YARRABILBA PRECINCT 3
FLOOD STUDY

VERSION 1A

PLANS AND DOCUMENTS
referred to in the PDA
DEVELOPMENT APPROVAL

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Author(s):	Nic Smith and Shaun Leinster
Reviewed By:	Ralph Williams
Approved By:	Shaun Leinster
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FLOOD STRATEGY SUMMARY

The *Yarrabilba Precinct 3 Flood Study* has been completed to support the third major development precinct release within the Lend Lease land in the Yarrabilba Priority Development Area (PDA). This study incorporates an updated flood model of the Upper Quinzeh Creek and details the proposed flood mitigation strategy elements to be adopted as part of Precinct 3 development. This model has been validated against the flood event of 1 May 2015 to confirm that flood behaviour and inundation within and downstream of the study area can be satisfactorily represented by the 2D hydraulic model.

The study assesses all design flood events between the 2 and 100 year ARI, for a range of storm durations for both the pre-development and post development (Precincts 3 and including existing Precinct 1 and 2 development) catchment conditions. The flood mitigation strategy adopts a two stage approach to ensure both the Precinct 3A (interim) and Precinct 3 total development area can achieve the required outcomes.

Precinct 3A (interim) strategy utilises existing Flood Basin 9 and existing interim Flood Basin 16-INT constructed as part of the Precinct 2 flood mitigation strategy. These basins were intentionally designed and constructed to provide future flood capacity to ensure development progress beyond Precinct 1 and 2.

The ultimate development of Precinct 3 total maintains existing Flood Basin 9 (for the minor western portion of P3) and adopts a larger regional scale flood Basin 15 in the southern catchment which replaces the interim Flood Basin 16-INT when development precinct 3B commences. Flood Basin 15 is intended to form a key component of the long term flood management strategy for the balance of future development precincts within the upper Quinzeh Creek catchment. Therefore, in the short to medium term (i.e. within the Precinct 3 development timeline), this basin will provide significant improvements to downstream flooding.

The detailed hydrologic and hydraulic modelling for the development precincts shows that the implementation of the interim and ultimate flood strategies for Precinct 3 meets the design objectives set out in the *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) and results in reduction to flood peak discharge leaving the site and reduced flood levels to broad areas of upper Quinzeh Creek downstream.

1 INTRODUCTION

1.1 OVERVIEW

The Lend Lease site within the Yarrabilba Priority Development Area (PDA) covers an area of 2,012 ha and is located within Logan City Council. The site is bounded by Waterford-Tamborine Road to the west, Plunkett Road to the south, existing rural residential areas to the north and Plunkett Conservation Park to the east as shown in Figure 1.

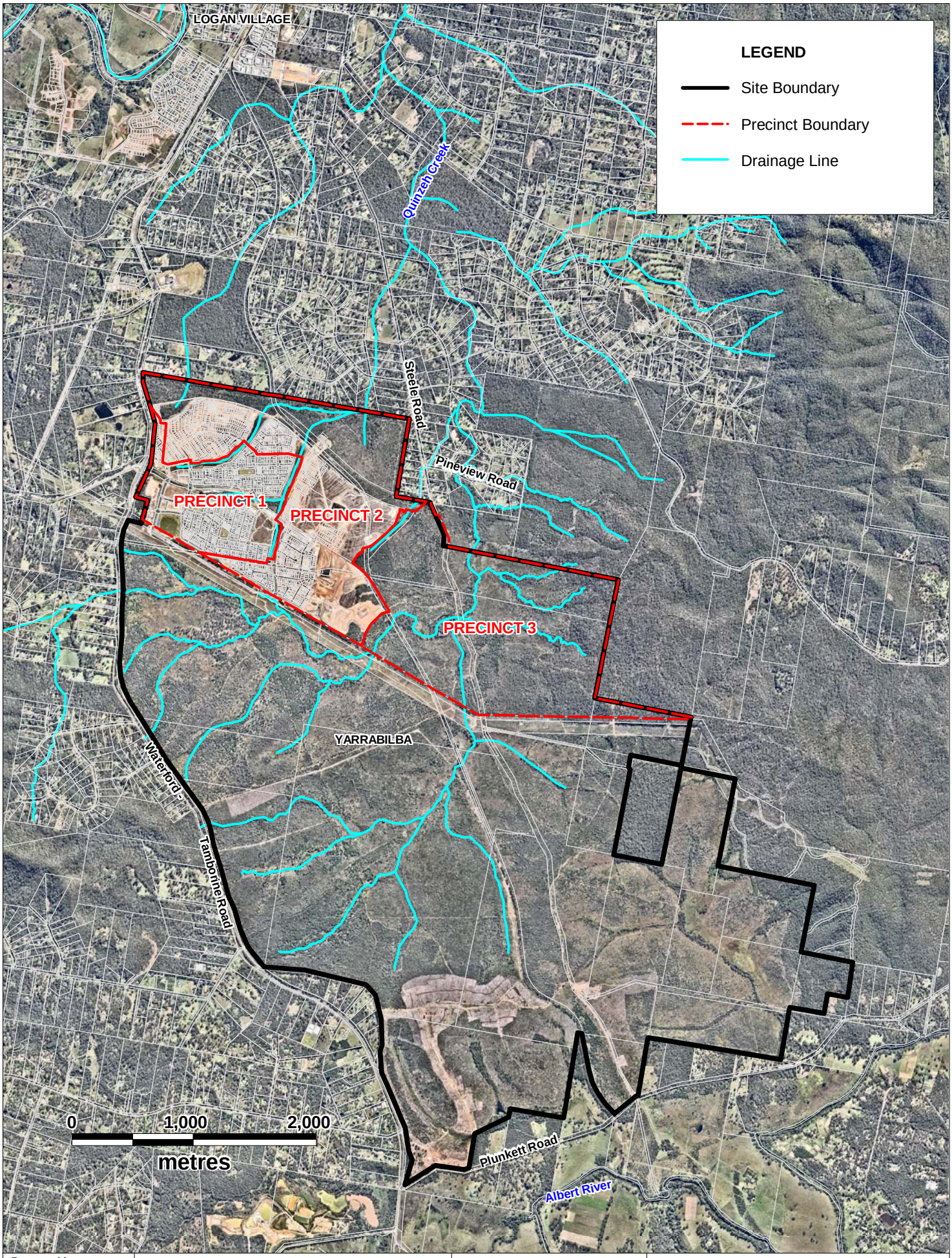
Development Precinct 3 (subject of this report) is the third major development area to be released at Yarrabilba and lies in the north eastern portion of the Lend Lease site extending from Precinct 2 across to the eastern site boundary adjoining Plunkett Reserve as shown in Figure 2. The precinct covers a total area of 254 ha which includes a significant proportion of waterway and conservation open space (approximately 157 ha or 60% of Precinct 3) as well as a major powerline easement buffer bordering the southern edge of the precinct.

1.2 SCOPE

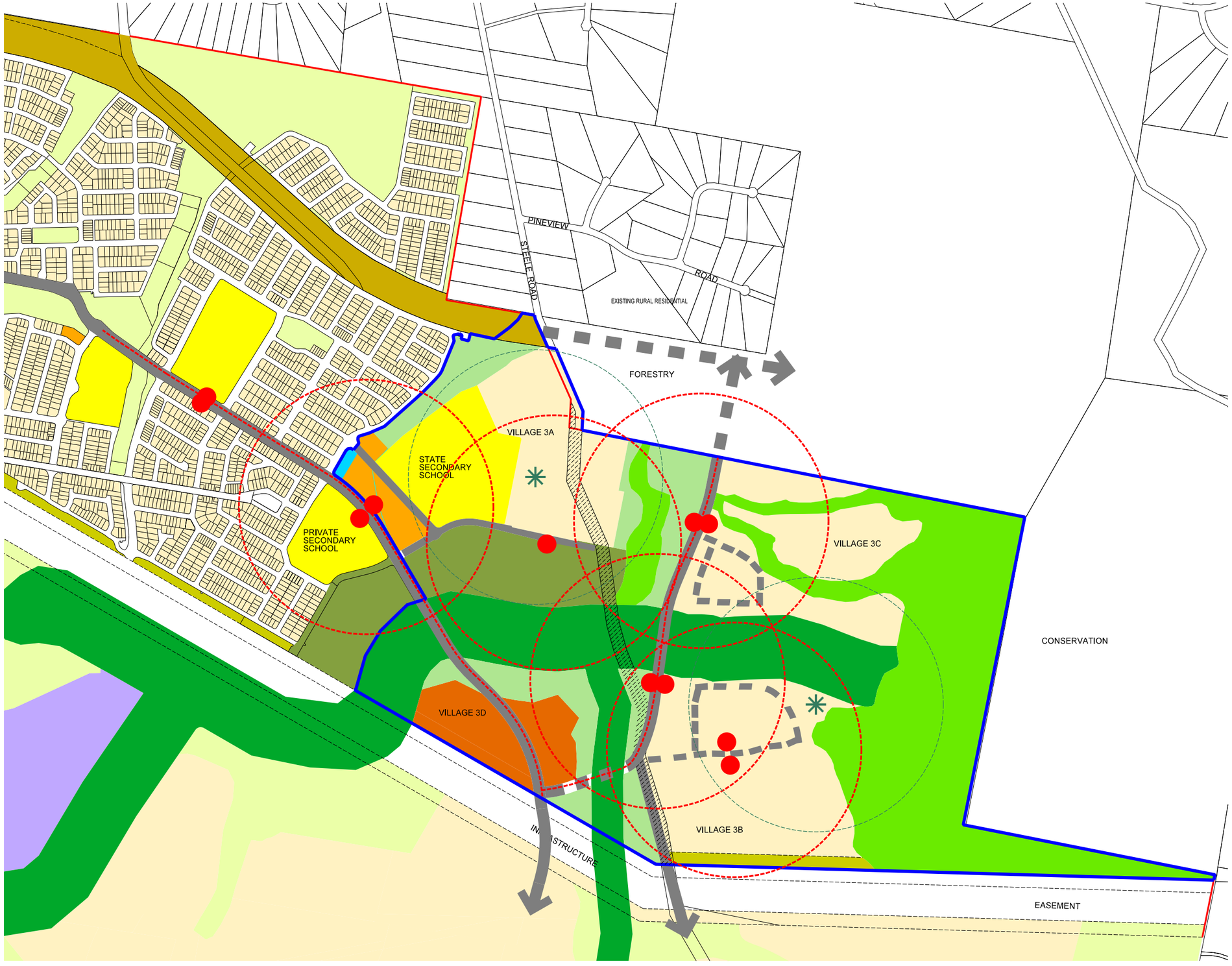
Lend Lease has commissioned DesignFlow to develop a flood management strategy for Precinct 3 to mitigate impacts of increased runoff from the development site and to integrate with the existing Precinct 1 and 2 flood management strategy documented in the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan* (DesignFlow, 2014).

The principles, objectives and broad concepts were developed as part of the *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) and the *Yarrabilba Total Water Cycle Management Strategy* (DesignFlow, 2012). These plans set consistent policy and design objectives to be applied across Yarrabilba for all future development applications and are reflected in the *Context Plan Area Strategy* (CPAS) for Precinct 3.

The Precinct 3 flood mitigation strategy is intended to form part of a broader long term flood strategy that incorporates major flood detention zones in key areas of the site to manage peak flood discharge from current and future development precincts. This enables efficient use of the natural topography onsite to manage flooding and reduce the number of locations in which flood infrastructure needs to be constructed and maintained. It also seeks to provide improvements (where practical) to the existing flooding issues experienced in the downstream catchment prior to any development occurring,



Prepared by: DesignFlow For: lendlease	Project: 4284 Yarrabilba Precinct 3 Flood Study	N W E S Scale: 1 : 40,000 (A4)	**FIGURE 1** **Site Layout**
	Client: Lend Lease	Date: 11 July 2016	



YARRABILBA

LEGEND

- YARRABILBA SITE BOUNDARY
- PRECINCT THREE BOUNDARY
- NEIGHBOURHOOD CENTRE
- RESIDENTIAL
- URBAN RESIDENTIAL
- EDUCATIONAL ESTABLISHMENT
- RETAIL/COMMUNITY/COMMERCIAL, MIXED USE & MULTI RESIDENTIAL
- INFRASTRUCTURE & EMPLOYMENT
- FAUNA CORRIDOR (ENVIRONMENTAL PROTECTION)
- ENVIRONMENTAL PROTECTION
- PARK
- MAJOR SPORTS PARK
- OPEN SPACE EXTERNAL TO pRECINCT 3
- NEIGHBOURHOOD RECREATION PARK & 400m RADIUS LOOP
- DISTRICT RECREATION PARK & 400m RADIUS LOOP
- ELECTRICITY EASEMENT
- LANDSCAPE BUFFER
- SOUTHERN INFRASTRUCTURE CORRIDOR
- PRIMARY MOVEMENT NETWORK
- SECONDARY MOVEMENT NETWORK
- BUS ROUTE
- BUS STOP/PROPOSED BUS STOP & 400M RADIUS LOOP
- EXISTING TRAILS
- ROAD TO BE CLOSED

TOTAL PRECINCT AREA	254 ha
GROSS RESIDENTIAL AREA	67ha
Approx 950 lots at an average density of 15dw/ha	
COMMUNITY FACILITIES	2.55ha
STATE SECONDARY SCHOOL	12.0ha
OPEN SPACE	157.0ha
ROAD	7.0ha

DISCLAIMER
The context plan is intended to guide development within the Yarrabilba Precinct Three area and show the preferred land use designations and structural elements. The context plan does not prescribe these designations and structural elements with complete accuracy and the final location will be determined through further detailed design and development applications.

NOTES
The contents of this plan are conceptual only. All areas are approximate only and subject to relevant studies, survey, engineering and relevant authority approvals.

YARRABILBA - PRECINCT THREE CONTEXT PLAN

NOTE: This plan is indicative only, and specific uses, road alignment, boundaries, setbacks, and building layout shown may vary due to detailed design consideration. ©2015 Lend Lease Communities (Australia). All rights reserved. Except as permitted by Lend Lease, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the permission of Lend Lease.

0 125 250 375 500 625m

Scale 1:12500 at A3

North

lendlease

File No. D

Dgn No. YAR_P03_PCP160613

Date 13th JUNE 2016

1.3 OBJECTIVES

The objectives of the Precinct 3 flood study are consistent with the *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) and reiterated in the *Precinct 3 Context Plan Area Strategy* as follows:

- Mitigate flood impacts on people, property and infrastructure external to Yarrabilba by preserving peak site discharge and flood levels upstream and downstream of the site to pre-development conditions for all events from 2 to 100 year ARI (2 to 100 year ARI); and
- Maintain flood conveyance through the site while providing 100 year ARI flood immune development.

1.4 CONSTRAINTS AND OPPORTUNITIES

A number of constraints exist within the Precinct 3 development zone and surrounding areas that must be considered in the development of the stormwater and flood management strategies. While not all constraints identified directly impact the ability to deliver a flood strategy, they may be impact the associated development infrastructure (such as roads, sewer and open spaces) that influence the flood strategy. Key constraints identified for Precinct 3 include:

- Fauna corridor and passage (exclusion zones for works and infrastructure while imposing requirements on fauna movement in design)
- Waterway riparian buffers (setbacks to earthworks and infrastructure)
- Vegetation protection zones (as for riparian buffers)
- Natural wetlands (protection of ecology and hydrology)
- Overhead powerlines (limitations on clearance to cables, flood depths and protection of tower foundations)
- Major road corridors (safe and/or flood free access)
- Waterway stability (protection of geomorphic stability of key waterways)
- Integration with urban design (flood storage requirements, batters and depths impact development footprint and public safety)
- Development staging (mitigating flood impacts at all stages of development, both Precinct 3 and future precincts)

By exploring these constraints and the limitations they pose on design, there are a number of key opportunities that arise out of this to provide flood management solutions within Precinct 3 including:

- Broad flat drainage lines (efficient flood storage upstream of road crossings)
- Multiple use open spaces (co-location of flood storage with stormwater quality treatment and public open spaces)
- Multi-functional fauna passage and flood bypass culverts (high level culverts suitable for fauna passage in minor floods and flood bypass in major events)
- Reduction in future flood infrastructure in broader catchment (by optimizing regional scale flood storage on branched drainage lines to manage flood timing)

1.5 COMMUNITY ENGAGEMENT

Prior to the commencement of development works onsite at Yarrabilba in around 2012, numerous properties in the downstream catchment were known to be flood prone based on the former Beaudesert Shire Council flood regulation mapping. Logan City Council updated this flood mapping in 2013 which involved engagement with the local community to gather and disseminate relevant information to residents in relation to the new flood regulation maps.

Since the commencement of development, resident concerns relating to flooding have been heightened due to the rapid rate of development, personal observations of rainfall runoff behaviour and a major local flood event in May 2015. Lend Lease have therefore responded with increasing community engagement to concerned and affected residents. This has occurred in consultation with Logan City Council, local Member of Parliament and Economic Development Queensland to provide a transparent information program with input from all key stakeholders. Some key activities and actions initiated by Lend Lease in consultation with relevant authorities to date include:

- Community flood information session
- Resident one-on-one site meetings
- Funding installation of a flood warning and rainfall gauge in Upper Quinzeh Creek
- Individual property flood information maps
- Site construction status letterbox drops
- Detailed flood and floor level surveys of private properties
- Flood warning and evacuation information
- Maintaining an open line of communication to concerned residents

Lend Lease will continue to provide a community engagement role as development progresses which will be flexible to adapt to the relevant concerns that may arise. Council's role is also crucial to ensure the long term management of flood risk is carried out as part of the city wide *Flood-Ready Logan* initiative.

1.6 PREVIOUS STUDIES

1.6.1 Logan City Council

Logan City Council has undertaken a number of previous studies in the Quinzeh Creek catchment that supported the update to the Logan Planning Scheme 2015 and associated flood hazard overlay mapping. These include:

- Quinzeh Creek Design Discharge Estimate (WRM, 2013)
- Revised Quinzeh Creek Flood Study (Engeny, 2013)
- Flood hazard overlay map (OM-05.00) version 2.1 (Logan Planning Scheme 2015 version 2.1)

Detailed discussion of the discharge estimate and flood study reports above has been provided previously in the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014). The flood hazard overlay map now forms part of the endorsed Logan Planning Scheme 2015.

1.6.2 Yarrabilba

Stormwater and flood assessments that have been commissioned by Lend Lease as part of the Yarrabilba development and approved by EDQ are:

- *Yarrabilba Northern Development Area Stormwater Quantity Management Plan* (Water Technology, February 2011) - Flood modelling completed for Precinct 1.
- *Yarrabilba Development: Flood Risk Management Strategy* (WBM BMT, 2012) - Broad scale flood modelling completed for the whole Yarrabilba site to inform the overarching site strategy for total water cycle management.
- *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) - Stormwater assessment for the whole Yarrabilba site to inform the overarching site strategy for total water cycle management.
- *Yarrabilba Total Water Cycle Management Strategy* (DesignFlow, 2012) – compilation of water related assessments and infrastructure master plans for the total Yarrabilba site.
- *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, February 2014) – Provided as an update and expansion to the Precinct 1 assessment based on EDQ conditions.
- *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 3* (DesignFlow, August, 2014) – Further updates and expansions to the previous version based on the updates to Logan City Council's Quinzeh Creek flood model.

1.7 THIS REPORT

This flood study provides the details and assessment of the Upper Quinzeh Creek catchment, flood behaviour, impacts and mitigation strategies to be adopted as part of Precinct 3 development at Yarrabilba. Information herein is provided in the following sections:

- Section 2 – Provides an overview of the site, catchment and waterway context in terms of the natural and engineered elements that contribute to and impact flood generation and behaviour.

- Section 3 – Details the hydrological assessment, data and modelling undertaken to generate rainfall-runoff information for use in the site flood model.

- Section 4 – Explains the development of the two dimensional hydraulic model for the site and downstream catchment to enable detailed assessment of flood propagation through the natural and developed landforms for comparative assessment of impacts pre- and post-development, actual events and validation of proposed mitigation strategies.

- Section 5 – Outlines the flood mitigation strategy and the infrastructure required to meet the interim and ultimate Precinct 3 development flood management objectives. It provides the preliminary flood detention infrastructure sizing and also discusses the management of frequent minor flows.

- Section 6 – Presents the results and discussion of the findings from the hydrologic and hydraulic modelling to inform and justify the proposed mitigation strategies adopted for Precinct 3.

- Section 7 – Summaries the flood study findings and provides concluding remarks in relation to both Precinct 3 development and future catchment development within Yarrabilba

1.8 STATUS OF FLOOD ESTIMATION IN AUSTRALIA

The flood assessment, modelling, results and interpretation presented herein are derived largely from the 1987 version the *Australian Rainfall and Runoff: A guide to flood estimation* (ARR87) data and methodologies which were industry best practice at the time of writing. It is however recognised that Engineers Australia (EA) is nearing the completion of a major review of ARR which will result in more extensive rainfall-runoff data across the country as well and improved approaches to assessment and infrastructure planning. This guideline is not yet released for industry wide adoption at the time of writing but is understood to be scheduled for this year.

The Yarrabilba Precinct 3 Flood Study therefore provides the required outcomes for the current development assessment at Yarrabilba but is cognisant of the importance of

ensuring flood management strategies remain viable in the long term. Future flood assessments and/or validation of existing strategies will therefore aim to adopt current best practice approaches as these are rolled out to industry.

1.9 TERMINOLOGY

The terminology relating to rainfall and flood probability used in this report has been retained from previous Yarrabilba and Logan City Council flood assessments and generally uses Average Recurrence Interval (ARI) to define the probability. However, in future reporting, and to be consistent with the current recommendations from the Engineers Australia's National Committee on Water Engineering, there will be a move towards revised terminology as part of the proposed updates to the ARR described above and associated data which is currently occurring.

Most notably is the use of **Annual Exceedance Probability (AEP)** and **Exceedances per Year (EY)** terminology instead of the traditional use of **Average Recurrence Interval (ARI)** which is discouraged due to confusion arising from use and interpretation. The relationship between terminology and the preferred usage is shown below (sourced directly from the Bureau of Metrology (BOM) website at the time of writing). BOM and Engineers Australia note that there is still ongoing review of terminology for the events between 1EY and 10% AEP and therefore changes may occur in future. As the IFD information on which this flood study is based is provided in ARI, this terminology has been retained for the current study.

Table 1: Rainfall and flood probability terminology

EY	AEP (%)	AEP (1 in x)	ARI	Uses in Engineering Design
6	99.75	1.002	0.17	Water sensitive urban design
4	98.17	1.02	0.25	
3	95.02	1.05	0.33	
2	86.47	1.16	0.50	
1	63.21	1.58	1.00	
0.69	50.00[1]	2	1.44	Stormwater/pit and pipe design
0.5	39.35	2.54	2.00	
0.22	20.00[1]	5	4.48	
0.2	18.13	5.52	5.00	
0.11	10.00	10	9.49	
0.05	5.00	20	19.5	
0.02	2.00	50	49.5	
0.01	1.00	100	100	
0.01	0.50	200	200	
0.002	0.20	500	500	
0.001	0.10	1000	1000	
0.0005	0.05	2000	2000	Floodplain management and waterway design
0.0002	0.02	5000	5000	Design of critical infrastructure (eg dams)

[1]It should be noted that for the 20% and 50% AEP the usual conversion to EY or ARI as simply the inverse of AEP does not apply; the corresponding correct EY and ARI values are shown in the table.

Source: http://www.bom.gov.au/water/designRainfalls/ifd/ifd-faq.shtml (26/4/16)

2 CATCHMENT OVERVIEW AND DATA

2.1 YARRABILBA SITE

The Yarrabilba site as a whole straddles two major river catchments, being the Logan River and the Albert River. Quinzeh Creek forms the major tributary of the Logan River into which the majority of the site drains northward into. This northern catchment is the focus of this and previous studies as it wholly contains the development Precincts 1 to 3.

