an extra 607m³ of flood storage volume is provided in the Post-Developed scenario, resulting in no net loss of floodplain storage during the regional Q100 storm event.

We trust this is acceptable.

Should you require any further information please do not hesitate to contact the undersigned.

Yours faithfully

BROWN CONSULTING (QLD) PTY LTD



Troy Schultz

Engineer – Urban Development





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