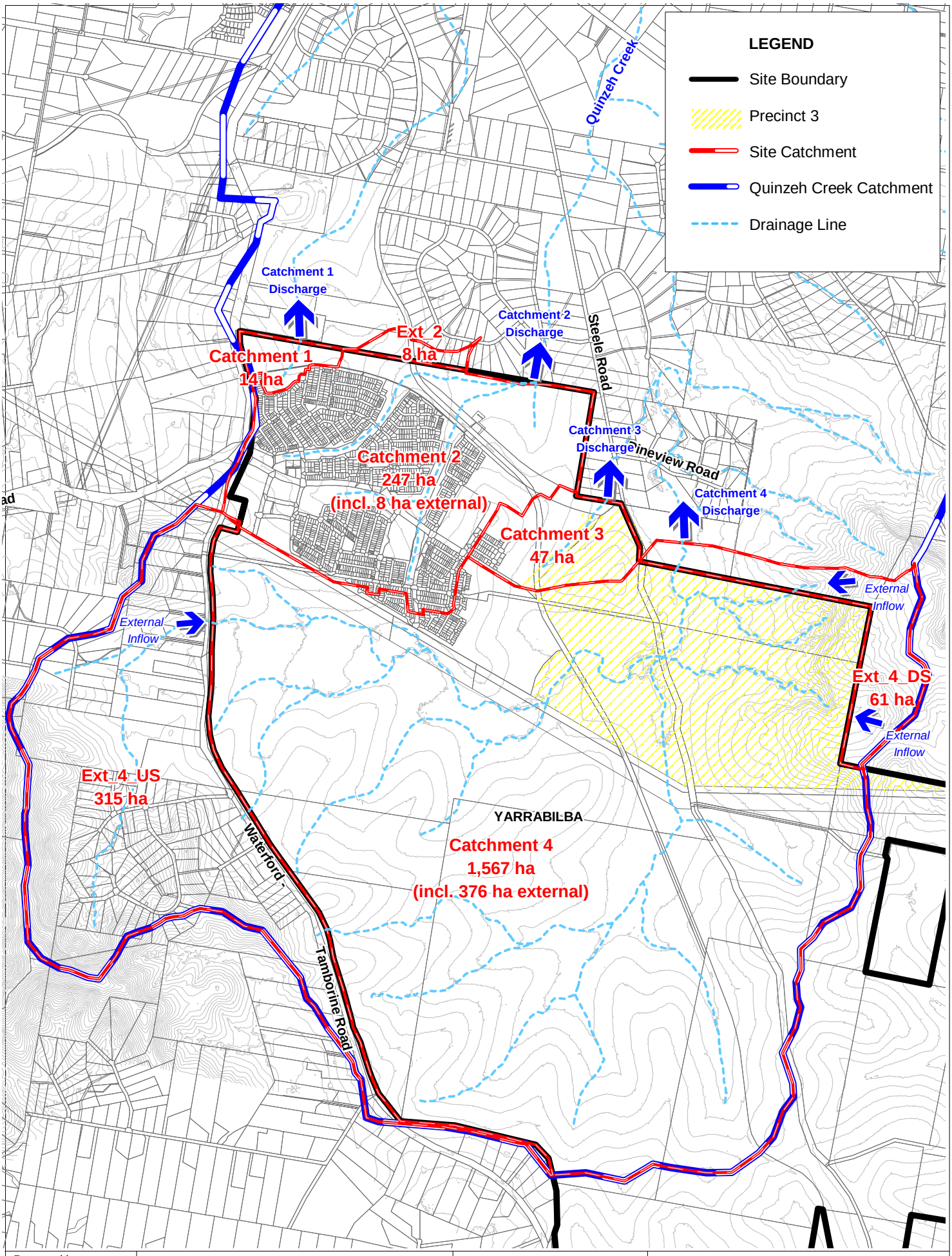
The portion of the site within the Albert River catchment has been assessed as part of the overall *Yarrabilba Development: Flood Risk Management Strategy* (WBM BMT, 2012). Until future development staging progresses across this catchment divide, no further assessment of this catchment is required for the Precinct 3 flood strategy as it has no influence on flooding in Quinzeh Creek.

The portion of the Yarrabilba development site draining north to Quinzeh Creek can be broadly divided into four main catchments defined by the discharge location downstream to either Quinzeh Creek or side tributaries. Each of these catchments varies significantly in size and requires consideration of the downstream drainage paths through either private property (overland flow paths) or directly into the main Quinzeh Creek watercourse. A description of each catchment discharge location is provided below and shown in Figure 3. Figure 4 provides an overview of properties immediately downstream of the Yarrabilba site boundary through which discharge from Precinct 3 occurs.

2.1.1 Catchment 1

Catchment 1 totals around 14 hectares (reduced from 23ha following development of Precinct 2) and discharges through the Main Roads infrastructure corridor to private property at the northern boundary of the Yarrabilba site (refer Figure 3). Immediately downstream of the site, a large farm dam accepts flows with overflows from the dam entering a short length of grass channel. Flows then enter a large parcel of land which is fully vegetated. No drainage easement is present through these properties.

The Precinct 1 and 2 stormwater management strategy resulted in a reduction in minor and major flood discharges from this catchment due to regrading of land for roads and lots leading to a reduction in catchment area. This provides for no worsening of flooding to downstream properties.



Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3 Flood Study

Client: Lend Lease

Scale: 1 : 30,000 (A4)

Date: 11 July 2016

FIGURE 3

Yarrabilba Discharge Locations

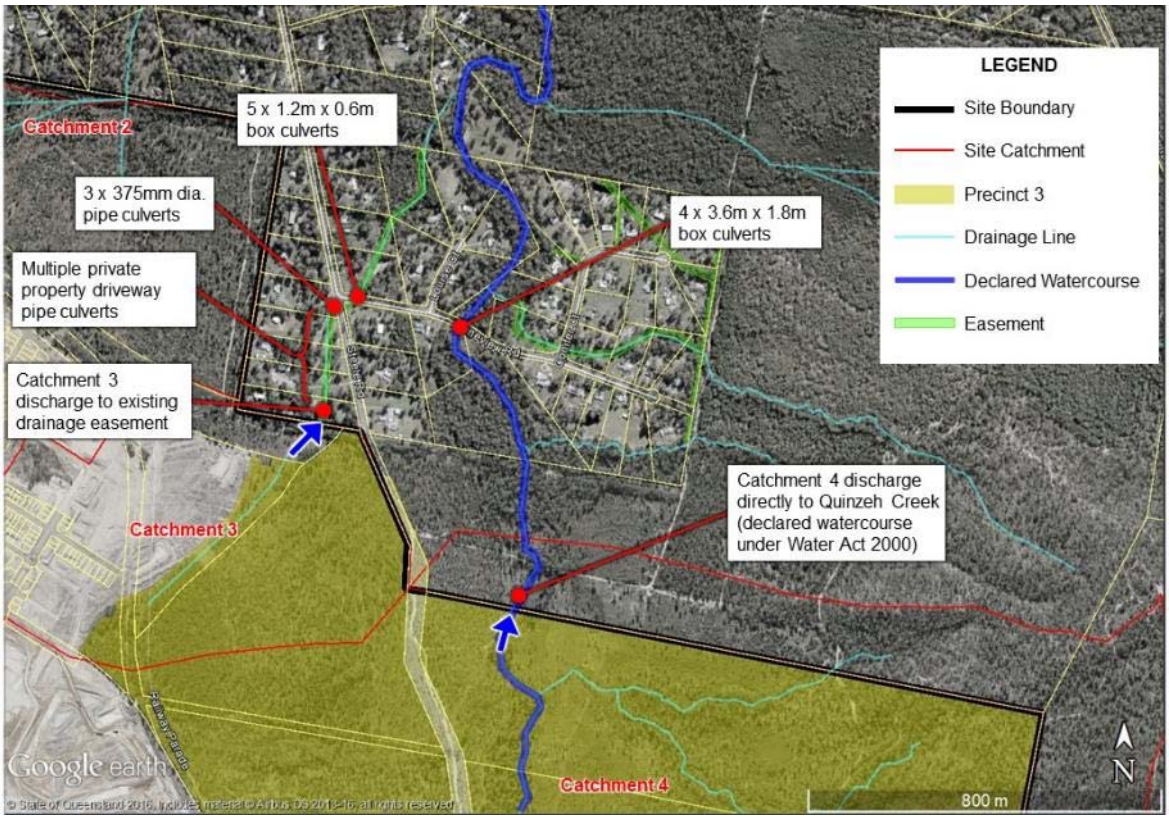


Figure 4: Precinct 3 downstream drainage

2.1.2 Catchment 2

The now largely developed Catchment 2 (comprising Precincts 1 and 2) totals 246 hectares and discharges to private property at the northern boundary of the Yarrabilba site (refer Figure 4). Flows travel approximately 1.5 km downstream from the Yarrabilba boundary through private property to Quinzeh Creek and then ultimately the Logan River.

Immediately downstream of the Yarrabilba boundary there is no defined waterway within the private property, just a flat wide overland flow path/ephemeral waterway. Creation of a drainage easement through the downstream property is currently occurring through the relevant state authorities to link the existing easement downstream of Georgina Drive (see below) to the Yarrabilba site boundary.

Where the flow path reaches Georgina Drive, it passes under the road via a set of culverts to enter a small constructed channel. The constructed channel is located within a drainage easement through private property and has very flat longitudinal grade (<0.5%) and congested with vegetation including pine regrowth. Although the capacity of the channel is limited, it conveys smaller flows all the way through a number of private properties and the Big River Country Park (soccer fields) to Quinzeh Creek. Overbank spill to private property from this channel appears to occur under

relatively low flows due to channel obstruction from vegetation and very low elevation difference of banks and adjoining land.

The *Yarrabilba Precinct 1 and 2 Stormwater Management Plan* (DesignFlow, 2014) addresses site discharges from this catchment and provides for no worsening of flooding to downstream properties. Lend Lease has also committed to working collaboratively with property owners and Logan City Council to manage the frequent minor flows through private property via constructed channel(s) in drainage easements.

2.1.3 Catchment 3

Catchment 3 covers around 47 hectares and includes the Main Roads infrastructure corridor. The catchment discharges to private property at the northern boundary of the site (refer Figure 4). Flows travel approximately 0.75 km downstream from the Yarrabilba boundary through private property to Quinzeh Creek. A 10m drainage easement exists through these properties which conveys low flows. Flood flows inundate areas beyond the easement.

The existing drain is characterised by a flat wide depression between the Yarrabilba site boundary and Steele Road with a number of intersecting farm dams and driveway crossings. At Pineview Road a 10m wide channel has been created ensuring low to moderate flows are contained within the easement. All the properties downstream of Catchment 3 are subject to existing flooding and has been the focus of recent Council and Lend Lease flood modelling. The confluence of the Catchment 3 tributary and Quinzeh Creek is a particular issue for flooding with a number of properties entirely inundated according to the Council flood modelling/mapping.

As part of the existing Precinct 1 and 2 stormwater strategy Flood Basin 9 has been constructed to manage Catchment 3 which was designed to accept discharge from northern portion of Precinct 3A. This strategy ensures stormwater quality is managed and peak flood flows are preserved. Ongoing work is also occurring in conjunction with downstream residents to further resolve the management of frequent minor flows and improve the immunity of the driveway crossings on the private properties downstream of Flood Basin 9. Further discussion of frequent minor flows is provided in Section 5.4.

2.1.4 Catchment 4

Catchment 4 is the major Yarrabilba catchment covering an area of approximately 1567 hectares and drains into the upper reach of Quinzeh Creek via a broad ephemeral drainage line as illustrated in Figure 3. The majority of Precinct 3 lies within catchment 4 and will therefore be the focus of this flood mitigation strategy as well as subsequent development stages in the future.

As part of the Precinct 1 and 2 flood management strategy, an interim flood detention basin (now referred to as Flood Basin 16-INT) was implemented to manage the portion of Precinct 2 that drained towards Catchment 4. This basin is located south of the powerline easement as identified in Section 5.2 and provides for additional flood

capacity for the initial stages of Precinct 3. This interim flood basin will remain in place until ultimate flood mitigation infrastructure is constructed as part of Precinct 3.

External Catchments

As shown in Figure 3, external catchments discharging into the Yarrabilba site exist at two main locations within Catchment 4. These areas have sufficient topographic separation from the site such that flooding and drainage within the site do not create backwater or flooding upstream. However, consideration of these external flow inputs to the Yarrabilba site are important to site drainage and flood conveyance. A brief description of these is provided below.

a) Waterford Tamborine Road – west

This external catchment is predominantly rural residential and slopes up from Waterford-Tamborine Road to the Quinzeh Creek catchment divide to the south west. Drainage is via broad informal overland flow paths through a number of farm dams which direct flows towards the major culverts (5 x 1.8m diameter pipes) under Waterford Tamborine Road. Overland flow from lower properties flows directly towards Waterford Tamborine Road and intercepted by roadside swales in minor storms) and overtops the road in major events.

b) Plunkett Reserve - east

Plunkett Reserve rises steeply from the eastern extent of Precinct 3 with the catchment boundary extending a short distance beyond the site boundary. The external catchment is relatively small and won't be subject to development in future (conservation area) but runoff from the area discharges through Precinct 3.

2.2 QUINZEH CREEK AND TRIBUTARIES

2.2.1 Waterway Condition

As shown previously in Figure 1 and Figure 3, Quinzeh Creek drains generally northward from catchment 4 of Yarrabilba via broad, low gradient (often braded) channels to approximately Pineview Road. Downstream of the Pineview Road culverts, the creek is more defined with low flow channel, banks and more permanent flow and pools. The creek does however dry out after extended periods of no rainfall. Based on aerial photography review and localised ground assessment, the creek exhibits a reasonably intact riparian buffer that is locally narrowed or broken at areas of clearing within private property. The majority of the upper and mid reaches of the creek lie within private rural and rural residential properties. Localised areas of instream works have occurred in the past to create online dams, creek crossings and/or clear /revegetate areas of land within private properties straddling the creek.

2.2.2 Roads and Culverts

A number of culvert crossings exist within the main creek and tributaries. Being within a rural residential zone, these drainage crossings generally have low flood immunity and are subject to frequent inundation (under existing catchment conditions prior to

Yarrabilba development). Drainage details immediately downstream of Precinct 3 are provided previously in Figure 4 with further discussion of drainage infrastructure external to the site is provided in Section 2.6.

As noted previously, some private properties are known to have constructed barriers across the main creek line to form farm storages or to gain access to the opposite side of the creek. These barriers and culverts cannot be accurately accounted for within the flood model without detailed site assessment. Limited survey of specific areas was captured during the flood surveys on private property discussed in Section 4.3. Further, any such modifications to the creek or overbank conditions (ground levels or vegetation) will influence the flood behaviour in these areas, particularly with regard to upstream water levels and the location/timing of overbank spill once the creek channel capacity is exceeded.

2.2.3 Waterway Classification

Quinzeh Creek is a declared watercourse under the *Water Act 2000* which extends into Catchment 4 of the Yarrabilba site as far south as the Powerline easement. An authorisation under the *Water Act* (riverine protection permit) is required to take water, interfere with the flow of water or excavate/ place fill in a watercourse. The balance of main drainage lines north from the balance of Precinct 1 and 2 catchments are classed as drainage features under the Water Act and lie within the Water Resource (Logan Basin) Plan 2007 area and which does not regulate the taking of or interference with overland flow.

From the *Fisheries Act 1994* perspective, the main waterway extending south into Precinct 3 is classed as a third order stream which is deemed to be a high risk of impact from waterway barrier works. Side tributaries from this main channel are first and second order streams with low and moderate risk ratings from barrier works under the Fisheries Act 1994. Fish passage assessment is therefore required as part of the detailed design of works crossing this main waterway.

2.3 TOPOGRAPHY AND AERIAL IMAGERY

2.3.1 Aerial Survey

Airborne laser scanning (ALS), also referred to as LiDAR survey data for the site and surrounding catchment has been collated from available sources. Yarrabilba site LiDAR provided by Lend Lease was generated in 2011 with a reported accuracy of ±150mm. The broader catchment LiDAR within Councils downstream flood model dates from 2008 also with a reported accuracy of ±150mm. LiDAR accuracy/tolerances are primarily due to the influence of ground vegetation of differing heights and density which impact the ground scanning technology. Post processing of this survey data by specialists does however produce the most efficient and accurate data available at this scale.

2.3.2 Ground Survey

Detailed ground level and flood level survey was undertaken on accessible properties in Pineview Road, Louise Court and Maranoa Drive that were affected by flooding in May

2015. This survey data was subsequently used in the flood model to correct digital elevation model (DEM) levels derived from LiDAR and for the calibration of modelled flood levels. Road crown levels were also surveyed on Pineview Road, Louise Court and Steele Road to confirm the overtopping of these roads is modelled as accurately as possible within the hydraulic model.

Detailed survey within the Yarrabilba site has also occurred to provide validation of LiDAR in areas of cut/fill and assign modification factors locally to ensure earthworks volumes are accurate. This resulted in a reduction of natural surface levels (i.e. LiDAR to actual) within the Precinct 1 Village 5 development zone of 120mm. Adjustments also occurred in other development zone however these were not directly impacting detention zones or flow paths and therefore not required for the flood model update.

2.3.3 Earthworks Model

Development earthworks have been sourced from KN Group civil engineering design based on either detailed or concept earthworks models. Where no design details were available at the time of modelling (e.g road crossing bunds) estimates were made and built into the hydraulic model terrain as raised 2D cells in the digital elevation model (refer Section 4).

2.3.4 Aerial Imagery

Aerial imagery has been obtained from a range of sources for both current and historical catchment conditions. Nearmap is used for high resolution and most current aerial imagery while Google Earth, Queensland Globe and Logan City Council online mapping has been reviewed or referenced where relevant.

2.4 SOILS AND VEGETATION

The majority of the broader site was formerly a pine plantation, with most of the vegetation in the proposed Precinct 3 development area (outside of drainage lines) consisting of grassland or pine and eucalypt/acacia re-growth with limited ecological value. The upper slopes on the eastern fringe of Precinct 3 adjoining Plunkett Reserve have remained naturally forested throughout the recent history of the site (presumably too steep to undertake forestry).

As illustrated in Figure 5, the grassland and pine areas represented roughly 80% of the pre-development land use across the portion of Yarrabilba discharging to Quinzeh Creek. The 2003 image highlights the minimal vegetation cover onsite with dense vegetation occurring (generally) only within waterways, drainage lines and steep upper slopes as identified previously. The subsequent images from 2009 and 2011 show the gradual regrowth of abandoned pine plantation areas as well as native regrowth of naturally propagated species across the formerly cleared/grassland areas. Vegetation along sections of waterway within Precinct 3 has been mapped as 'Of Concern' (RE 12.3.11) and 'Least Concern' (RE 12.9-10.17, 12.3.7 and 12.9-10.19) Regional Ecosystems.

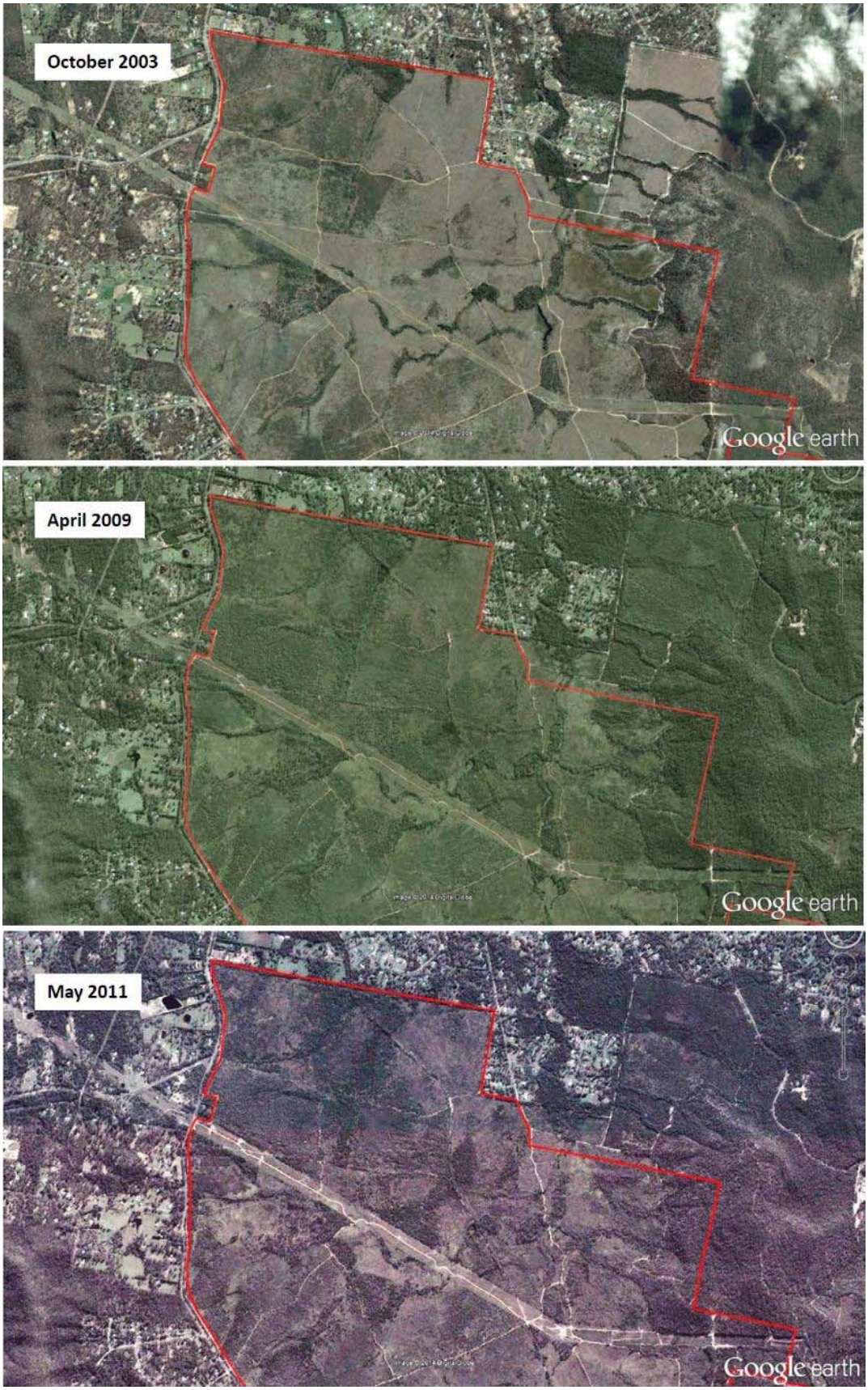


Figure 5: Vegetation clearing and regrowth recent history

The geology of the site area is characterised by sandstone, siltstone, shale and conglomerate of the Woogaroo sub-group of the Bundamba group. These consist typically of weathered and cemented sequences of fine grained sedimentary rock. Surficial soils above these weathered sequences are typically silty sands.

Based on the findings of the *Broadscale Geotechnical Investigation* (Bowler, 2004) and the preliminary investigations in Precinct 3, there were broadly consistent soil conditions existing across the site, albeit with differing profile depths. Bowlers (2004) appraisal of the silty sands found in the surface layers indicated that these tend to be loose in-situ, can carry water after periods of wet weather and are slow to drain and dry out.

This is an important aspect of the hydrogeology and stormwater runoff on the site. During wet conditions the ground becomes waterlogged and is slow to drain or dry out or water is re-expressed back to the surface.

2.5 LAND USE

2.5.1 Pre-Development

Pre-development data relating to the Yarrabilba site and surrounding catchment is based on review of aerial photography and site inspections. Generally, pre-development conditions are based on a fully undeveloped site at Yarrabilba being predominantly ex-pine plantation. Existing rural residential land-use of surrounding land to the north and west of the site is considered as pre-development for the purpose of flood assessment for Yarrabilba. Plunkett conservation area to the east is and will continue to remain natural bushland.

2.5.2 Recent Development

Since the commencement of ground works for development at Yarrabilba in 2012, residential and commercial land uses have been expanding across the Precinct 1 and 2 areas of the site. These are included as 'post- development' or ultimate catchment conditions within the context of the Precinct 3 flood assessment.

2.5.3 Proposed Development

Future development areas within Precinct 3 have been assigned land use parameters for imperviousness and roughness based on the land use master plan developed by Lend Lease (2014). These are discussed further in Section 3.3. For the purpose of this flood study, development has been broadly defined as Precinct 3A (interim) and Precinct 3 total (comprising Precinct 3A to 3D). Figure 6 provides the indicative precinct staging (referred to as 'Villages').

YARRABILBA

LEGEND

YARRABILBA SITE BOUNDARY

PRECINCT THREE VILLAGE BOUNDARIES

PINEVIEW

STEELE ROAD

ROAD

EXISTING RURAL RESIDENTIAL

FORESTRY

STATE SECONDARY SCHOOL

VILLAGE 3A

NON GOVERNMENT SECONDARY SCHOOL

YARRABILBA DRIVE

VILLAGE 3C

VILLAGE 3C

VILLAGE 3D

VILLAGE 3D

VILLAGE 3D

VILLAGE 3C

VILLAGE 3B

CONSERVATION

INFRASTRUCTURE

EASEMENT

DISCLAIMER
The context plan is intended to guide development within the Yarrabilba Precinct Three area and show the preferred land use designations and structural elements. The context plan does not prescribe these designations and structural elements with complete accuracy and the final location will be determined through further detailed design and development applications.

NOTES
The contents of this plan are conceptual only. All areas are approximate only and subject to relevant studies, survey, engineering and relevant authority approvals.

YARRABILBA - PRECINCT THREE - SUB STAGING
INDICATIVE VILLAGE STAGING

NOTE: This plan is indicative only, and specific uses, road alignment, boundaries, setbacks, and building layout shown may vary due to detailed design consideration. ©2015 Lend Lease Communities (Australia). All rights reserved. Except as permitted by Lend Lease, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the permission of Lend Lease.

0 100 200 300 400 500m

Scale 1:10000 at A3

North

lendlease

File No. YAR P03 Dgn No. YAR_P03_VS 160613 Date 13th JUNE 2016

2.6 DRAINAGE INFRASTRUCTURE

2.6.1 External to Site

Information relating to drainage infrastructure upstream and downstream of Yarrabilba has been sourced from Logan City Council's existing flood model data provided. Where additional data or verification was required, detailed survey was subsequently undertaken in 2016 at specific locations and input to the revised flood model.

Additional survey was undertaken on the major culverts upstream of the site on Waterford-Tamborine Road to allow the external catchment to be accurately modelled. Previously, this catchment was modelled as a boundary condition to the site which did not accurately account for the natural attenuation that occurs upstream of these road culverts in a broad natural depression. Further discussion of the model expansion is provided in Section 4.2.1 with details of drainage infrastructure included in the flood model provided in Section 4.4.

Additional structures in the lower portions of Quinzeh Creek were provided by Council on 3 June 2014 and understood to form part of the broader Logan-Albert River flood model. These structures are bridge type waterway crossings and are represented as 2D structures in TUFLOW. Details of these are provided in Table 13. However, the Yarrabilba flood model is not intended to be used as defined flood mapping/inundation in this area as this is dominated by Logan River flooding and reference should be made to Council's mapping.

2.6.2 Internal to Site

Drainage infrastructure within the Yarrabilba site has been collated from as-constructed information or from current or proposed design details available (where not constructed or in progress). This modelling also serves to validate existing designs based on the detailed ground level survey and design earthworks updated with the model (previously conceptual earthworks in the Precinct 1 and 2 flood assessment).

Existing drainage infrastructure for major road culverts and/or detention basins internal to the site is adopted generally in accordance with the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014) which been adjusted to reflect the detailed design and as-constructed information. Section 4.4 details the main hydraulic structures within the site. Note that this internal site infrastructure, while largely already constructed, is considered only in the post-development scenario. The pre-development case assumes the total site is undeveloped to ensure flood mitigation strategies for all development stages/precincts (in isolation and combination) meet the pre-development flood objectives.

As part of the design of Precinct 1 and 2 detention basin outlet structures, flexibility was designed into the structures to allow future modification should discharge timing become an issue as future development progressed on the main Quinzeh Creek watercourse which may cause flow peak or timing issues. This was achieved by constructing oversized pipes and installing constriction/orifice plates over part of the

pipe to restrict discharge capacity back to original design. Discharge from these basins can then be manipulated in future by modifying or removing constriction plates on specific outlets. These are specifically noted in Table 10 in Section 4.4 where relevant.

2.7 FLOOD BEHAVIOUR

Upper Quinzeh Creek is subject to localised flash flooding occurring from intense rainfall over a number of consecutive hours. This causes rise of flood waters in a major rainfall event to occur over a few hours (depending on location in the catchment) which contrasts to major river flooding (such as the Logan River backwater influencing flooding in lower Quinzeh Creek) which reaches critical flood peaks after a number of days.

The historical development of rural residential allotments up to and straddling Quinzeh Creek watercourse means the natural floodplain associated with the creek encompasses largely private land. Early flood regulation mapping developed for Quinzeh Creek was carried out many years ago prior to the availability of high resolution terrain based flood modelling software and was therefore a more crude estimate of flooding (albeit the best available at that time). This mapping combined with landholder knowledge therefore defined where and how people used the land interfacing the creek.

Recent advancements in computing power and software now allows more detailed modelling of floods both within and overtopping banks onto floodplains. Further, the current accepted defined flood regulation level is now the 100 year ARI flood (formerly 50 year ARI under the Beaudesert Shire Council). These factors therefore mean that areas within the catchment previously assumed to be flood free (based on old mapping) are actually classed as flood prone, further limiting the legal use of the land (for housing) or advised uses (for non-habitable uses).

Existing local flooding is known to occur at a number of locations in Upper Quinzeh Creek (downstream of Yarrabilba) which, in recent events, has been concentrated around Pineview Road, Louise Court and Maranoa Drive where houses have been flooded. This flood risk existed prior to Yarrabilba and will continue to be present with the development in place due to the historic subdivision and of the creek and floodplain described above. However, the development of Yarrabilba can only occur (under state legislation) by integrating sufficient flood mitigation infrastructure into the development to ensure that the downstream flooding is no worse than pre-development in terms of the peak flood flow and corresponding flood levels from additional runoff generated from urban land use.

2.8 FLOOD HISTORY

Former Beaudesert Shire Council flood mapping within Quinzeh Creek was generally based on a defined flood event of 50 year ARI and identified significant areas adjoining Quinzeh Creek as flood prone.

Over a number of decades, the gradual subdivision and development of former rural land parcels into smaller rural residential lots does not appear to have sufficiently allowed for flood free land for housing or flood free access for roadways resulting in numerous private properties lying well below the current 100 year ARI defined flood level adopted under the Logan Planning Scheme. Flooding is therefore an existing problem and will continue to be a potential issue for low lying properties adjacent to Quinzeh Creek and its tributaries.

A number of recent flood events within the Logan River and Quinzeh Creek catchments are discussed briefly below as far as they relate to the Yarrabilba site and local catchment. Flooding has occurred prior to these events however there is little information or data available to enable sufficient analysis within and downstream of the Yarrabilba site.

2.8.1 January 2011

This flooding occurred prior to commencement of Yarrabilba development works and was associated with the major rainfall event that caused the catastrophic floods in Toowoomba and Lockyer Valley and subsequently in Ipswich and Brisbane regions from major River flooding. The primary impact of this flood event within Quinzeh Creek was backwater flooding from the Logan River (resulting from long duration (multiple days) sustained rainfall) and was understood not to result in major flooding in the Yarrabilba locality or upper Quinzeh Creek.

2.8.2 January 2013

Heavy rainfall on the 28th and 29th of January 2013 attributed to the aftermath of Cyclone Oswald, caused flooding to a number of properties in the upper Quinzeh Creek catchment. More significant flooding occurred within the broader Logan/Albert catchments further downstream from the same event.

Analysis by Council found this event to be in the order of between 5 and 10 year ARI flood event in Upper Quinzeh Creek. Flood/debris level survey was undertaken by Council following this event and was used to calibrate the *Revised Quinzeh Creek Flood Study* (Engeny 2013) and similarly for verification of flood modelling used in the *Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014).

2.8.3 May 2015

A major local flood event occurred on 1 May 2015 resulting from a large intense weather system that moved southward through much of South East Queensland causing extreme flooding to a number of localities. This event was recorded by the new water level and rainfall gauge at Pineview Road, Logan Village (installed 2.5 months prior). The gauge recorded over 230mm in a 36 hour period with the most intense period causing around 170mm rainfall in 6 hours to 8pm on Friday 1 May,

A number of properties and dwellings in the Upper Quinzeh Creek catchment were inundated during this event which was estimated to be between a 50 and 100 year ARI

rainfall event. This major flash flooding occurred (at this locality) as a result of the local catchment/creek water levels rising quite rapidly after the intense peak of the rainfall.

Flood level and debris surveys were subsequently undertaken by Lend Lease on private properties affected by this event to capture as much data as practical to support further validation of the Yarrabilba flood model. Further discussion of this event is provided in Section 4.5.

3 HYDROLOGY

3.1 MODEL

Catchment hydrology has been modelled using XPRAFTS software (version 2013 SP1). This was used in the previous Precinct 1 and 2 flood model as well as by Logan City Council in the original Quinzeh Creek assessment and is a widely used hydrological modelling package by the flood modelling industry.

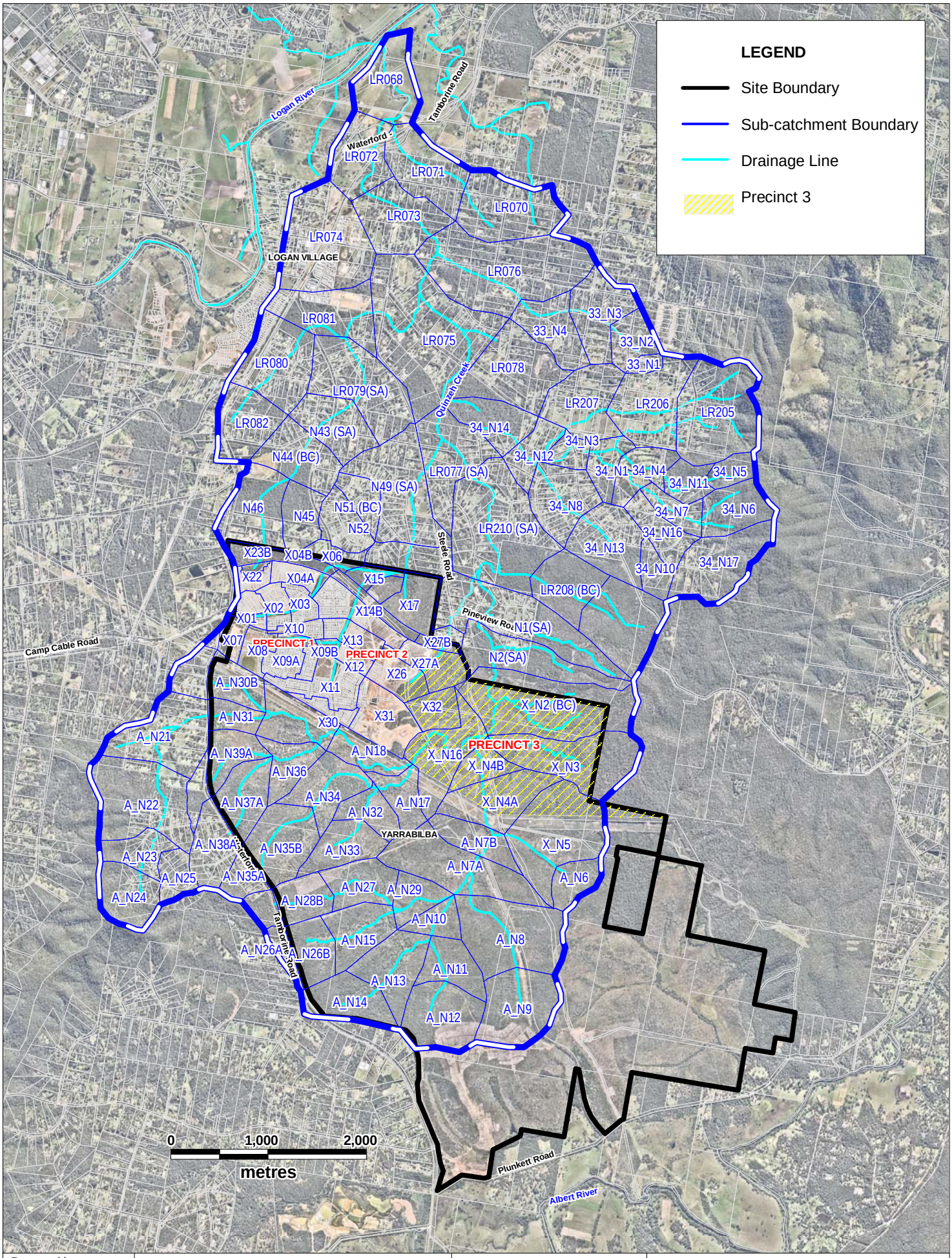
3.2 CATCHMENT DELINEATION

Existing (pre-development) catchment delineation within Yarrabilba Precincts 1 to 3 (P1 to P3) area is based on the aerial laser survey (ALS) prior to the commencement of any development works. Post-development catchments in Precinct 1 and 2 were delineated based on the earthworks and drainage design for the development, while Precinct 3 details were still being resolved so catchment boundaries remained as per pre-development (with relevant land use parameters changed accordingly).

The broader Quinzeh Creek sub-catchment delineation (external to the Yarrabilba P1 to P3 sub-catchments but within Yarrabilba) is based on the WRM/Engeny (Council) hydrologic model but with the Yarrabilba catchment parameters applied as per Section 3.3. The total catchment layout used in XPRAFTS is shown in Figure 7. The updated pre and post development catchment delineation within Yarrabilba Precinct 1 and 2 is shown in Figure 8 and 9 respectively. Pre-development catchment data specifically relating to Precinct 3 assessment is summarised in Table 2 with post development in Table 3 (Precinct 3A interim) and Table 4 (Precinct 3 total). Data for the balance of sub-catchments not immediately intersecting Precinct 3 is provided in Appendix A.

A number of original Council sub-catchments within Yarrabilba have been further split to better represent the contribution of flows to key areas of the site. This improves the localised assessment of flows and water levels at specific locations within Yarrabilba but will have no discernible impact to the total discharge leaving the site. It is anticipated that as resolution of future development precincts occurs, additional splitting or reconfiguring of local sub-catchments will occur to ensure the most accurate accounting of sub-catchment discharge is achieved. Generally, where suffix A, B, C is appended to catchment names, these are original catchments split into smaller sub-catchments. All sub-catchment data for Yarrabilba site is provided in Appendix A.

Two development scenarios have been modelled within Precinct 3 to represent the first stage (Precinct 3A) and the ultimate total development of Precinct 3 (Precinct 3A, 3B 3C and 3D). This staging is necessary as the ultimate P3 total flood strategy relies on the construction of the regional scale Flood Basin 15 (see Section 5.2) which will not be constructed until precinct 3B is progressed. Model scenarios are therefore referred to herein as Precinct 3A (P3A) and Precinct 3 total (P3 total).



Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3 Flood Study

Client: Lend Lease

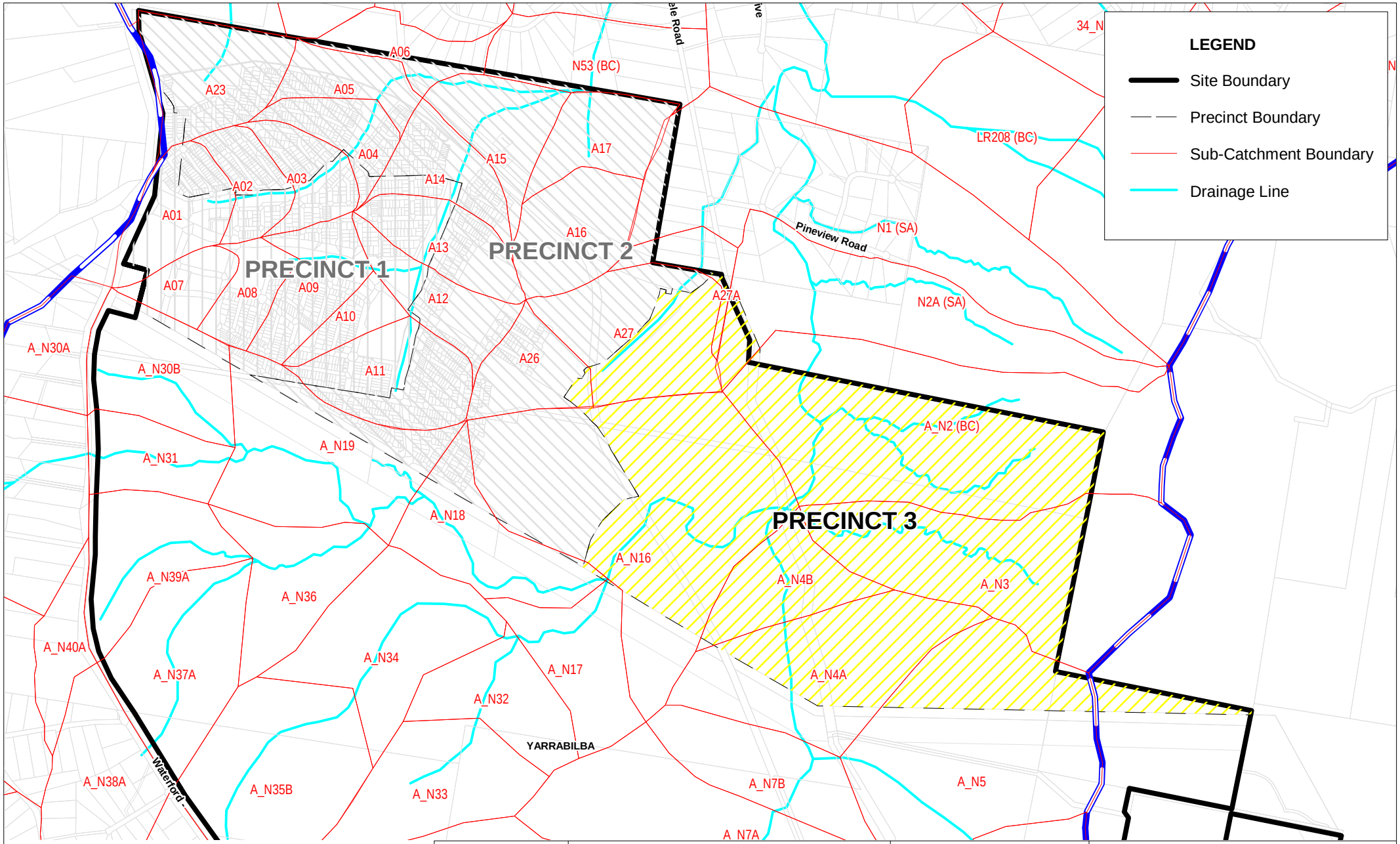
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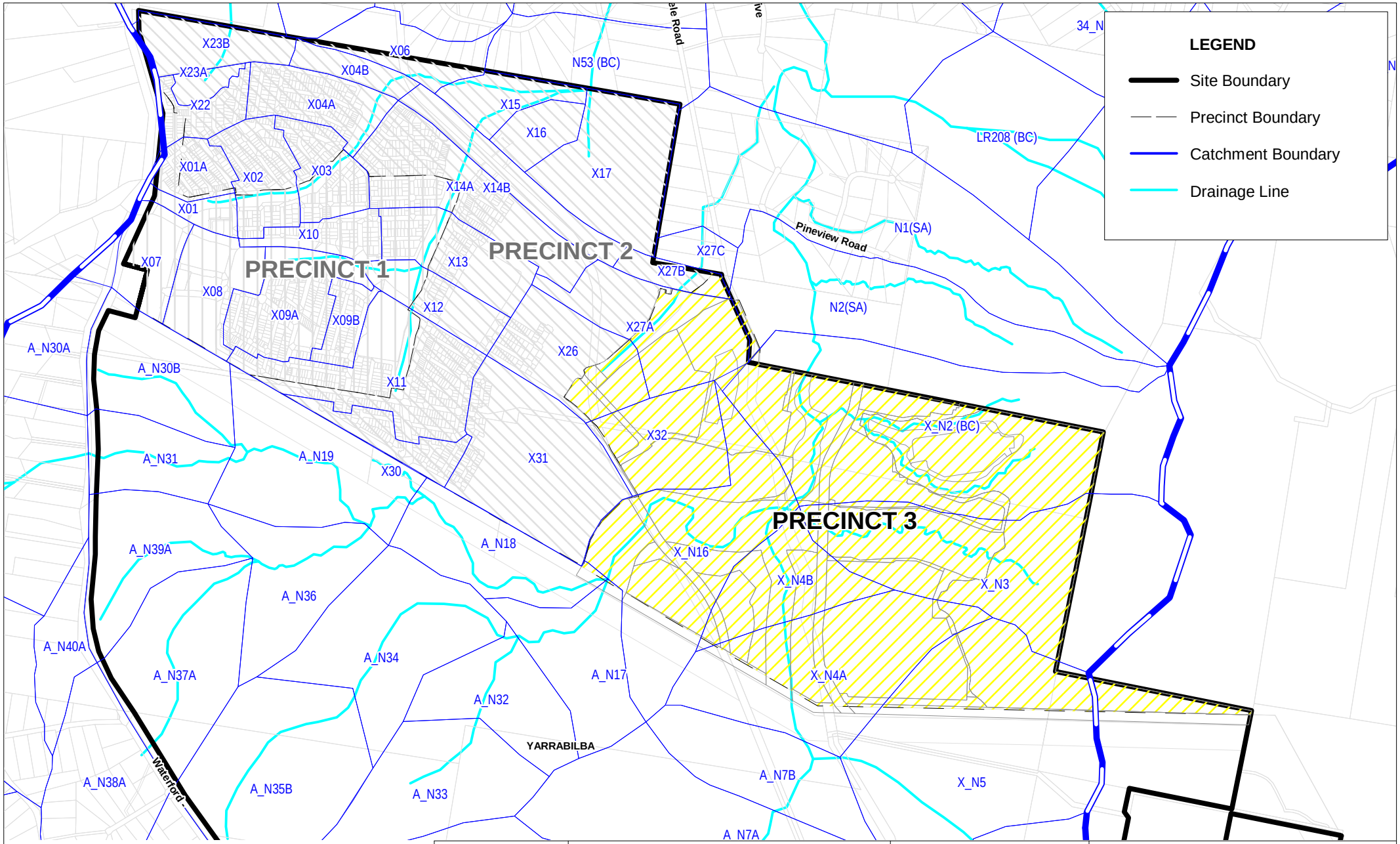
Date: 11 July 2016

FIGURE 7

Overall Quinzeh Creek Sub-catchment Plan



Prepared by: DesignFlow For: lendlease	Project: 4284 Yarrabilba Precinct 3 Flood Study	N W E S Scale: 1 : 20,000 (A4)	**FIGURE 8** **Pre-Development Sub-Catchment Plan**
	Client: Lend Lease	Date: 11 July 2016	



Prepared by: DesignFlow For: lendlease	Project: 4284 Yarrabilba Precinct 3 Flood Study	N W E S Scale: 1 : 20,000 (A4)	**FIGURE 9** **Precinct 1 to 3 Development Sub-Catchment Plan**
	Client: Lend Lease	Date: 11 July 2016	

Table 2: Pre-development sub-catchment summary (P3 area only)

Catchment	Area (ha)	Slope (%)	Impervious (%)	Land Use *
A26	14.30	3.9	0	Ex-pine plantation
A_N27	30.21	2.3	0	Ex-pine plantation
A_N2 (BC)	96.89	7.9	0	Ex-pine plantation, conservation
A_N3	65.00	3.9	0	Ex-pine plantation, conservation
A_N4A	44.06	2.4	0	Ex-pine plantation
A_N4B	18.31	2.4	0	Ex-pine plantation
A_N5	76.12	3.1	0	Ex-pine plantation, conservation
A_N16	90.93	0.1	0	Ex-pine plantation

* Some localised areas of remnant vegetation exist within parts of sub-catchments

Table 3: Post development P3A catchment summary

Catchment	Area (ha)	Slope (%)	Impervious (%)	Land Use *
X26	19.81	3.5	63	Part P2 and P3 residential and open space
X27A	22.99	2.5	56	P2 and part P3
X27B	4.45	2.5	1	Undeveloped SIC corridor
X32	18.02	1.6	43	Residential and sports fields
X_N16	45.50	0.1	37	Northern portion only - residential, sports fields and fauna corridor, balance is undeveloped
X_N2 (BC)	96.89	7.9	7	Western portion only – residential and open space, balance is undeveloped, conservation
A_N3	65.00	3.9	0	Undeveloped (as per Table 2)
A_N4A	44.06	2.4	0	Undeveloped (as per Table 2)
A_N4B	18.31	2.4	0	Undeveloped (as per Table 2)
A_N5	90.93	0.1	0	Undeveloped (as per Table 2)

* Some localised areas of remnant vegetation exist within parts of sub-catchments

Table 4: Post development P3 (total) catchment summary

Catchment	Area (ha)	Slope (%)	Impervious (%)	Land Use *
X26	19.81	3.5	63	Part P2/P3 residential, open space
X27A	22.99	2.5	56	P2 and part P3
X27B	4.45	2.5	1	Undeveloped SIC corridor
X32	18.02	1.6	43	Residential and sports fields
X_N16	45.50	0.1	37	Northern portion only - residential, sports fields and fauna corridor, balance is undeveloped
X_N2 (BC)	96.89	7.9	7	Western portion only – residential and open space, balance is undeveloped
X_N3	65.00	3.9	5	Fauna corridor, conservation minor residential portion
X_N4A	44.06	2.4	37	Residential, open space, fauna corridor
X_N4B	18.31	2.4	33	Infrastructure/employment, fauna corridor, minor residential portion
X_N5	76.12	3.1	32	Residential, electrical easement

* Some localised areas of remnant vegetation exist within parts of sub-catchments

3.3 RAINFALL RUNOFF PARAMETERS

3.3.1 Land Use and Imperviousness

All catchments (both pre and post development) were modelled in XPRAFTS with the pervious and impervious fraction as separate sub-catchment areas with 0% and 100% imperviousness respectively. This split catchment approach reflects best practice modelling of urban drainage in XPRAFTS and enables the rainfall losses and catchment roughness to be appropriately assigned to these parts of the sub-catchment separately. Table 5 summarises the assumptions used for each land use which are generally consistent with the *Queensland Urban Drainage Manual* (QUDM) (as required by the Logan Planning Scheme).

The Yarrabilba site (prior to development) comprised a fully undeveloped catchment (former pine plantation with a mix of open grassland, pine regrowth and scattered native bush) and assigned 0% imperviousness. Where sub-catchments extended across the site boundary into existing rural residential or road areas, the portion of the sub-

catchment that was developed was defined and imperviousness applied in accordance with Table 5 below.

Developed case land-use was derived from the Lend Lease Land Use Master Plan (2014) for Precinct 1, 2 and 3 with the relevant land use impervious fraction then applied as per Table 5. Land use categories include road areas in impervious fraction definition.

Table 5: Land use and impervious fraction

Land Use	Impervious Fraction
Ex-plantation, grassland, bush or regrowth (retained existing)	0
Rural Residential (existing)	0.05 – 0.20*
Residential (low density)	0.60
Residential (high density)	0.80
Commercial/Retail/Industrial	0.90
Town Centre	1.00
School	0.70
Public Open Space	0.05**
Conservation Open Space	0
SIC (Southern Infrastructure Corridor)	0/0.90***

* Varies - actual imperviousness was derived from aerial photography

** QUDM (2013) Table 4.5.1 groups all open space and parks with zero impervious fraction. However, allowance is made above for public open space assuming some embellishments contributing to imperviousness. Conservation open space (zero imperviousness) refers to all other areas with no embellishments.

*** Where the future SIC discharges internal to the site, ultimate imperviousness was included for infrastructure sizing. Where it discharges downstream of the site, undeveloped land use was assumed as flow increases from major roads are the responsibility of QLD Traffic and Main Roads (TMR).

3.3.2 Slope

Existing (pre-development) sub-catchment slope was assigned based on the average equal area slope of a minimum of four slope paths overlaid on the Digital Elevation Model (DEM) for each sub-catchment within Precincts 1 to 3. Developed case sub-catchment slopes were derived from the design DEM (where available) along the main road and/or overland flow paths. Where no design grading was available in future precincts/stages, the pre-development grading was retained. The development regrading carried out to date (in Precinct 1 and 2) have generally resulted in reduced slopes compared to the pre-development case, and therefore the above approach will represent a conservative catchment slope. Slope data for sub-catchments is provided in Appendix A.

All other sub-catchments within Yarrabilba (outside Precincts 1 to 3) have retained the slope data provided by Council.

3.3.3 Catchment Roughness

Catchment roughness was assigned to sub-catchments within the Yarrabilba site based on values provided in Table 6. The pervious values are representative of the surface roughness change from the existing site (as a mix of grassland, ex-pine plantation and some bushland) to urbanised (landscaping and lawn) while the impervious roughness were kept constant (and generally applies to development only).

Table 6: Catchment roughness

Catchment condition	Catchment Manning's n	
	Pervious	Impervious
Existing/undeveloped	0.05	0.015
Developed	0.035	0.015

Additional catchment roughness parameters were also defined as part of the hydraulic model validation assessment to capture partial development and construction phase conditions during the 1 May 2015 validation flood event. These are discussed in detail in Section 4.5 and Table 14.

3.3.4 Rainfall

Intensity-Frequency-Duration (IFD) data was sourced from the Bureau of Meteorology (BOM) and Australian Rainfall and Runoff (1987 version, ARR87) for hydrologic modelling in XPRAFTS. Recent and ongoing revisions to the ARR87 data and methods for flood estimation in Australia means that while more updated information is currently available for some parameters (i.e. 2013 IFD data), it is not yet recommended for use in design flood studies until the AR&R review team has resolved the updates to a range of other flood estimation parameters and datasets. It is recognised that as ARRR revisions are released and adopted by industry, sensitivity testing and design review will need to be undertaken to ensure long term suitability of all stormwater and flood management infrastructure within Yarrabilba.

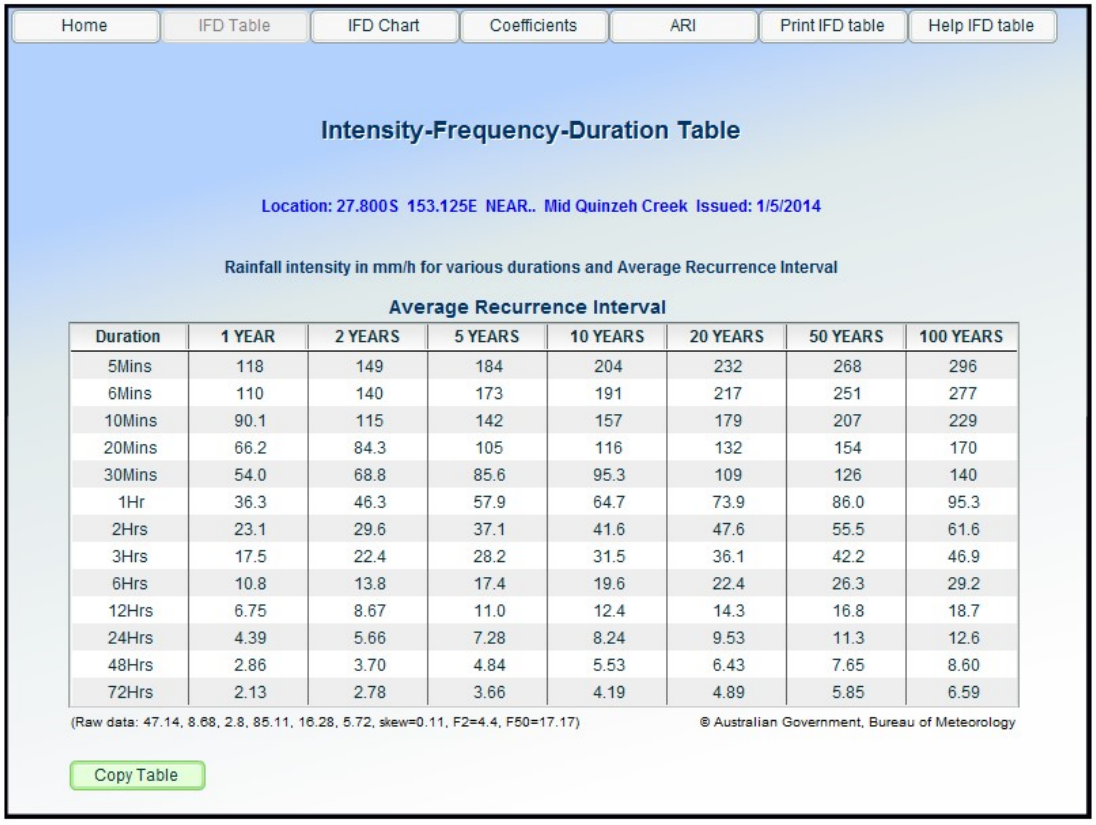
Key hydrological parameters are presented and discussed in the following sections. This discussion focusses primarily on the Yarrabilba site hydrology (Zones 3 and 4 as identified in Figure 10 in Section 4.2.3) as this is where the detailed analysis has been undertaken by DesignFlow. All other hydrological parameters for Quinzeh Creek (downstream of Yarrabilba) have been derived by Council (or their consultants) and reference to the relevant flood study reports should be made for these.

XPRAFTS automatic storm generator is then used to undertake multiple storm and duration assessments for standard annual exceedance probability storm events. The two XPRAFTS models provided by Council (WRM/Engeny) adopted slightly different IFD

data between each model. In order to verify a suitable data set for the combined model, the IFD data was obtained from BOM for 3 locations within Quinzeh Creek representing the lower, mid and upper catchment. While rainfall intensities varied by less than 1mm/hr for the major event, this subtle difference can translate to peak flow variations when applied over thousands of hectares. The IFD data corresponding to approximately Pineview Road locality (middle of catchment) was adopted as the most appropriate for the catchment wide assessment.

Actual rainfall data from the Upper Quinzeh Creek gauge (Pineview Road) was translated into suitable file format for importing into XPRAFTS. This data enabled hydrological inputs to validation runs of TUFLOW against the gauged flood levels at Pineview Road. This is discussed further in Section 4.5.3.

Table 7: IFD Data Summary (ARR87)



Home | IFD Table | IFD Chart | Coefficients | ARI | Print IFD table | Help IFD table

Intensity-Frequency-Duration Table

Location: 27.800S 153.125E NEAR.. Mid Quinzeh Creek Issued: 1/5/2014

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	118	149	184	204	232	268	296
6Mins	110	140	173	191	217	251	277
10Mins	90.1	115	142	157	179	207	229
20Mins	66.2	84.3	105	116	132	154	170
30Mins	54.0	68.8	85.6	95.3	109	126	140
1Hr	36.3	46.3	57.9	64.7	73.9	86.0	95.3
2Hrs	23.1	29.6	37.1	41.6	47.6	55.5	61.6
3Hrs	17.5	22.4	28.2	31.5	36.1	42.2	46.9
6Hrs	10.8	13.8	17.4	19.6	22.4	26.3	29.2
12Hrs	6.75	8.67	11.0	12.4	14.3	16.8	18.7
24Hrs	4.39	5.66	7.28	8.24	9.53	11.3	12.6
48Hrs	2.86	3.70	4.84	5.53	6.43	7.65	8.60
72Hrs	2.13	2.78	3.66	4.19	4.89	5.85	6.59

(Raw data: 47.14, 8.68, 2.8, 85.11, 16.28, 5.72, skew=0.11, F2=4.4, F50=17.17)

© Australian Government, Bureau of Meteorology

Copy Table

Source: Bureau of Meteorology website (downloaded 1/5/2014)

3.3.5 Temporal Patterns

Rainfall temporal patterns for Zone 3 have been adopted for each design storm duration at Yarrabilba in accordance with 1987 Australian Rainfall and Runoff.

As discussed previously, it is recognised that current revision of the Australian Rainfall and Runoff data and methods is in progress and future sensitivity testing and

assessment against revised information will need to occur in subsequent flood assessments.

3.3.6 Losses

Losses adopted for the Yarrabilba site are provided in Table 8. These have been selected following literature reviews, previous comparison of peak flows with the Rational Method in the Precinct 1 and 2 Stormwater Management Plan and in consideration/validation of the broader Quinzeh Creek Flood Assessment undertaken by Logan City Council. These values have been applied to sub-catchments directly impacting the Yarrabilba site while the default Council parameters have been retained for downstream catchments for all events up to and including the 100 year ARI.

Table 8: Design storm rainfall losses

Surface type	Design Storm Event	Initial Loss (mm)	Continuing Loss (mm/hr)
Pre-development pervious	2 – 100 year ARI	30*	2.5
Developed pervious	2 – 20 year ARI 50 – 100 year ARI	15** 0	2.5 2.5
Impervious	All	0	0

* The pre-development initial loss of 30mm is consistent with *Australian Rainfall Runoff* (1987) and *Modelling Losses in Flood Estimation* (M. Ilahee, 2005) for the Logan catchment. *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) recommends an initial loss of 49mm based on Rational Method verification. DesignFlow has reviewed the assumptions and calculations which underpin this parameter and feel the forest assumption and C10 values used for Yarrabilba are not correct. If these are adjusted to values recommended by QUDM (2013) for moderate density bushland the resulting flows related well to an initial loss of approximately 30mm. Engeny adopted an area weighted average of loss of 38mm for the range of land uses derived by WRM. This loss was retained for areas outside Yarrabilba.

** *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) recommends 19mm initial loss. Site specific review against the Rational Method and the final hydraulic model results in the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014) concluded that 15mm was more appropriate for the Yarrabilba site. This is still generally consistent with Australian Rainfall Runoff, generates close agreement with the Rational Method calculation and is more conservative (i.e. creates larger post development flows and therefore greater flood detention requirements).

When applying initial losses to major design storms, it should recognised that in reality, there is often lead up rain (hours or days) that occurs prior to the design storm burst. This can often lead to saturated catchment conditions that can significantly reduce or remove the initial loss within a design storm. This was reinforced by findings by Engeny (refer Appendix F, *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 3*, DesignFlow, 2014) who tested the impact of design initial losses on the calibration event of January 2013 used in the *Revised Quinzeh Creek Flood Study* (Engeny, 2013). This has guided the conservative approach to adopting zero initial loss for the major post-development design storms to ensure that detention basins have

sufficient volume and discharge control to cater for runoff from a fully saturated catchment prior to storm burst.

3.3.7 Critical Storm Duration

A range of storm durations were generated in XPRAFTS in order to determine which storm durations were critical for the site and downstream reporting locations (See Figure 19 in Section 5.4 for locations). For this analysis, a range of durations were tested from 30 minutes to 12 hours. The longer durations were tested in order to ensure the delayed catchment response time was capture with the introduction of detention basins. Table 9 provides the critical durations down the catchment at reporting locations for the minor (2 year ARI) and major (100 year ARI) event. The critical duration within the development site (post development) for the purpose of maximum flood detention depth was typically between 60 and 120 minutes.

Table 9: Critical duration assessment

Reporting Location		Location	Critical Duration (min)			
			PRE		DEV*	
			2 year ARI**	100 year ARI	2 year ARI**	100 year ARI
Site Discharge	4	Upstream of Gerogina Dr	180	90	180	120
	9	Upstream of Steele Rd (at Pineview Rd)	180	90	120	90
	A23	Upstream of Lot 8 RP203663	120	90	120	90
	8	Upstream of Pineview Rd	360	120	360	180
Downstream	12	Quinzeh Ck (adjacent to Maranoa Drive cul-de-sac)	360	180	360	180
	14	Quinzeh Ck (adjacent to Ellen Ct)	360	180	360	180

* post-development (DEV) critical duration occurs with flood detention basins in place and/or developed catchment diversion.

** critical duration for minor events is longer due to lower flow and comparatively longer flow time through catchment

3.3.8 Other Parameters

Bx Parameter

The XPRAFTS Bx parameter is a storage coefficient multiplication factor used to uniformly modify all sub-catchment storage time delay coefficient values to achieve a lumped calibration of catchment outflow peak. In the absence of accurate gauged discharge data for this catchment, there is no justification for modifying this parameter and was therefore retained as 1.0 (default).

It is recognised that while Council's original hydrological model utilised a Bx value of 1.2, this was derived from a verification involving the Rational Method at a single point

downstream (refer to *Yarrabilba Precinct 1 and 2 Stormwater Management Plan* (DesignFlow, 2014)) and not actual gauged flow data. This was therefore considered to insufficiently represent the in stream storage/attention, particularly within areas of the Yarrabilba site.

All other parameters relating to the Laurenson method utilised in XPRAFTS were left unchanged from recommended defaults.

3.4 MODEL VERIFICATION

The previous *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014) undertook a detailed comparison of modelled flows from XPRAFTS to the Rational Method. This has not been duplicated as part of this assessment as the catchment parameters have not been altered and therefore remain validated from the previous assessment.

4 HYDRAULICS

4.1 MODEL

Hydraulic assessment of the site and downstream Quinzeh Creek was undertaken using TUFLOW (1D/2D linked hydrodynamic model) to determine the flood inundation under existing and developed site conditions. The current TUFLOW model for Precinct 3 represents an update since the previous version utilised in the *Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014) to include improved survey data, expanded model area and validation against gauged flood from May 2015.

As shown in Figure 10, the overall catchment has been delineated into model zones to reflect the model configuration, data source and any modifications made. The hydraulic model downstream of the Yarrabilba site boundary has been merged and expanded from Council's original hydrologic and hydraulic models provided in 2013 (refer to Section 9.3.3 of the abovementioned stormwater management plan). The discussion below therefore refers primarily to the development of the Yarrabilba component of the broader Quinzeh Creek hydraulic model and improvement to the immediate flood affected area downstream. For details of the overall downstream model, refer to the *Revised Quinzeh Creek Flood Study* (Engeny, August 2013) and *Quinzeh Creek Design Discharge Estimation* (WRM, September 2013).

4.2 BOUNDARIES

4.2.1 2D Model area

The TUFLOW model is based on a 3m grid in line with Council's original model supplied. This grid size is considered to provide a satisfactory trade-off between ground/hydraulic detail and the associated computing run time required to execute such models.

The previous TUFLOW model included a nested 1D channel developed by Engeny for Logan City Council as part of the original Quinzeh Creek model setup (Refer to *Revised Quinzeh Creek Flood Study*, Engeny, 2013). During more detailed analysis of flooding behaviour as part of the May 2015 flooded event, this section of the model was reverted to a full 2D grid to better capture the creek bank breakout points, flow patterns and instream barriers (such as farm dams and track crossings). This was reinforced by additional detailed survey along the creek banks of interest to capture the longitudinal and cross section of these key areas.

Further, a review of the 1D cross section data used previously by Engeny compared with the DEM through this section of waterway indicated that the full 2D terrain was reasonably close to the surveyed cross section (and differed mainly in the invert low flow channel with comparatively minor flood capacity), and further, the 1D model actually inserted some DEM derived cross sections into the 1D channel where survey was insufficient. The spacing of the 1D cross sections was also quite large (i.e. 100-200m in area of interest) for the variable width of the channel and the tight meanders that occur downstream of Pineview Road.

Other factors leading to use of full 2D model in this portion of the catchment include:

- Flow behaviour (mounding) around tight meanders influencing breakout over banks
- Particular interest in moderate to major flood flows as defined by overbank breakout (not minor low flow channel flows)
- No representation of online farm dams in 1D previously

The full 2D model was subsequently adopted for the Precinct 3 analysis of pre- and post-development scenarios and for validation against the recorded flood of 1 May 2015.

The previous Yarrabilba flood model was also expanded west of Yarrabilba to include the upstream external catchment discharging through the culverts under Waterford-Tamborine Road. This was previously included in the overall flood model as an inflow hydrograph boundary condition in TUFLOW. The extent of TUFLOW model boundary, catchment and underlying terrain is shown in Figure 11.

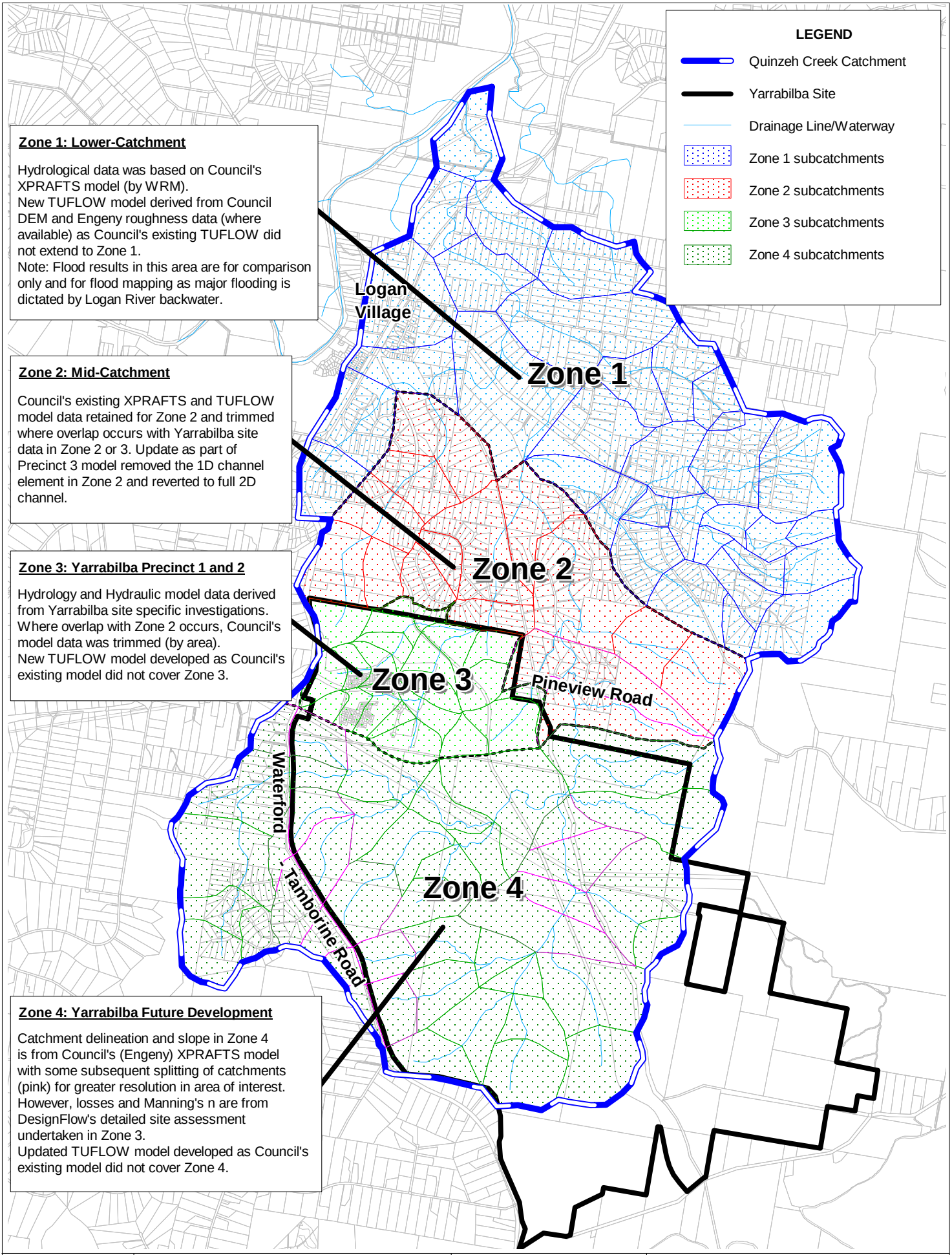
4.2.2 Tailwater

Quinzeh Creek discharges directly into the Logan River approximately 7 km downstream from the northern site boundary of Yarrabilba. Under regional Logan River flooding (100 year ARI), the backwater impact extends up Quinzeh Creek around 4.5km from the downstream confluence (to just north of Ellen Court). This indicates that peak flood levels in the lower half of Quinzeh Creek are dominated by the Logan River and not from the local Quinzeh Creek flooding. The regional flood is dominated by a significantly longer duration critical storm event (72 hours) compared to Quinzeh Creek (6 hours). It is therefore practical to expect that the Quinzeh Creek flood peak would occur well before the regional flood peak (assuming catchment wide rainfall).

For the purpose of this assessment, the comparative assessment of pre and post development peak flows and flood levels (for the full range of ARIs) has assumed no Logan River flooding and adopted a normal flow discharge slope at the downstream boundary of the model. This provides sufficient offset from any boundary conditions (particularly in minor flood events) that will impact the flood assessment focussed on the Yarrabilba site discharge tributaries and the confluence of these in the main channel of Quinzeh Creek.

4.2.3 Inflows

All inflows to the TUFLOW model within and upstream of Yarrabilba are based on the XPRAFTS local sub catchment outputs (as hydrographs) input as source on area inputs throughout the catchment. Downstream of the site, a combination of source-area inputs as well as boundary condition inputs have been applied based on Council's model or derived data as delineated in the model zones depicted in Figure 10.



Zone 1: Lower-Catchment

Hydrological data was based on Council's XPRAFTS model (by WRM).
New TUFLOW model derived from Council DEM and Engeny roughness data (where available) as Council's existing TUFLOW did not extend to Zone 1.
Note: Flood results in this area are for comparison only and for flood mapping as major flooding is dictated by Logan River backwater.

Zone 2: Mid-Catchment

Council's existing XPRAFTS and TUFLOW model data retained for Zone 2 and trimmed where overlap occurs with Yarrabilba site data in Zone 2 or 3. Update as part of Precinct 3 model removed the 1D channel element in Zone 2 and reverted to full 2D channel.

Zone 3: Yarrabilba Precinct 1 and 2

Hydrology and Hydraulic model data derived from Yarrabilba site specific investigations.
Where overlap with Zone 2 occurs, Council's model data was trimmed (by area).
New TUFLOW model developed as Council's existing model did not cover Zone 3.

Zone 4: Yarrabilba Future Development

Catchment delineation and slope in Zone 4 is from Council's (Engeny) XPRAFTS model with some subsequent splitting of catchments (pink) for greater resolution in area of interest. However, losses and Manning's n are from DesignFlow's detailed site assessment undertaken in Zone 3.
Updated TUFLOW model developed as Council's existing model did not cover Zone 4.

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Yarrabilba Precinct 3 Flood Study

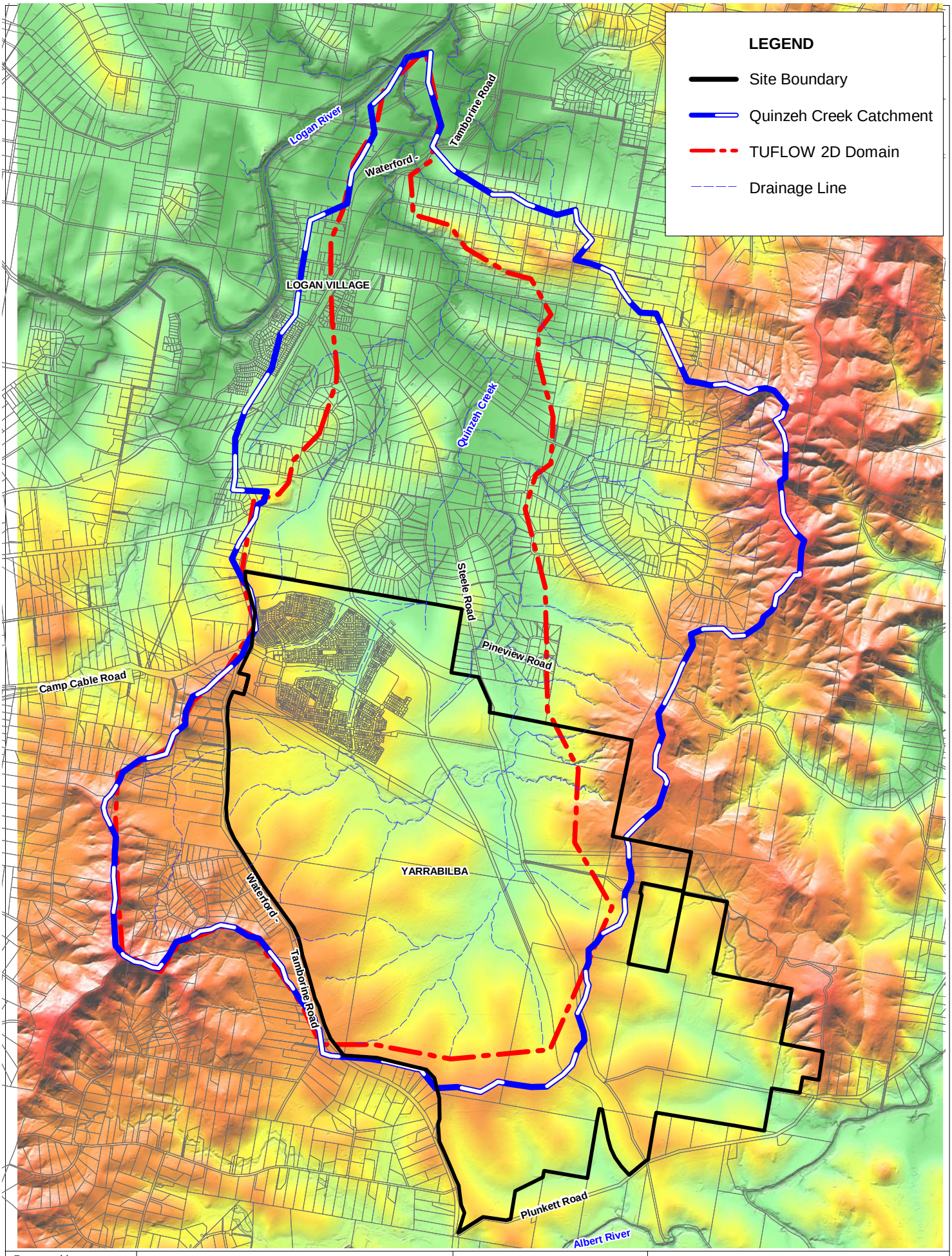
Client: Lend Lease

Scale: 1 : 50,000 (A4)

Date: 11 July 2016

FIGURE 10

Flood Model Data Zones



Prepared by: DesignFlow For: lendlease	Project: 4284 Yarrabilba Precinct 3 Flood Study	N W E S Scale: 1 : 50,000 (A4)	**FIGURE 11** **TUFLOW Model Terrain and Extent**
	Client: Lend Lease	Date: 11 July 2016	

4.3 TERRAIN AND ROUGHNESS

As noted in Section 2.3, the catchment LiDAR survey with local corrections from detailed ground survey, was used as the basis for the 2D hydraulic model to represent the pre-developed catchment. Development earthworks and survey digital elevation models were overlaid onto the base LiDAR to then create the post development landform for the subsequent impact assessment.

4.3.1 Detailed survey

The detailed survey of the northern area of Precinct 2 found that the LiDAR was an average of 120mm higher than the surveyed ground level. While not a great issue for areas of overland flow, this was found to have implication for the large flood storage area of Flood Basin 6. Accordingly, the LiDAR DEM was lowered in this zone to accurately account for the volumes within the natural terrain zone bounded by constructed bunds (which are built to design levels).

4.3.2 Detention Basins

Flood detention basins and major road crossings have been compiled from as-constructed information or detailed design information where under construction.

Proposed detention areas associated with Precinct 3 have been modelled using design TINs where available or by simple creation of vertical walls within the DEM to mimic future road or bund crossings (where design information was not completed at the time of modelling).

4.4 HYDRAULIC STRUCTURES

4.4.1 Precinct 1 and 2 Structures

Outlet structures and culverts associated with road crossings and detention basins in Precinct 1 and 2 have been compiled from as-constructed information or detailed design information where not yet fully constructed.

Where high flow bypass weirs exist as part of a detention basin, these have also been modelled in the 1D domain which provides a more accurate prediction of weir flow than relying on the DEM to account for these (due to the comparatively coarse grid size in relation to some weirs). Any weirs that do appear in the design DEM have been 'filled in' for the purpose of modelling by use of 2D_shp command in the TUFLOW setup to avoid potential for duplication of weir flow in both the 1D and 2D domain. Table 10 provides the data for Yarrabilba site hydraulic structures that have been constructed.

Table 10: Precinct 1 and 2 drainage and flood infrastructure

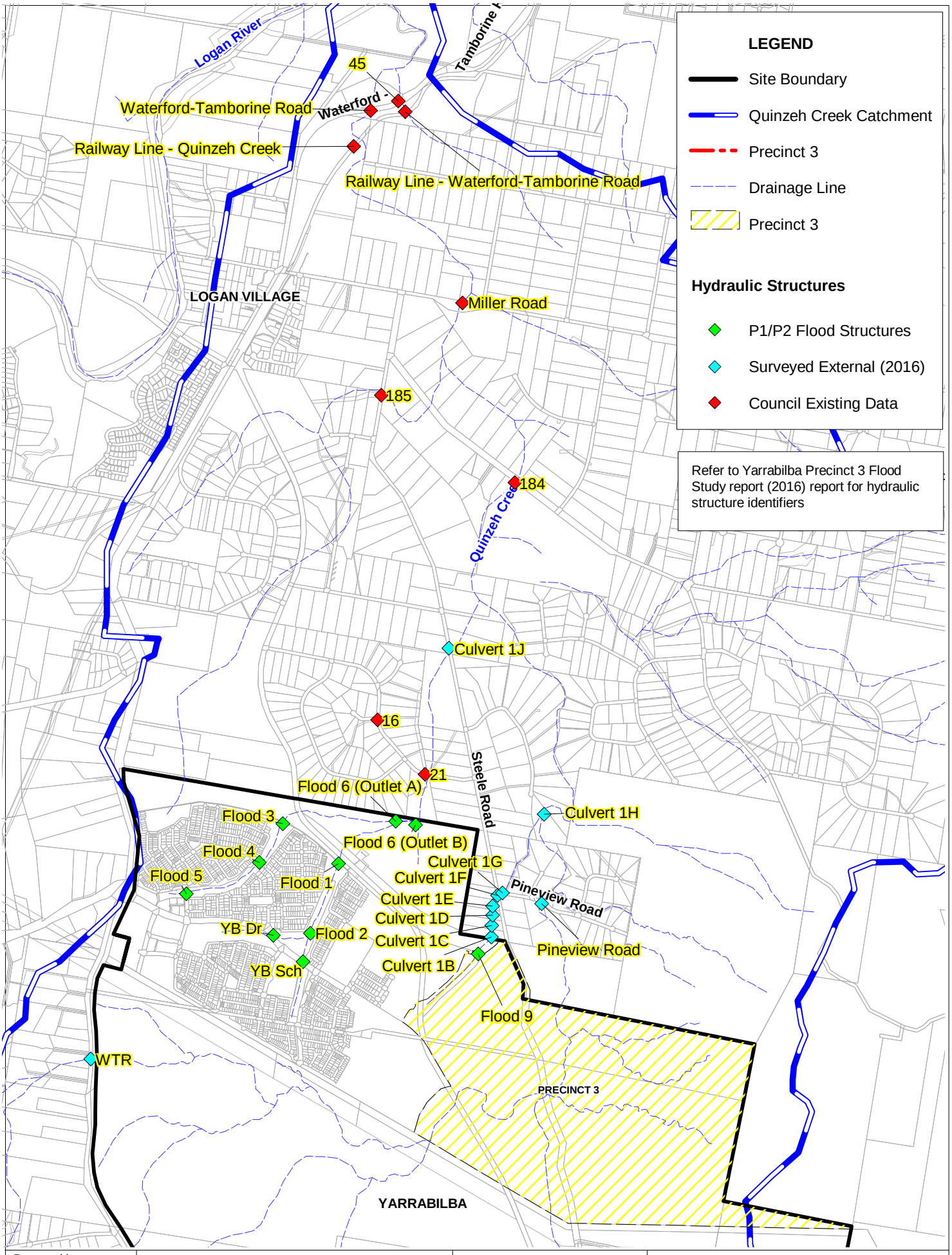
Basin/culvert ID	Structure Component ID	Type/Size/Levels [1]	Crest	USIL	DSIL	Length
			mAHD	mAHD	mAHD	m
Flood 1	FL1_Lo	2/ 825 dia RCP	-	24.0	23.9	30.5
	FL1_Pit	10m x 2.5m pit	26.31	26.31	24.1	-
	FL1_Hi	5/ 1050 dia RCP [2]	-	24.1	23.99	23.2
	FL1_Weir	25m weir	26.89	26.89	-	-
Flood 2	FL2_Lo	4/ 1200 dia RCP	-	28.05	28.01	12.2
	FL2_Weir	20m weir	29.85	29.85	-	-
Flood 3	FL3_Lo	5/ 925 dia RCP [3]	-	28.86	28.76	
	FL3_Weir	20m weir	30.99	30.99	-	-
Flood 4	FL4_pipes	3/ 1200 RCP				
Flood 5	FL5_pit-RC	0.9 x 1.2m pit (low level) 1.5m x 1.2m pit (high level) (as combined rating curve)	43.30 43.80	- -	41.3 41.3	- -
	FL5_pipe	1/ 1200 RCP	-	41.3	41.0	82.0
Flood 6	FL6-A_L-orif	1.2m x 0.5m orifice	-	20.53	-	-
Outlet A	FL6-A_Lo-pit	8.5m x 2.5m pit	22.45	22.45	20.5	-
	FL6-A_pipes	4/ 975 dia RCP [4]	-	20.5	20.44	26.8
	FL6-A_Weir	50m weir	23.02	23.02	-	-
Flood 6	FL6-B_L-orif	1.2m x 0.5m orifice	-	20.49	-	-
Outlet B	FL6-B_Lo-pit	8.5m x 2.5m pit	22.45	22.45	20.47	-
	FL6-B_pipes	4/ 975 dia RCP [4]	-	20.47	20.4	26.8
	FL6-B_Weir	20m weir	23.02	23.02	-	-
YB Dr	YBDr_out	3/ 2.4m x 0.75m RCBC	-	32.01	31.91	31.7
YB Sch	YBSch_out	3/ 2.7m x 0.6m RCBC	-	30.05	29.75	39.04

Notes:

1. RCP = reinforced concrete pipe, RCBC = reinforced concrete box culvert
2. 1200 dia RCP constructed with constriction plates fitted to equivalent 1050 dia RCP area.
3. 925 dia RCPs are representative of 1050mm dia pipes with constriction plates fitted to reduce area to equivalent 925mm dia for each pipe.
4. 975 dia RCPS are representative of 1200mm dia pipes with constriction plates fitted to reduce area to equivalent 975mm dia for each pipe.

4.4.2 External culverts and bridges

As noted in Section 2.6, road culverts external to the site have been compiled from both Council data as provided with the Quinzeh Creek flood model and from additional detailed survey of key areas of interest or where data was not available. Table 11 and 12 provide the drainage culverts upstream and downstream of the Yarrabilba site respectively (modelled as 1D structures) while Table 13 provides the bridges structure details provided by Council and modelled as 2D structures in TUFLOW.



Prepared by: DesignFlow For: lendlease	Project: 4284 Yarrabilba Precinct 3 Flood Study	N W E S Scale: 1 : 30,000 (A4)	**FIGURE 12** **Hydraulic Structures**
	Client: Lend Lease	Date: 11 July 2016	

Table 11: Existing cross road drainage upstream of site (1D structures)

TUFLOW ID	Location	Type and Size	Length (m)	US : DS Invert (m AHD)
WTR	Waterford-Tamborine Rd	5/ 1.8m dia RCP	18.1	17.08 : 16.99

Table 12: Existing cross road drainage downstream of site (1D structures)

TUFLOW ID	Location	Type and Size	Length (m)	US : DS Invert (m AHD)
16	Georgina Dr (west)	4/ 1.2m x 0.6m RCBC	18.1	17.08 : 16.99
21	Georgina Dr (east)	7/ 900mm dia RCP	20.6	16.60 : 16.45
Pineview Rd *	Pineview Road (east)	4/ 1.8m x 3.6m RCBC	19.0	19.06 : 18.91
Culvert 1B *	Private Property (Steele Rd)	1/ 375mm dia RCP	4.16	22.88 : 22.77
Culvert 1C *	Private Property (Steele Rd)	3/ 375mm dia RCP	6.2	22.1 : 22.19
Culvert 1D *	Private Property (Steele Rd)	2/ 375mm dia RCP	4.6	21.90 : 21.80
Culvert 1E *	Private Property (Steele Rd)	1/ 375mm dia RCP	4.44	21.1 : 21.09
Culvert 1F *	Steele Rd (south)	3/ 375mm dia RCP	11.3	20.83 : 20.74
Culvert 1G *	Pineview Rd (west)	5/ 1.2m x 0.6m RCBC	14.8	19.96 : 19.86
Culvert 1H *	Private Property	5/ 750mm dia RCP	10.75	17.59 : 17.45
Culvert 1J *	Steele Rd (south of Wandearah Rd)	6/ 375mm dia RCP	16.0	14.92 : 14.82
45	Waterford-Tamborine Rd (north of Logan Village)	2/ 1.5m dia RCP	18.5	5.96 : 5.86
184	Quinzeh Ck Rd (at Quinzeh Ck)	1/ 1.25m x 1.2m RCBC	4.25	10.5 : 10.5
185	Steele Rd (north of Allawah Ct)	4/ 1650mm dia RCP	9.9	13.82 : 13.72

RCP = Reinforced concrete pipe, RCBC = Reinforced concrete box culvert

* Culverts added/updated based on 2016 detailed survey

Table 13: Existing bridge structures downstream of site (2D structures)

Location	Obvert (mAHD)	Deck Height (m)	Rail Height (m)
Miller Rd	10.14	0.50	1.01
Railway Line -Quinzeh Creek	10.97	1.03	-
Railway Line – Waterford – Tamborine Rd	11.27	1.03	-
Waterford – Tamborine Rd	8.38	0.7	1.10

4.5 MODEL VALIDATION

4.5.1 Area of interest

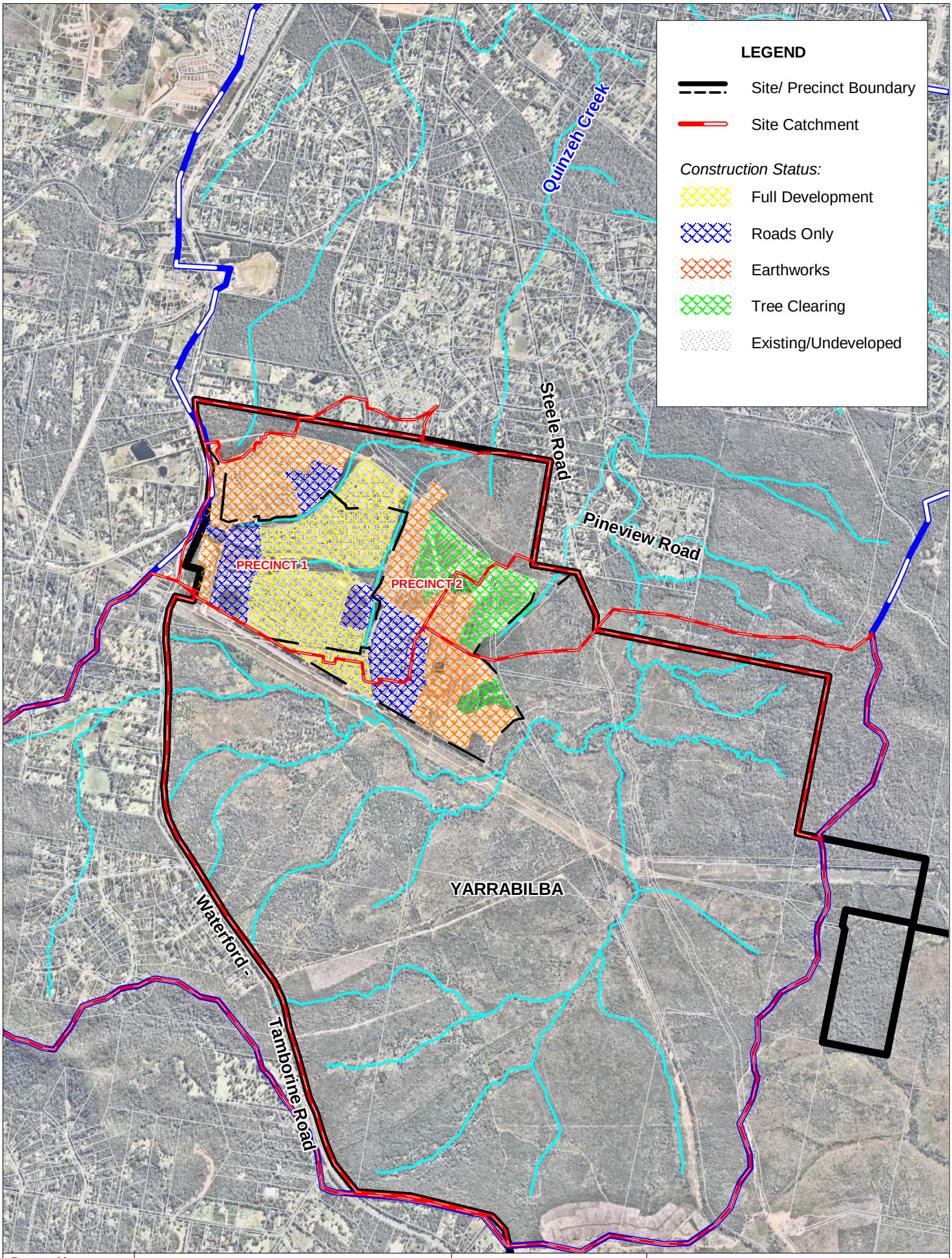
The flood event of 1 May 2015 described in Section 2.8.3 was used to undertake a validation of the current flood model revision for Precinct 3. This event was captured by the Upper Quinzeh Creek gauge providing both rainfall and water level data. This event caused significant flooding to a number of properties downstream of Yarrabilba in the Pineview Road, Louise Court and Maranoa Drive area. The model validation is therefore focussed around this area as there is a number of known and estimated flood levels within private properties that were surveyed following the event. The automatic rainfall and flood level gauge on the upstream side of Pineview Road provides further detailed data in this location.

4.5.2 Catchment Condition

As the Yarrabilba development site was in a partially developed state at the time of this significant event, it was necessary to refine the hydrological model to capture the relevant catchment and infrastructure conditions. Figure 13 broadly identifies the catchment ground conditions which was based on as-constructed data and advice from the civil contactor combined with aerial photography review (high resolution imagery was available from 1 week prior to rainfall event). Catchment conditions were broadly defined within the validation hydrological model as:

- Fully developed (all roads and houses constructed)
- Road construction only (no houses on lots)
- Earthworks only
- Tree clearing only
- Undeveloped

The balance of the catchment within Yarrabilba south and east of Precinct 2 remained undeveloped.



Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3
Flood Study

Client: Lend Lease

N W E S

Scale: 1 : 30,000 (A4)

Date: 11 July 2016

FIGURE 13

Catchment Status
1 May 2015 Event

In order to undertake partial development assessments and validation, it was also necessary to derive rainfall-runoff parameters for the clearing and bulk earthworks phase in addition to the pre- and post-development data presented in Section 3.3. By their nature, these interim ground conditions are quite variable and change over short periods of time as works progress. The estimates in Table 14 therefore attempt to bridge the surface conditions between going from undeveloped to fully developed and the area of each part developed land use was applied as an area weighted manning's within the XPRAFTS sub-catchment.

Table 14: Partial development catchment conditions

Catchment condition	Catchment Manning's n	Imperviousness
Tree clearing	0.025	0%
Bulk earthworks	0.025	0%
Roads	0.015	100%

Note: for 'Roads only' catchments, the impervious catchment Manning's n value in Table 14 was applied to the road area only (typically 15% of the catchment). The bulk earthworks n was then applied to the balance of the lot areas and the subsequent weighted area manning's calculated.

As for the ground surface conditions, the status of the flood mitigation infrastructure construction was collated to enable accurate modelling of the detention basins within the validation simulation. Table 15 provides the relevant status of this infrastructure at the time of the event. Where partial or no construction had occurred, the relevant areas within the overall (ultimate Precinct 1 and 2) TUFLOW flood model were modified or removed to reflect the terrain and hydraulic structures in place.

Table 15: Precinct 1 and 2 Flood mitigation infrastructure construction status

Flood Basin	Construction Status at 1 May 2015
Flood 2, 4, 5	Completed as per design
Flood 1	Bund height RL26.0 (partial construction) Temporary low flow pipe = 750mm dia RCP
Flood 3	Bund height RL30.25 (partial construction) Temporary low flow pipe = 750mm dia RCP
Flood 6, Wetland W2, Flood 9	Not constructed

4.5.3 Gauge Data

Rainfall data for the 1 May 2015 event was recorded at the Upper Quinzeh Creek gauge (Pineview Road) which was used in the simulation. It is recognised however that the storm event was not uniformed across the catchment and this gauged rainfall is therefore only representative of the immediate area. A review of historical radar images from the event and the water level at Pineview Road indicate the following:

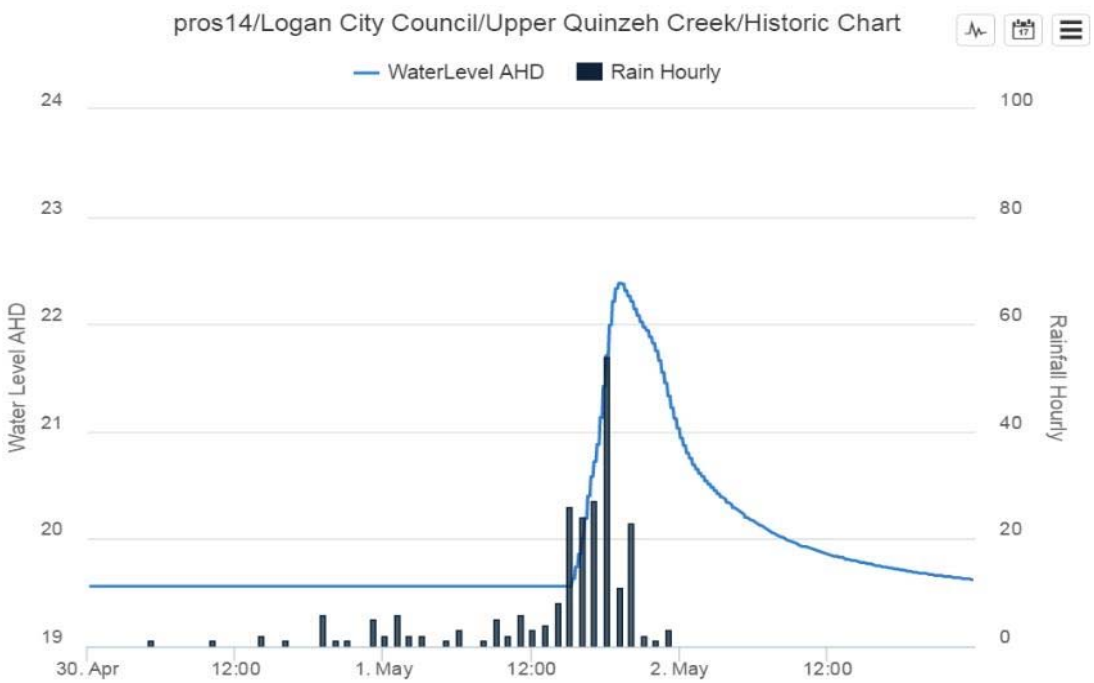
- Rainfall generally moved from north to south with some gradual shift from north-north west to north-north east over the duration.

- Rainfall intensity varied significantly over the long duration event with quite pronounced peak periods

- Most intense rainfall occurred between approximately 5pm and 6pm after numerous hours of moderate to heavy falls, by which time Quinzeh Creek had already risen significantly

While no detailed correlation of rainfall data to radar images has been undertaken in this instance, the variability of total catchment rainfall has been considered in the interpretation and validation of the hydraulic model to the gauged and surveyed flood levels.

Figure 14 shows the flood level plot recorded on the upstream side of Pineview Road culverts with the corresponding hourly rainfall totals displayed (columns). The subsequent plot in Figure 16 overlays the modelled water level plot derived from the TUFLOW model. The data presented has assumed 50% blockage to the culverts based on visual inspection of the area following the storm (photos in Figure 15). Again, there is no certainty around the timing of debris build-up, whether there was multiple build-up/releases of debris during the event and therefore this comparison should only be relied upon as a general guide of flood behaviour.



Note: The gauge sensor sits at approximately 0.5m above the culvert invert to avoid regular siltation/debris impacts and therefore does not record low flow at depths below this.

Figure 14: 1 May 2015 flood event rainfall and water level gauge output



Figure 15: Pineview Road culvert upstream debris following 1 May 2015

The XPRAFTS hydrologic model was run for 72 hours to capture low intensity lead up rainfall (i.e. from midnight on Thursday 30 April through to 11:59pm on 2 May 2015). The TUFLOW model simulation was commenced at 36 hours into the 72 hour period to capture the major flooding period of the flooding between midday and midnight on 1/5/2015.

In absence of additional numbers of recorded storm events with significant water level rise gauged, there was little impetus to undertake significant changes to the hydrologic or hydraulic model. With the data available and with the uncertainties described above around rainfall distribution and blockage, the current model is considered to provide an acceptable interpretation of the flood behaviour occurring in the Yarrabilba site and Upper Quinzeh Creek catchment.

The simulated water level plot at Pineview Road in Figure 16 shows an earlier rising limb to the hydrograph which may be partly due to the application of the gauged rainfall data to the total upstream catchment as uniform rain.

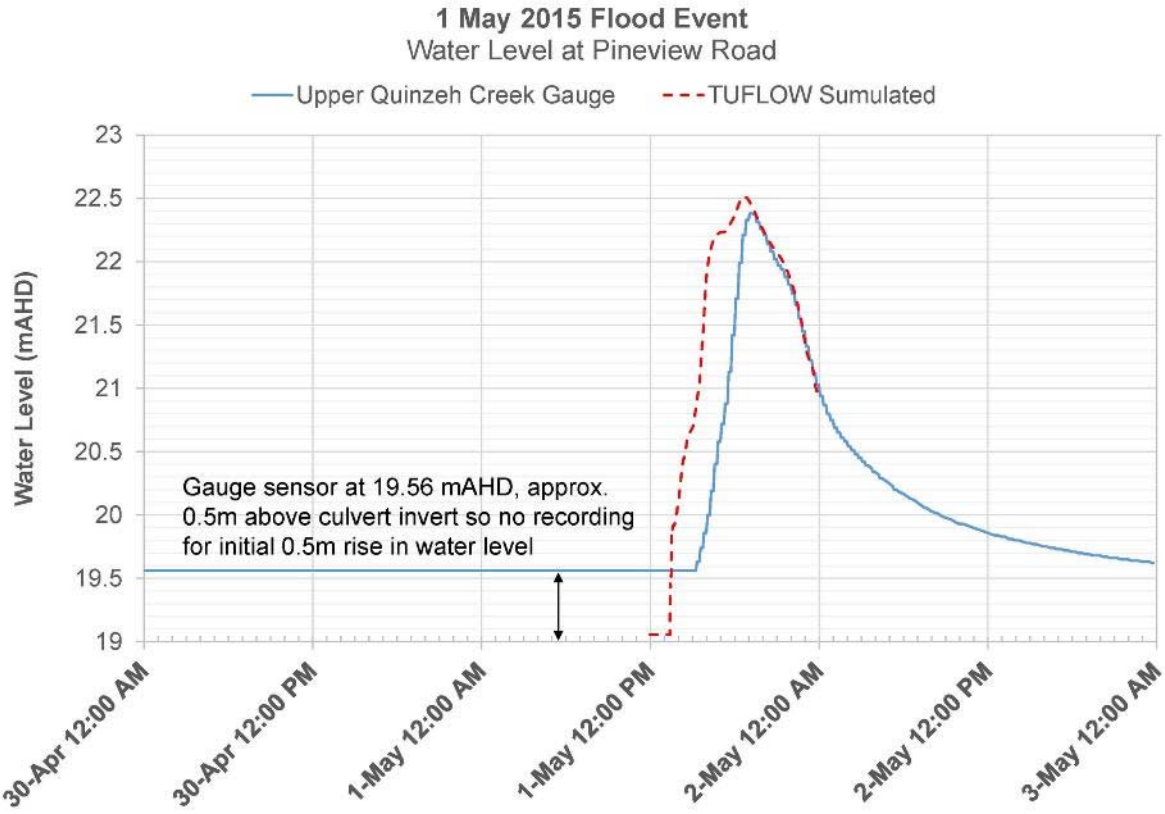


Figure 16: Modelled and recorded water level at Upper Quinzeh Creek gauge

4.5.4 Flood Survey Data

A detailed survey of flood marks on private properties affected by the 1 May 2015 flood was undertaken in order to obtain addition information to validate the hydraulic model. This survey was limited in extent to those property owners who responded to the request and granted access to the surveyors. Flood levels surveyed were based mainly on visible water marks, a known reference point in relation to house floor levels or a debris mark on fence or tree.

All these flood level indicators are influenced by localised water mounding or debris accumulation as a result of on-ground structures or features not discretely accounted in the hydraulic model (e.g. trees, fences, sheds, houses, vehicles and machinery). Accuracy is therefore commensurate to the type and location of the flood level indicator. Table 16 provides the location of surveyed and modelled flood levels from the 1 May event which are mapped in Figure 17.

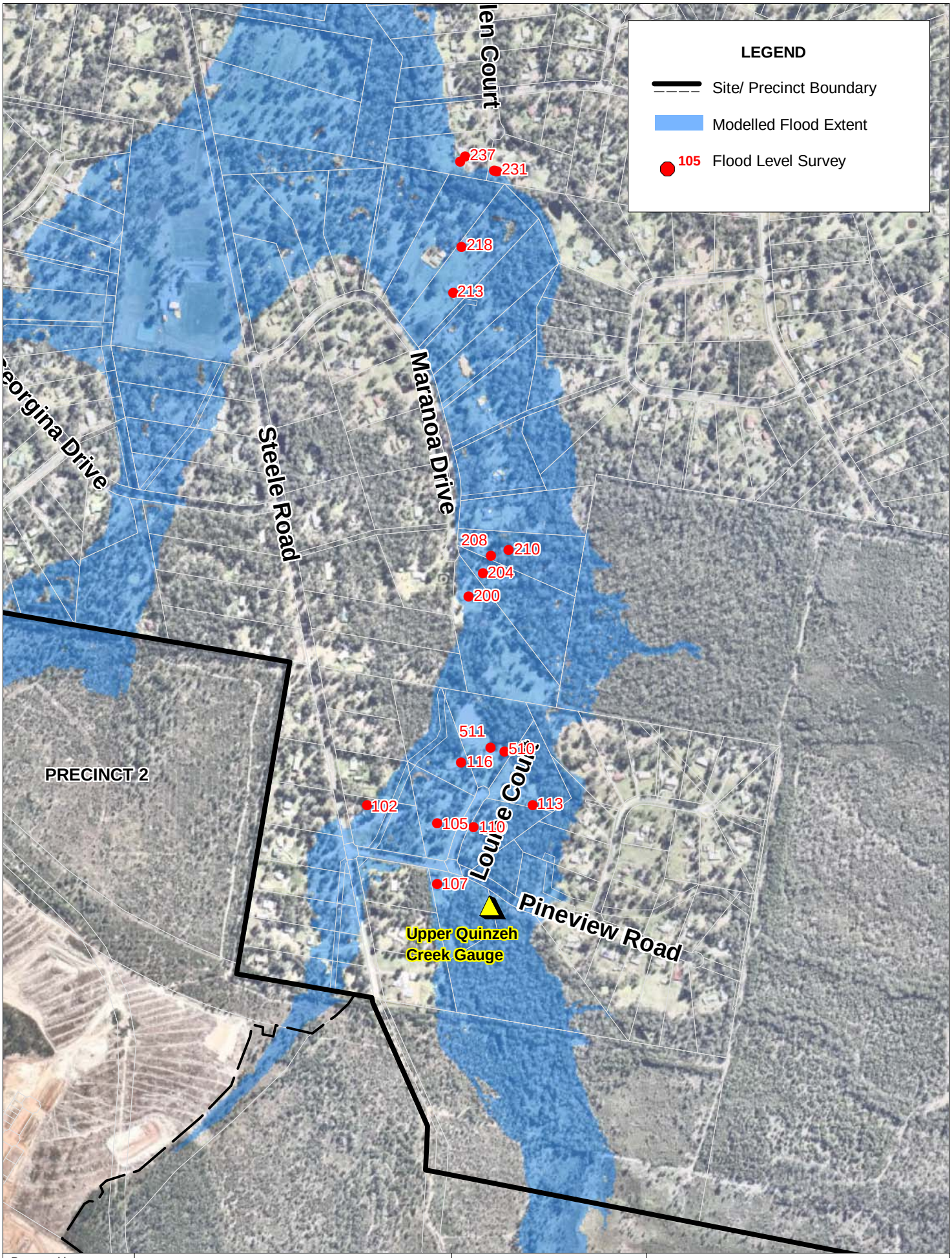
There is generally good agreement with the predicted and observed flood levels at these locations. Variability is generally within an acceptable tolerance given the uncertainty and errors described above. Further, the LiDAR (aerial survey) ground surface data utilised in the hydraulic model has a tolerance of ±150mm which reinforces the tolerance limits of comparing observed flood levels with those simulated through the best available software and data.

Table 16: Surveyed vs modelled flood level from 1 May 2015 event

Survey Point ID	Location	Flood Mark Type [1]	Surveyed Flood Level (mAHD)	Modelled Flood Level (mAHD)	Difference (m)
102	2-16 Steel Road	D	21.52	*21.32* [2]	*-0.20* [2]
105	2 Louise Court	R	21.90	21.78	-0.12
107	17-29 Pineview Road	R	22.45	22.50	0.05
110	1 Louise Court	R	21.84	21.93	0.08
113	19 Louise Court [3]	W	21.53	21.51	-0.02
116	18 Louise Court [3]	R	21.05	20.94	-0.12
200	96 Maranoa Drive	R	20.45	20.41	-0.04
204	94 Maranoa Drive	R	20.04	20.13	0.10
208	90-92 Maranoa Drive	R	19.91	19.96	0.05
210	90-92 Maranoa Drive	W	19.83	19.84	0.01
213	40-46 Maranoa Drive	W	18.31	18.26	-0.05
218	40-46 Maranoa Drive	W	17.48	17.55	0.08
231	1 Ellen Court	R	17.64	*17.33* [2]	*-0.31* [2]
232	1 Ellen Court	W	17.52	17.33	-0.20
237	2 Ellen Court	R	17.40	*17.11* [2]	*-0.29* [2]
241	2 Ellen Court	R	17.30	17.11	-0.19
510	20 Louise Court	U	21.42	21.11	-0.31
511	20 Louise Court	U	21.19	21.04	-0.15

Notes:

1. Flood mark type: W = water mark, R = Reference point, D = debris mark, U = uncertain approximate/anecdotal level
2. Modelled flood extent did not overlap these survey points. Modelled flood level and difference is taken from nearest flood extent/level (typically 5-6m away or two grid cells in hydraulic model).
3. Resident noted that local flood levels on property were influenced by fence that caused higher than normal water levels compared to areas beyond fence.



Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3 Flood Study

Client: Lend Lease

Scale: 1 : 10,000 (A4)

Date: 11 July 2016

FIGURE 17

TUFLOW Model Validation Locations 1 May 2015 Event

4.5.5 Discussion

Flood mark types used in Table 16 provide an indication of the potential accuracy/uncertainty in the maximum flood levels experienced at a particular location. Generally, water level marks are considered good evidence based levels, Reference points (e.g. brick mortar level) are similarly relatively accurate but open to observation/perspective interpretation during or after a flood. Debris levels are slightly less accurate again due to the thickness and buoyancy influence of these marks and mobility during flow. Finally, anecdotal/uncertain flood marks (such as 'almost to floor level') are of considered useful but of lower accuracy than above as they are open to greater interpretation of descriptive flood levels.

From the surveyed versus modelled flood levels presented in Table 16 there is slightly poorer agreement at the two Ellen Court properties (typically 0.2-0.3m difference from model). An uncertainty lies in the hydrologic and hydraulic inputs to this lower part of the validation area as it is under greater influence of Councils model data (Zone 2 as per Figure 10 in Section 4.2.3). Potential causes of higher discrepancy may be attributed to:

- Manning's roughness assumption of 0.05 (hydraulic model) within creek channel adjacent may be too low compared to on-ground conditions (or vegetation growth at time of event may have exceeded original model assumptions).

- Hydrological assumptions for catchment LR208 (BC) draining into Quinzeh Creek via eastern tributary upstream of Ellen Court (as TUFLOW boundary input) causing lower inflows to TUFLOW model and/or hydrograph timing differences.

- Inflow input to TUFLOW model (as 2D_SA type) from sub-catchment LR210 (SA) containing Ellen Court occurring downstream of subject validation locations

Therefore, further detailed review of Council's component of the model would be required to ascertain the discrepancy here.

4.5.6 Summary of Model Validation

Based on the comparison of the gauged water level at Pineview Road and indicative flood levels surveyed on affected properties downstream of Yarrabilba, the current hydrologic and hydraulic models are considered to sufficiently represent flooding in the upper Quinzeh Creek catchment within the limitation of the input and validation data. Some key interpretations from the validation process include:

- Water level rise at Pineview Road indicates the model predicts a faster catchment response than actually occurred which may be attributed to the rain storm moving north to south (i.e. the point rainfall intensity recorded at the gauge was assumed to be occurring uniformly across the catchment)

- Early water level rise simulated in the model may also suggest that the actual catchment has a slower flood response time than modelled. In this case, the model shows a conservative (i.e. shorter) than actual time to flood peak.

- Peak water levels are similar between model and gauge with uncertainty and inherent variability in the amount and timing of debris build-up upstream of culverts and guard rails potentially impacting this factor over the course of the flood.

- Flood levels within private properties are well represented in the model in the upper catchment indicating that despite localised timing difference, the flood levels in properties once overbank spill (or shortcutting) occurs are less sensitive to these anomalies.

The overall flood model is therefore considered suitable for the Precinct 3 flood impact assessment. With additional gauge data in future, further assessment and potential for calibration of model parameters will be possible.

5 FLOOD MITIGATION STRATEGY

5.1 OVERVIEW

The flood mitigation strategy developed for Precinct 3 and the interim staging of this precinct draws on a significant amount of detailed understanding gained from the Precinct 1 and 2 flood assessment as well as monitoring of actual flood events in recent years.

As discussed in Section 9.5.6 of the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 3* (DesignFlow, 2014), the timing of flood hydrographs converging downstream from site catchments 2 and 3 (predominantly Precinct 1 and 2) and catchment 4 (predominantly Precinct 3) requires careful consideration of not only peak flow attenuation leaving site but of the effect of delayed flood peaks due to detention basins and the coincidence of these with the falling hydrograph limb of downstream tributaries.

The detailed discussion of this occurrence is not reproduced here and reference should be made to Section 9.5.6 of the abovementioned report for detail. It does however remain an important factor in the assessment and design of all flood mitigation measures adopted within catchment 4 at Yarrabilba and designs must consider the use of interim and ultimate outlet structures to ensure there is the necessary flexibility to achieve the required outcomes regardless of the potential changes in roll out of development. This approach has been adopted as part of the Precinct 1 and 2 detention basin design to allow future modification to site discharge based on gradual changes in downstream flood behaviour as development upstream progresses.

5.2 PRECINCT 3 FLOOD MITIGATION

Due to the complex nature of the Yarrabilba site hydrology involving site discharge to multiple tributaries which in turn discharge at varying distances downstream into Quinzeh Creek, a flood mitigation strategy has been resolved for Precinct 3 that ensures:

(a) Protection of properties immediately downstream of the site from increase in flooding impact

(b) Consideration of existing Precinct 1 and 2 flood mitigation on side tributary discharge hydrograph timing (with main creek) to verify no increase in flooding downstream of confluences

(c) Recognition that upstream catchments (in Yarrabilba) will continue to undergo development (and therefore hydrological modification) over time and design downstream infrastructure accordingly.

To achieve these outcomes, the following broad strategy components have been adopted for Precinct 3:

1. Existing Flood Basin 9 manages the northern portion of Precinct 3A (in catchment 3)
2. Retention of the interim Flood Basin 16-INT in catchment 4 (already constructed as part of Precinct 1 and 2) allows the southern portion of Precinct 3A development to occur
3. Construction of Flood Basin 15 (as road crossing embankment) as part of the commencement of works in Precinct 3B to manage the balance of Precinct 3.

The location of these measures is shown in Figure 18.

Flood Basin 15 is intended to form part of the future flood strategy for the broader site that attenuates flood discharge from a number of development precincts and manages coincident flooding within and downstream of the site.

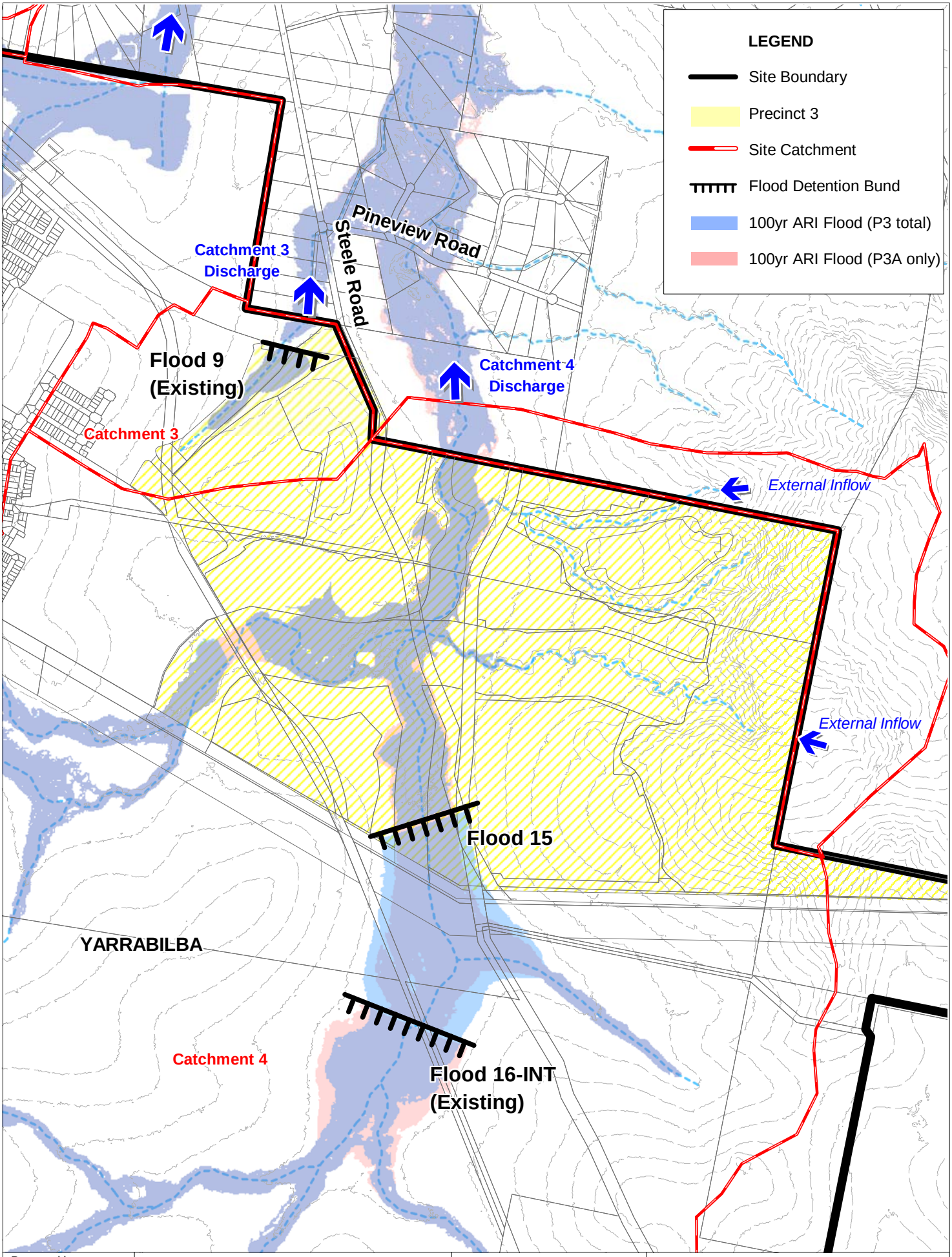
The flood strategy has therefore been staged to ensure that flood mitigation requirements can be met at all stages of development in Precinct 3 as well as allow for future development within the catchment. The detailed analysis and results of the interim and ultimate strategies is discussed in Sections 5.4 below.

5.3 DETENTION BASIN DETAILS

A description of the major flood mitigation infrastructure for Precinct 3 is provided in Table 17 with the hydraulic structures controlling discharge from these areas detailed in Table 18. The Yarrabilba Drive extension has been included in the descriptions not specifically as a flood attenuation zone but for completeness due to being a major waterway and fauna corridor crossing.

Table 17: Precinct 3 detention basin details

Basin ID	Description
Flood 9	Existing flood detention basin constructed as part of the Precinct 2 development (catchment 3 discharge)
Flood 16-INT	Existing interim flood detention basin constructed as part of Precinct 2 to manage staging of Precinct 2 development expansion into catchment 4. Only required for Precinct 3A.
Flood 15	Proposed large scale detention basin upstream of future road crossing to Precinct 3B. Utilises broad flat vegetated drainage line extending southward through site. Manages total Precinct 3 (plus future development capacity)
Yarrabilba Drive Extension	*Major road crossing of waterway. No specific flood detention function due limited instream flood storage but accounted for in hydraulic modelling of upstream catchment impacts*



Prepared by: DesignFlow For: lendlease	Project: 4284 Yarrabilba Precinct 3 Flood Study Client: Lend Lease	N W E S Scale: 1 : 15,000 (A4) Date: 11 July 2016	**FIGURE 18** **Precinct 3 Flood Mitigation Strategy Infrastructure**

Table 18: Precinct 3 detention basin outlet structures

Basin ID	Structure Component ID	Type/Size				
			Crest	USIL	DSIL	Length
Flood 9	FL9_Lo	600 x 450 orifice	-	24.29	-	-
	FL9_Pit	3.0m x 1.5m pit	26.3	24.29	-	-
	FL9_Hi	2/ 825 RCP [3]	-	24.29	24.09	34.16
	FL9_Weir	10m weir	26.70	-	-	-
Flood_16-INT	FL16_Lo	1/ 1200 x 900 RCBC and 2/ 1050 x 900 RCBC [4]	-	25.95	25.875	30.5m
	FL16_Weir	2/ 50m weirs	28.8	-	-	-
Flood 15	FL15_Lo	1/ 1200 x 900 RCBC and 2/ 1050 x 900 RCBC [4]	-	25.1	24.92	60m
	FL15_Hi	2/ 3000 x 2400 RCBC [5]	-	27.5	27.2	60m

Notes:

1. All dimensions in millimetres unless otherwise shown
2. RCP = reinforced concrete pipe, RCBC = reinforced concrete box culvert, USIL = upstream inert level, DSIL = downstream invert level
3. Flood 9 outlet pipes constructed with 900mm dia. pipes with constriction plates to equivalent area of 825mm dia. pipes.
4. 1050 RCBCs modelled to mimic 1200 wide RCBCs with 150mm fish passage baffles vertically as outermost cells in a 3 cell culvert (1200 RCBC in centre without baffles)
5. High level culverts are fauna passage culverts generally immune up to 2 year ARI

5.4 FREQUENT MINOR FLOW

Urbanisation of catchments causes an increase in the rate, volume and frequency of runoff response to rainfall due to the combined effect of lower infiltration, impervious surfaces and efficient drainage systems.

In major floods, this increase is less pronounced compared to the minor floods. The flood mitigation strategy discussed above provides the detailed assessment and mitigation infrastructure to manage the flood impacts arising from development that can potentially impact the safety of people, property and infrastructure downstream. The premise behind this is that the excess flood volume that is generated from an urban catchment is captured and temporarily stored within the site (in flood basins) and only allowed to discharge at a rate that is at or below pre-development rates and that does not cause peak flood levels downstream to exceed what they would have done in a pre-development scenario.

However, flood mitigation does not specifically target the management of the very frequent runoff that occurs from urban areas in periods of minor rainfall that arises every couple of weeks to months. These events don't typically present a risk to life,

property or infrastructure but can change the flow patterns and duration through drainage lines, and cause them to be wet or flowing more frequently and for longer durations. Where downstream drainage line is a defined watercourse such as Quinzeh Creek, this flow is generally contained within the natural channel and of little consequence. However, where drainage lines are formed through property or parkland as shallow swales or ill-defined depressions, often with primary uses in dry weather (e.g. paddock, driveway), the frequent impact of very minor flows becomes more apparent and often deemed a nuisance by those affected (rather than a hazard that is associated with flooding).

Lend Lease has identified this as a critical component of discharge management from Precinct 3 and in conjunction with the water sensitive urban design (WSUD) stormwater management approaches being adopted onsite for stormwater quality management (refer to the Yarrabilba Precinct 3 Stormwater Quality Management Plan (DesignFlow, 2016)) are proposing to work with residents downstream of Precinct 3 to provide drainage improvements to manage the nuisance element of runoff. A

As shown previously Figure 4 in Section 2.1, the north western portion of Precinct 3 drains via catchment 3 through private property (with drainage easement) towards Quinzeh Creek. A number of driveway crossovers exist within these properties that currently have pipe culverts with varying capacity to convey flows. The existence of farm dams typically on the upstream side of driveways often means that the culverts are relatively high in the landscape with very low freeboard o the driveway level. With high frequency runoff and longer duration discharge from Flood Basin 9, these driveway culverts are likely to struggle to convey even the most minor of flows without overtopping. Therefore, these properties will be assessed (with landowner permission) to define any potential upgrades required to pipes and or driveway levels to avoid frequent impacts post-development.

The portion of Precinct 3 draining via catchment 4 discharges directly to Quinzeh Creek which adequately conveys frequent minor flows and is therefore not targeted for drainage infrastructure upgrades.

6 RESULTS

Results from the TUFLOW hydraulic modelling for the interim development stage of Precinct 3A and the ultimate full development of Precinct 3 are provided in the following sections for the 2 year and 100 year ARI representing the minor and major bounds of flood management requirements. Results for all ARIs are provided in Appendix B.

Flood inundation mapping for the 2, 20 and 100 year ARI are provided in Appendix C for the pre-development, P3A interim development and the ultimate P3 development scenarios.

Flood afflux mapping (i.e. the difference in flood levels compared to pre-development) for the site and downstream is provided in Appendix D for the P3A interim and P3 total scenarios (same ARIs as above).

The tables below provide summary results for key reporting locations identified in Figure 19 downstream of the.

6.1 PRECINCT 3A INTERIM

Table 19: Precinct 3A peak discharge results summary

Location	Discharge m³/s					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	9.58	6.11	-3.47	42.17	34.76	-7.41
9	1.81	1.15	-0.66	7.90	5.59	-2.31
A23	1.09	0.58	-0.52	4.67	2.54	-2.13
8	39.65	34.05	-5.60	162.83	127.90	-34.93
12	43.62	38.49	-5.13	180.09	145.22	-34.87
14	49.14	45.95	-3.19	196.38	174.55	-21.84
16	3.94	3.41	-0.52	20.14	17.66	-2.48
QC87	60.30	57.70	-2.60	250.54	236.03	-14.51

* Note that the large reductions in peak flow have resulted from a conservative approach to flood hydrograph timing management in the upstream (undeveloped) catchment in Yarrabilba as discussed in Section 5.1. This strategy is subject to optimisation as part of detailed flood assessment and design.

PRE = pre-development, DEV = post-development

Table 20: Precinct 3A peak water level results summary

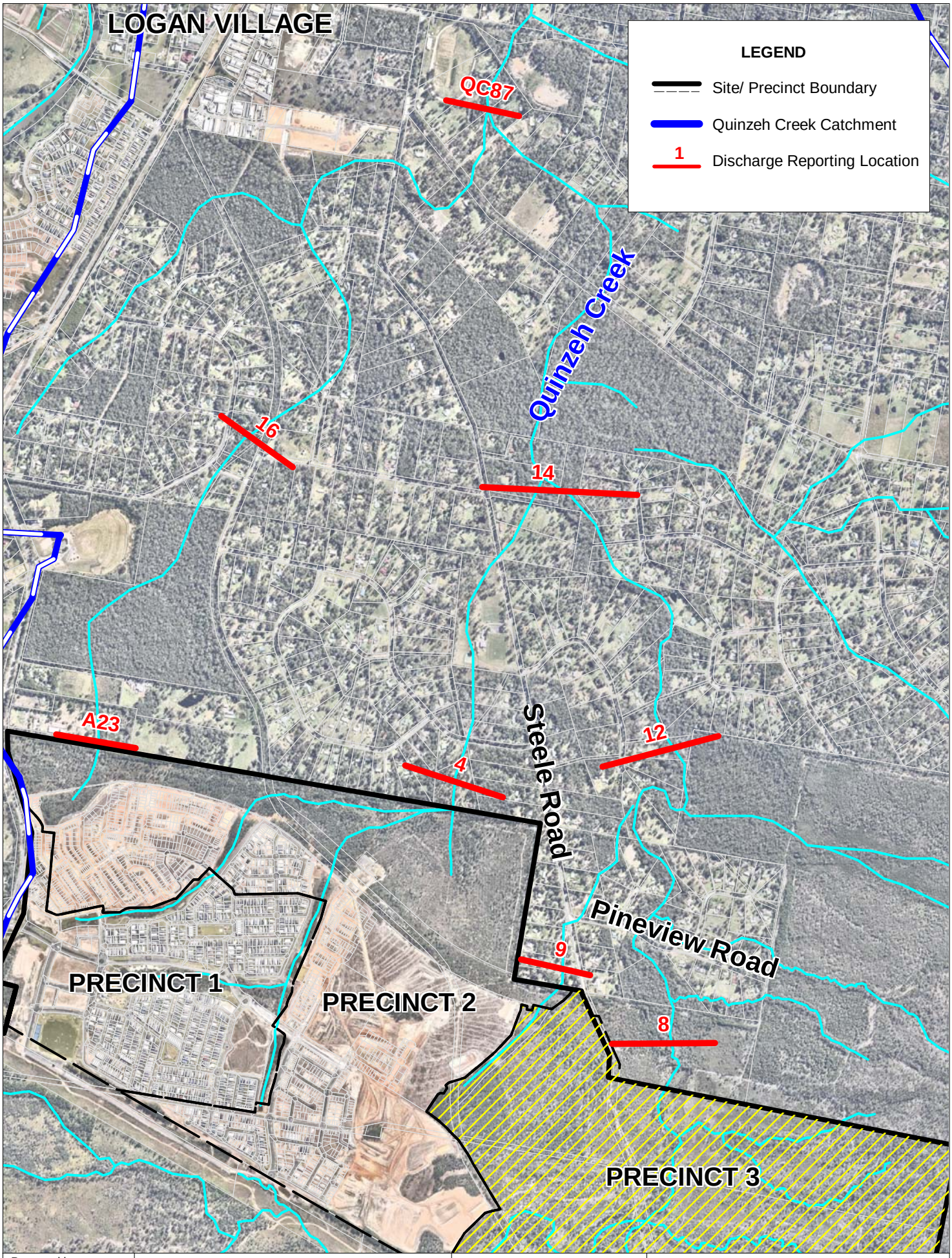
Location	Water Level (mAHD)					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	19.58	19.52	-0.06	19.95	19.88	-0.06
9	22.77	22.73	-0.04	22.90	22.86	-0.04
A23	37.44	37.43	-0.02	37.56	37.48	-0.08
8	22.72	22.65	-0.07	23.52	23.39	-0.13
12	18.24	18.12	-0.12	19.57	19.44	-0.13
14	15.18	15.11	-0.07	16.35	16.26	-0.09
16	20.12	20.06	-0.06	20.49	20.46	-0.03
QC87	10.98	10.95	-0.03	12.28	12.21	-0.07

* note that the peak water levels above are only for a single maximum point in the cross section location identified. They do not provide any indication of the variability of floodwater levels from one side of the floodway to the other and therefore provided for comparison only.

Table 21: Precinct 3A peak velocity result summary

Location	Velocity (m/s)					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	0.64	0.80	0.16	1.02	1.05	0.03
9	0.53	0.48	-0.05	0.86	0.79	-0.07
A23	0.80	0.64	-0.15	1.22	1.00	-0.22
8	1.49	1.46	-0.03	1.75	1.54	-0.21
12	1.26	1.30	0.05	1.74	1.76	0.03
14	0.91	0.97	0.06	1.47	1.34	-0.13
16	1.17	1.12	-0.05	1.64	1.63	-0.01
QC87	1.50	1.58	0.08	1.40	1.42	0.02

* note that the peak velocities above are only for a single maximum point in the cross section location identified. They do not provide any indication of the variability of floodwater velocity from one side of the floodway to the other and therefore provided for comparison only.



Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3
Flood Study

Client: Lend Lease

N W E S

Scale: 1 : 20,000 (A4)

Date: 11 July 2016

FIGURE 19

Flood Discharge Reporting Locations

6.2 PRECINCT 3 OVERALL

Table 22: Precinct 3 overall peak discharge results summary

Location	Discharge m³/s					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	9.58	6.12	-3.47	42.17	34.75	-7.41
9	1.81	1.15	-0.66	7.90	5.59	-2.31
A23	1.09	0.58	-0.52	4.67	2.54	-2.13
8	39.65	26.74	-12.91	162.83	101.33	-61.50
12	43.62	30.76	-12.86	180.09	118.99	-61.10
14	49.14	38.71	-10.43	196.38	149.73	-46.65
16	3.94	3.41	-0.52	20.14	17.66	-2.48
QC87	60.30	50.35	-9.95	250.54	214.26	-36.28

* Note that the large reductions in peak flow have resulted from a conservative approach to flood hydrograph timing management in the upstream (undeveloped) catchment in Yarrabilba as discussed in Section 5.1. This strategy is subject to optimisation as part of detailed flood assessment and design.

Table 23: Precinct 3 overall peak water level results summary

Location	Water Level (mAHD)					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	19.58	19.52	-0.06	19.95	19.88	-0.06
9	22.77	22.73	-0.04	22.90	22.86	-0.04
A23	37.44	37.43	-0.02	37.56	37.48	-0.08
8	22.72	22.54	-0.18	23.52	23.28	-0.24
12	18.24	17.94	-0.30	19.57	19.32	-0.25
14	15.18	14.95	-0.23	16.35	16.12	-0.23
16	20.12	20.06	-0.06	20.49	20.46	-0.03
QC87	10.98	10.88	-0.10	12.28	12.11	-0.16

* note that the peak water levels above are only for a single maximum point in the cross section location identified. They do not provide any indication of the variability of floodwater levels from one side of the floodway to the other and therefore provided for comparison only.

Table 24: Precinct 3 overall peak velocity result summary

Location	Velocity (m/s)					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	0.64	0.80	0.16	1.02	1.05	0.03
9	0.53	0.48	-0.05	0.86	0.79	-0.07
A23	0.80	0.63	-0.16	1.22	1.00	-0.22
8	1.49	1.42	-0.07	1.75	1.65	-0.10
12	1.26	1.49	0.24	1.74	1.75	0.02
14	0.91	0.83	-0.08	1.47	1.28	-0.20
16	1.17	1.11	-0.06	1.64	1.63	-0.01
QC87	1.50	1.62	0.12	1.40	1.43	0.03

* note that the peak velocities above are only for a single maximum point in the cross section location identified. They do not provide any indication of the variability of floodwater velocity from one side of the floodway to the other and therefore provided for comparison only.

As noted in Table 24, minor peak velocity exceedances in the 2 year ARI and two very minor exceedances in the 100 year ARI occurred at reporting locations 4, 12 and 87. Further inspection of these areas in the two-dimensional velocity output map found that these exceedances were very localised attributed to cell gradient within the DEM and the average cross sectional velocity was at or below the pre-development conditions. These exceedances are marginal, not considered to represent adverse impact and therefore accepted within the hydraulic limitations of the TUFLOW model.

6.3 DETENTION BASIN FUNCTION

Detention basins in Precinct 3A and Precinct 3 total development scenarios provide more than adequate flood attenuation to manage downstream flood discharge and water level to at or below pre-development conditions as illustrated in Section 6.1, 6.2 and Appendix B. Detained water levels within the relevant basins is provided in Table 25.

Table 25: Precinct 3 (and 3A) detention basin peak water levels

Basin	Peak Water level (mAHD)			Basin Invert	Top of Bund
ARI →	2 year	20 year	100 year	(mAHD)	(mAHD)
Flood 9	25.95	26.54	26.83	24.29	27.50
Flood 15	26.87	27.72	28.28	25.10	TBA
Flood 16-INT[1]	*27.98*	*28.97*	*29.15*	26.45	*30.00*

Notes:

1. Flood 16-INT flood levels apply only for the Precinct 3A development scenario and is not required in the total Precinct 3 flood mitigation strategy
2. Flood 15 only applies to the Precinct 3 total development scenario
3. Flood 9 is an existing basin and applies to both development scenarios

6.3.1 Detention Depth

The peak water levels shown in Table 26 (and Appendix B) result in flood storage depths of up to 3.2 metres under major 100 year ARI flood conditions. The ultimate flood depths in Precinct 3 total scenario are mapped in Appendix E. Precinct 3A scenario will exhibit the same flood depth in Flood Basin 9, however, as the interim Flood Basin 16-INT does not interface with any urban area, mapping was not required. Logan City Council requires detention basins to be designed in accordance with QUDM (2013) with regard to public safety. Specifically, it is desirable (where suitable land is available) to maintain flooded depths to 1.2m for the 20 year ARI and greater if possible. However, (as QUDM states*), 'in cases where this is neither practical nor economical, and the provision of a detention basin is considered to be better on safety grounds than other alternatives, greater depths may be acceptable. Notwithstanding this, designers are responsible for investigating the overall safety risks associated with the basin, design of the basin and the surrounding landscape in a manner that minimises safety risks and satisfying any safety requirements specified by the local government.'*

Table 26: Detention basin depth

Basin	Maximum Depth (m)		
ARI →	2 year	20 year	100 year
Flood 9	1.66	2.25	2.54
Flood 15	1.77	2.62	3.18
Flood 16-INT	1.53	2.52	2.70

Given the topography of the Yarrabilba site and the conservative approach to hydrologic modelling (i.e. high initial loss for pre-development scenario vs zero initial loss for post developed), it is neither practical nor economical to achieve the 1.2m

depth. In fact, a number of low gradient drainage lines within the site already exhibit flood depths in excess of 1.2m deep under pre-development conditions.

To manage safety risk in these areas the following has been adopted for design around the detention basins:

- 1 in 6 batters used where flood depths in detention zones are greater than 1.2m
- system will be planted out with vegetation and trees to discourage access
- warning signage provided
- depth indicators to be installed.
- Areas with slopes steeper than 1 in 4 will require steps and a handrail to assist egress (however this is an undesirable outcome and will be designed to meet dot point 1 as far as practical)

(Note: Fencing is not recommended by QUDM unless the flood risk is extreme)

There will be no passive or active recreation proposed 'within' in the low areas of flood detention basins that will be subject to flood depths greater than 1.2m or will have a velocity depth product (Vxd) greater than 0.6m^2/s.

Detailed design of all flood detention zones will also be undertaken to ensure that safety is maintained under non-design operating conditions. Specifically, high level outlets, discharge weirs or road crossings (where applicable) will be designed to ensure that under 100% blockages of low level outlets and/or 50% blockage of screened road culverts (in accordance with QUDM) under the major design storm, the velocity x depth product of overflows at these locations does not exceed 0.6 m^2/s. Where this can't be achieved, public access must be restricted in accordance with QUDM.

6.3.2 Blockage Analysis

An analysis of the flood behaviour within Yarrabilba Precinct 3 was undertaken in TUFLOW to identify any risk areas associated with property flooding or infrastructure impacts.

Blockage factors adopted for the assessment are summarised in Table 27. These are consistent with QUDM (2013) Sections 5.8.2 and 10.4.10 and Table 7.1 in Australian Rainfall and Runoff Project 11: *Blockage of Hydraulic Structures* (Engineers Australia, 2013).

Table 27: Blockage factors for hydraulic structures

	Adopted Design Storm Blockage Factor
Low level detention basin outlets	100%
Grated pit structures (where not acting as low level outlet)	100% (≤1.5m square)* 50% (> 1.5m square)*
Culverts (with width < 3m, height < 5m)	20% unscreened 50% screened **
Weirs	No blockage

* These pit sizing blockage factors have been proposed for Yarrabilba to account for the higher likelihood of smaller grated pit structures becoming fully blocked and are not specifically stated in QUDM but adopted here based on conservative design approach.

** All pipe and box culverts (except those on main waterway areas of Quinzeh Creek) have been assumed to be screened for the purpose of this assessment based on the requirement for screens at Yarrabilba Drive and Flood 4 culverts in Precinct 1 (already constructed).

The blockage analysis was carried out for the 100 year ARI event with durations between 60 and 180 minutes (representing the critical durations for the peak water level in the various detention basins within the site). The critical areas impacted by changes to the flood behaviour within Precinct 3 are provided in Table 28. No issues arise with respect to property flooding, bund overtopping or public safety in these areas.

Table 28: Blockage analysis impact

Location	100 year ARI Flood level (mAHD)		Increase (m)	Impact
	no blockage	with blockage		
Flood 9	26.83	26.97	0.14	0.53m below bund RL27.5 (overflow contained by bypass weir)
Flood 15	28.28	28.35	0.08	1.15m below nominal bund of RL29.5, fauna culverts carry bypass flow

No blockage assessment was undertaken for the Interim flood basin 16-INT (Precinct 3A development only) as this basin is not located near any development at present. However, the bypass weir constructed within this basin has more than sufficient capacity to convey the 100 year ARI event if the low culverts were partial (or fully) blocked.

6.4 DOWNSTREAM FLOODING

Pre-development results indicate that the main channel of Upper Quinzeh Creek (from approximately Pineview Road downstream) generally contains flow within its banks up to approximately 2 year ARI flows, with very minor road overtopping at Pineview Road culverts (approximately 50mm). In larger events, creek channel capacity is exceeded at numerous locations (increasing number of locations with magnitude of event), with a number of properties inundated and/or flood bypass flows occurring through low areas of land adjoining the creek. Yarrabilba catchment 4 is the primary area contributing to flows originating upstream of Pineview Road and contains the bulk of Precinct 3.

The smaller tributary from catchment 3 shows the majority of driveway crossings between the site boundary and Steele Road experience inundation in minor design storm events including the 1 year ARI. At the downstream end of these properties, an under capacity pipe culvert crosses Steele Road then a box culvert/causeway crosses Pineview Road to connect with the open drain running north towards Quinzeh Creek. An existing drainage easement runs from the northern boundary of Yarrabilba catchment 3 through to Quinzeh Creek.

Under both the interim Precinct 3A and ultimate Precinct 3 flood mitigation strategies, flood discharge and flood levels are reduced downstream of the site. Afflux maps in Appendix D denote the variability of this reduction downstream.

6.5 SITE FLOODING

Main stream flooding within Precinct 3 largely contained within the broad waterway defining the uppermost reach of Quinzeh Creek. Proposed development levels are generally well above the 100 year ARI flood levels through this area due to the natural terrain and/or fill required to achieve the grades required for development lots and roads.

Precinct 3B levels are dictated by the attenuation function of the road crossing of the southern waterway. This detention zone (referred to as Flood Basin 15) allows for flooding up to around 3.5-4.0m deep behind the road (under ultimate future development). Preliminary development (road) levels adjacent to Flood Basin 15 are 29.5 mAHD with lot levels grade up from this, providing more than sufficient freeboard (approximately 1.2m) to 100 year ARI flood levels under Precinct 3 Development conditions, as well as for the ultimate full upstream catchment development which preliminary assessment has indicated has a 100 year ARI flood level of 28.8 mAHD.

6.6 UPSTREAM FLOODING

Minor storm runoff from the main external catchment upstream of Waterford Tamborine Road enters the site through existing 5 x 1.8m diameter pipes under the road. The natural terrain on the south western side of Waterford Tamborine Road culvert crossing causes overland flow from upstream properties to concentrate in a roadside swale drain and be directed towards the culverts. In moderate rainfall events (approximately 5 year ARI), this swale capacity is exceeded and shallow road overtopping occurs over a length of 50-80m. In major flood events, water levels rise upstream of the main culverts, however, the major road overflow still occurs from the overland flow crossing the sag of the road to the south of the culverts over a length in the order of 120m. Any blockage of the culverts would exacerbate flooding to the land upstream which has not been specifically analysed in this location. Blockage would not however affect the overland flow component that appears to be causing to road overflow.

This is an existing flooding issue that is not caused by the Yarrabilba site but must be considered in the management of flood flows downstream. Further, if any subsequent work is undertaken by Council or Main Roads at this culvert crossing, there is the potential for greater peak flows to enter the Yarrabilba site (i.e. if culverts are upsized, less natural detention of flood waters occurs upstream of Yarrabilba Drive). It is therefore included here as an external input to the site flood behaviour for the Precinct 3 development area downstream and for any future flood analysis.

6.7 FLOOD WARNING TIME

The 100 year ARI flood hydrographs for four key flow reporting locations downstream of Precinct 3 (refer to Figure 19 in Section 6.1**Error! Reference source not found.**) are provided in Figure 20. The plots indicate that the flood mitigation strategy preserves the major flood hydrograph peak timing compared to pre-development, while reducing the peak discharge at each location.

Also noted on the flood discharge plots in Figure 20 is the presence of an early minor peak in locations 8, 12 and 14 (main Quinzeh Creek) marked as A, B and C respectively on the plots. This occurs partly as a result of increased imperviousness in the developed portion of the catchment, but also due to the conservative approach to pre and post development modelling that compares a pre-development flood with and initial loss of 30mm to a post development loss of zero. In reality (as discussed previously in Section 3.3.6), the lead up rain to a 100 year ARI storm burst event in either scenario will typically saturate a catchment such that the rainfall burst will create instantaneous runoff (akin to zero loss at the start of the burst). A discussion of these early peaks or rises is provided in Table 29 in terms of the relative impact to the specific locations. Location 9 (on catchment 3) does not experience this impact due to comparatively small size and single tributary).

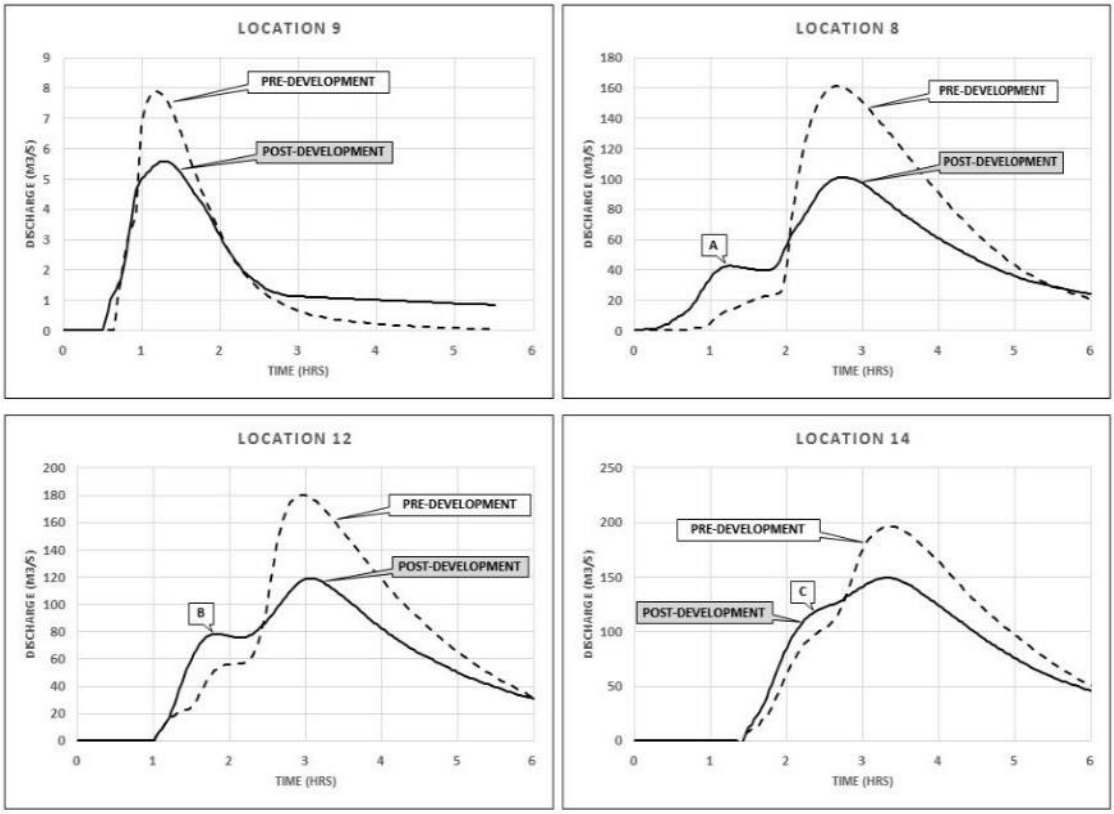


Figure 20: 100 year ARI flood warning time

Table 29: Minor peak within major flood discussion

Label (refer Figure 20)	Discussion
A (Location 8)	Early minor peak of ~40 m^3/s occurs approximately 0.8 hours earlier than the equivalent flow in the pre-development case. This flow is close to a 2 year ARI flow and is contained within the creek banks and therefore not a flood risk to dwellings or access. The subsequent major flood peak discharge of ~100 m^3/s occurs 1.5 hours after the early minor peak is significantly lower than the pre-development case (160 m^3/s) and therefore improves peak flooding downstream.
B (Location 12)	Early minor peak of just under 80 m^3/s occurs 0.6 hours earlier than the equivalent flow in the pre-development case. This is close to a 10 year ARI flow and relates to very shallow overbank flow from upstream. This does not impact dwellings or access routes from properties in this location. The subsequent major flood peak discharge of ~120 m^3/s is significantly lower than the pre-development case (180 m^3/s) and therefore improves peak flooding downstream.
C (Location 14)	Early minor rise to just over 120 m^3/s occurs 0.4 hours earlier than the equivalent flow in the pre-development case. At the equivalent time in the pre-development scenario, flood flows have already overtopped the creek banks in this location with no direct flooding of dwellings or access routes from properties. The subsequent major flood peak of approximately 150 m^3/s approximately 1 hour later is significantly lower than the pre-development scenario (200 m^3/s) and therefore improves peak flooding downstream.

6.8 GEOMORPHOLOGIC ASSESSMENT

The TUFLOW model also provides key data to permit the stability of the main waterway to be assessed from the geomorphological perspective. Bed shear stress and velocity outputs have been activated in the model to provide this data. A detailed assessment of the waterway stability has been documented in a separate report *Yarrabilba Precinct 3 Waterway Stability Assessment* (DesignFlow and Hyrobiology, 2016).

7 CONCLUSIONS

The proposed flood mitigation strategy for Precinct 3 and the staging of this strategy for Precinct 3A in the short term meets the flood objectives outlined in Section 1.3 and defined in the *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012).

This flood strategy has been developed within the context of the overall Yarrabilba site and therefore considers both the existing development within Precinct 1 and 2 as well as the future integration of Precinct 3 flooding within the broader catchment development. As a result, the provision of infrastructure as part of this strategy will result in significant reduction in major flood discharge downstream in the short to medium term until the upstream catchment is gradually urbanised. Under ultimate development conditions within the upper catchment (beyond Precinct 3), the site flooding objectives from Section 1.3 will remain in place and the downstream flood impacts will still be at or below pre-development conditions.

The interim flood mitigation strategy for Precinct 3A utilises the spare flood detention capacity within the existing flood detention basins 9 and 16-INT constructed as part of the Precinct 2 flood strategy.

The ultimate development of Precinct 3 total maintains existing Flood Basin 9 (for the minor western portion of P3) and adopts the large regional scale Flood Basin 15 in the southern catchment which replaces the interim Flood Basin 16-INT when development precinct 3B commences. Flood Basin 15 is intended to form a key component of the long term flood management strategy for the balance of future development precincts within the upper Quinzeh Creek catchment. Therefore, in the short to medium term (i.e. within the Precinct 3 development timeline), this basin will provide significant improvements to downstream flooding.

The *Yarrabilba Precinct 3 Flood Study* presented herein therefore provides the required assessment, flood modelling and justification to support the development of Precinct 3A in the interim as well as the overall precinct in the longer term.

APPENDIX A – XPRAFTS CATCHMENT DATA

Catchment data associated with the Yarrabilba site and upstream catchments is provided in Tables A1 to A3 below for Pre-development (total site), Precinct P3A development (including existing P1 and P2) and Precinct 3 total development (including P1 and P2) respectively. Data for the sub-catchment areas downstream of the site have not been altered as part of this study and are therefore not reproduced here. Reference be made to Logan City Council's flood assessment reporting for these areas.

Typically, where impervious percentage is shown in the pre-development case, this will relate to existing rural residential development and/or road area external to or interfacing with the Yarrabilba site. The balance of pre-development catchments within Yarrabilba have zero impervious fraction. Pre-development catchments within and upstream of the site have been assigned a prefix 'A' to broadly identify them.

Developed case catchments (or portions thereof) have been typically re-assigned a prefix 'X' to broadly identify where catchment properties have changed (and where balance of catchments remain in existing condition). Where a developed 'X' catchment has been defined or modified in shape from pre-development, there may be a subsequent reduction in the area of the adjoining undeveloped 'A' catchment (e.g. pre-development catchment A_N19 = 42.95ha has reduced in area to 32.91ha in the developed case due development catchments X11 and X30 adjacent accounting for this area). Catchment layouts are provided previously in Figure 8 and 9 in Section 3.2.

Table A1: XPRAFTS Pre-development case catchment data

Catchment ID	Area (ha)	Slope (%)	Imperv. (%)
A_N10	15.85	1.7	0
A_N11	27.18	1.8	0
A_N12	48.01	4.1	0
A_N13	39.97	2.1	0
A_N14	35.79	3.7	1
A_N15	33.20	2.4	0
A_N16	90.93	0.1	0
A_N17	21.19	1.7	0
A_N18	25.63	1.3	0
A_N19	42.95	1.8	0
A_N2 (BC)	96.89	7.9	0
A_N21	57.71	2.1	5
A_N22	74.20	4.6	1
A_N23	22.39	8.9	4
A_N24	33.96	14.0	2
A_N25	16.48	10.7	5
A_N26A	9.01	4.1	29
A_N26B	26.64	4.0	0
A_N27	30.21	2.3	0
A_N28A	10.59	8.4	23
A_N28B	23.83	3.8	0
A_N29	19.80	1.8	0
A_N3	65.00	3.9	0
A_N30A	16.70	6.7	18
A_N30B	25.68	2.6	0
A_N31	15.46	1.8	0
A_N32	20.41	3.8	0
A_N33	29.86	2.9	0
A_N34	36.11	1.3	0
A_N35A	14.66	9.0	20
A_N35B	46.10	3.0	0
A_N36	23.21	2.0	0

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Catchment ID	Area (ha)	Slope (%)	Imperv. (%)
A_N37A	33.04	2.2	0
A_N38A	31.14	9.6	14
A_N39A	24.13	2.2	0
A_N40A	10.82	6.4	17
A_N4a	44.06	2.4	0
A_N4b	18.31	2.4	0
A_N5	76.12	3.1	0
A_N6	19.18	4.9	0
A_N7a	64.07	1.4	0
A_N7b	24.48	1.4	0
A_N8	73.28	1.6	0
A_N9	53.39	2.4	0
A01	17.03	4.2	0
A02	10.20	3.3	0
A03	11.16	2.7	0
A04	10.80	3.0	0
A05	10.80	2.8	0
A06	11.48	1.7	4
A07	8.59	5.0	0
A08	9.35	3.4	0
A09	15.40	3.8	0
A10	6.66	5.2	0
A11	22.17	3.9	0
A12	14.33	3.4	0
A13	15.60	3.1	0
A14	14.32	2.5	0
A15	16.54	1.4	0
A16	19.82	3.5	0
A17	15.18	1.6	0
A23	22.76	4.0	0
A26	14.30	3.9	0
A27	31.23	2.3	0

Table A2: XPRAFTS Precinct 3A case catchment data

Catchment ID	Area (ha)	Slope (%)	Imperv. (%)
A_N10	15.85	1.7	0
A_N11	27.18	1.8	0
A_N12	48.01	4.1	0
A_N13	39.97	2.1	0
A_N14	35.79	3.7	1
A_N15	33.20	2.4	0
A_N17	21.19	1.7	0
A_N18	22.16	1.3	0
A_N19	32.91	1.8	0
A_N21	57.71	2.1	5
A_N22	74.20	4.6	1
A_N23	22.39	8.9	4
A_N24	33.96	14.0	2
A_N25	16.48	10.7	5
A_N26A	9.01	4.1	29
A_N26B	26.64	4.0	0
A_N27	30.21	2.3	0
A_N28A	10.59	8.4	23
A_N28B	23.83	3.8	0
A_N29	19.80	1.8	0
A_N3	65.00	3.9	0
A_N30A	16.70	6.7	18
A_N30B	23.52	2.6	54
A_N31	15.46	1.8	86
A_N32	20.41	3.8	0
A_N33	29.86	2.9	0
A_N34	36.11	1.3	0
A_N35A	14.66	9.0	20
A_N35B	46.10	3.0	0
A_N36	23.21	2.0	0
A_N37A	32.74	4.6	86
A_N38A	31.14	9.6	14
A_N39A	24.13	2.2	81
A_N40A	10.82	6.4	17
A_N4A	44.08	2.4	48
A_N4B	18.30	2.4	56

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Catchment ID	Area (ha)	Slope (%)	Imperv. (%)
A_N5	76.12	3.1	0
A_N6	19.18	4.9	0
A_N7A	64.07	1.4	0
A_N7B	24.48	1.4	0
A_N8	73.28	1.6	0
A_N9	53.39	2.4	0
X_N16	45.50	0.1	37
X_N2 (BC)	96.89	7.9	7
X01	3.90	2.0	69
X01A	6.72	3.0	62
X02	11.63	3.0	53
X03	10.03	3.0	53
X04A	12.19	3.0	50
X06	12.15	1.7	15
X07	10.01	3.0	79
X08	12.75	3.0	47
X09A	16.58	3.5	45
X09B	5.21	4.0	61
X10	6.79	2.5	67
X11	28.05	3.0	59
X12	9.91	3.0	51
X13	14.87	3.0	53
X14A	24.72	3.0	54
X14B	11.04	3.0	89
X15	7.95	1.0	1
X16	6.64	1.5	21
X17	24.70	1.5	46
X22	6.64	2.0	61
X23A	2.84	2.0	8
X23B	10.78	2.0	0
X26	19.81	3.5	63
X27A	22.99	2.5	56
X27B	4.45	2.5	1
X30	7.72	1.5	41
X31	34.10	3.0	49
X32	18.02	1.6	43

Table A3: XPRAFTS Precinct 3 total case catchment data

Catchment ID	Area (ha)	Slope (%)	Imperv. (%)
A_N10	15.85	1.7	0
A_N11	27.18	1.8	0
A_N12	48.01	4.1	0
A_N13	39.97	2.1	0
A_N14	35.79	3.7	1
A_N15	33.20	2.4	0
A_N17	21.19	1.7	0
A_N18	22.16	1.3	0
A_N19	32.91	1.8	0
A_N21	57.71	2.1	5
A_N22	74.20	4.6	1
A_N23	22.39	8.9	4
A_N24	33.96	14.0	2
A_N25	16.48	10.7	5
A_N26A	9.01	4.1	29
A_N26B	26.64	4.0	0
A_N27	30.21	2.3	0
A_N28A	10.59	8.4	23
A_N28B	23.83	3.8	0
A_N29	19.80	1.8	0
A_N30A	16.70	6.7	18
A_N30B	23.52	2.6	0
A_N31	15.46	1.8	0
A_N32	20.41	3.8	0
A_N33	29.86	2.9	0
A_N34	36.11	1.3	0
A_N35A	14.66	9.0	20
A_N35B	46.10	3.0	0
A_N36	23.21	2.0	0
A_N37A	33.04	2.2	0
A_N38A	31.14	9.6	14
A_N39A	24.13	2.2	0
A_N40A	10.82	6.4	17
A_N6	19.18	4.9	0
A_N7A	64.07	1.4	0
A_N7B	24.48	1.4	0

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Catchment ID	Area (ha)	Slope (%)	Imperv. (%)
A_N8	73.28	1.6	0
A_N9	53.39	2.4	0
X_N16	45.50	0.1	31
X_N2 (BC)	96.89	7.9	21
X_N3	65.00	3.9	5
X_N4A	44.06	2.4	37
X_N4B	18.31	2.4	33
X_N5	76.12	3.1	32
X01	3.90	2.0	69
X01A	6.72	3.0	62
X02	11.63	3.0	53
X03	10.03	3.0	53
X04A	12.19	3.0	50
X07	10.01	3.0	79
X08	12.75	3.0	47
X09A	16.58	3.5	45
X09B	5.21	4.0	61
X10	6.79	2.5	67
X11	28.05	3.0	59
X12	9.91	3.0	51
X13	14.87	3.0	53
X14A	24.72	3.0	54
X14B	11.04	3.0	89
X15	7.95	1.0	1
X16	6.64	1.5	21
X17	24.70	1.5	46
X22	6.64	2.0	61
X23A	2.84	2.0	8
X23B	10.78	2.0	0
X26	19.81	3.5	63
X27A	22.99	2.5	56
X27B	4.45	2.5	1
X30	7.72	1.5	41
X31	34.10	3.0	49
X32	18.02	1.6	43

APPENDIX B – TUFLOW RESULTS SUMMARY

Results are presented in Tables B1 to B8 below for pre and post development at the reporting locations identified in Figure 19 in the main report and at the respective detention basins (post-development only). The results from the blockage scenario (Section 6.3) are also presented in Table B7 to reflect the increase in flood level. Flood impact mapping is provided in Appendix C to E while the flood safety (velocity x depth) mapping is in Appendix F.

Results presented in the following tables are for Precinct 3A interim and Precinct 3 total respectively:

- Discharge (Table B1, B4)
- Water level (Table B2, B5)
- Velocity (Table B3, B6)
- Detention Basin Water Level (Table B7)
- Detention Basin Depth (Table B8)

Table B1: Precinct 3A Discharge

	Discharge m^3/s																	
	2 year ARI			5 year ARI			10 year ARI			20 year ARI			50 year ARI			100 year ARI		
Location	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.
4	9.58	6.11	-3.47	16.31	12.10	-4.20	20.45	15.92	-4.53	26.16	20.92	-5.24	34.60	28.12	-6.48	42.17	34.76	-7.41
9	1.81	1.15	-0.66	3.12	1.39	-1.74	3.91	2.11	-1.79	5.02	3.07	-1.95	6.58	4.63	-1.95	7.90	5.59	-2.31
A23	1.09	0.58	-0.52	1.83	0.98	-0.84	2.31	1.24	-1.07	2.98	1.62	-1.36	3.86	2.08	-1.77	4.67	2.54	-2.13
8	39.65	34.05	-5.60	66.27	51.88	-14.39	82.72	63.60	-19.11	106.40	79.97	-26.43	135.92	103.28	-32.63	162.83	127.90	-34.93
12	43.62	38.49	-5.13	69.39	58.47	-10.92	86.95	69.50	-17.44	114.79	89.78	-25.01	150.76	118.53	-32.24	180.09	145.22	-34.87
14	49.14	45.95	-3.19	80.75	72.62	-8.13	94.83	83.91	-10.92	123.12	108.65	-14.47	162.96	146.09	-16.87	196.38	174.55	-21.84
16	3.94	3.41	-0.52	7.20	6.14	-1.06	9.21	7.98	-1.23	12.43	10.50	-1.94	16.66	14.56	-2.10	20.14	17.66	-2.48
QC87	60.30	57.70	-2.60	104.10	97.46	-6.64	111.09	107.21	-3.88	149.94	143.01	-6.93	205.49	196.91	-8.58	250.54	236.03	-14.51

Table B2: Precinct 3A Peak Water Level

	Water Level (mAHD)*																	
	2 year ARI			5 year ARI			10 year ARI			20 year ARI			50 year ARI			100 year ARI		
Location	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.
4	19.58	19.52	-0.06	19.66	19.61	-0.05	19.71	19.66	-0.05	19.77	19.71	-0.05	19.88	19.79	-0.09	19.95	19.88	-0.06
9	22.77	22.73	-0.04	22.81	22.74	-0.07	22.83	22.78	-0.06	22.85	22.81	-0.04	22.88	22.84	-0.04	22.90	22.86	-0.04
A23	37.44	37.43	-0.02	37.46	37.44	-0.03	37.48	37.45	-0.03	37.53	37.46	-0.07	37.54	37.47	-0.07	37.56	37.48	-0.08
8	22.72	22.65	-0.07	23.01	22.86	-0.15	23.15	22.99	-0.17	23.30	23.13	-0.17	23.42	23.29	-0.14	23.52	23.39	-0.13
12	18.24	18.12	-0.12	18.72	18.59	-0.13	19.10	18.73	-0.37	19.29	19.13	-0.16	19.46	19.31	-0.15	19.57	19.44	-0.13
14	15.18	15.11	-0.07	15.63	15.54	-0.09	15.76	15.65	-0.11	15.98	15.86	-0.12	16.21	16.11	-0.10	16.35	16.26	-0.09
16	20.12	20.06	-0.06	20.28	20.24	-0.04	20.34	20.28	-0.05	20.38	20.36	-0.02	20.45	20.42	-0.03	20.49	20.46	-0.03
QC87	10.98	10.95	-0.03	11.39	11.33	-0.06	11.44	11.41	-0.03	11.73	11.69	-0.04	12.05	12.01	-0.04	12.28	12.21	-0.07

* Peak water level is representative of a single point in flowpath/channel only – refer to flood afflux maps for detail of variability of peak water level changes over full extent of flow paths

Table B3: Precinct 3A Peak Velocity

	Velocity (m/s)*																	
	2 year ARI			5 year ARI			10 year ARI			20 year ARI			50 year ARI			100 year ARI		
Location	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.	PRE	P3A DEV	Diff.
4	0.64	0.80	0.16	0.74	0.86	0.11	0.83	0.90	0.08	0.92	0.96	0.04	1.00	1.01	0.00	1.02	1.05	0.03
9	0.53	0.48	-0.05	0.63	0.50	-0.13	0.68	0.57	-0.11	0.75	0.64	-0.10	0.85	0.74	-0.11	0.86	0.79	-0.07
A23	0.80	0.64	-0.15	0.92	0.77	-0.15	0.99	0.84	-0.15	1.05	0.88	-0.17	1.16	0.95	-0.21	1.22	1.00	-0.22
8	1.49	1.46	-0.03	1.61	1.53	-0.08	1.65	1.55	-0.10	1.71	1.56	-0.14	1.74	1.54	-0.21	1.75	1.54	-0.21
12	1.26	1.30	0.05	1.37	1.39	0.01	1.44	1.43	-0.01	1.52	1.48	-0.04	1.70	1.68	-0.03	1.74	1.76	0.03
14	0.91	0.97	0.06	0.82	1.01	0.19	0.91	1.03	0.12	1.31	1.22	-0.10	1.45	1.30	-0.15	1.47	1.34	-0.13
16	1.17	1.12	-0.05	1.43	1.31	-0.12	1.47	1.45	-0.02	1.49	1.51	0.02	1.63	1.59	-0.04	1.64	1.63	-0.01
QC87	1.50	1.58	0.08	1.37	1.36	0.00	1.39	1.39	0.00	1.38	1.39	0.01	1.40	1.41	0.01	1.40	1.42	0.02

* Peak velocity is representative of a single point in flowpath/channel only and does not account for significant variation across channel and depth – refer to flood velocity maps for detail of variability

Table B4: Precinct 3 Discharge

	Discharge m^3/s																	
	2 year ARI			5 year ARI			10 year ARI			20 year ARI			50 year ARI			100 year ARI		
Location	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.
4	9.58	6.12	-3.47	16.31	12.10	-4.20	20.45	15.92	-4.53	26.16	20.92	-5.24	34.60	28.12	-6.48	42.17	34.75	-7.41
9	1.81	1.15	-0.66	3.12	1.39	-1.74	3.91	2.11	-1.79	5.02	3.07	-1.95	6.58	4.63	-1.95	7.90	5.59	-2.31
A23	1.09	0.58	-0.52	1.83	0.98	-0.84	2.31	1.24	-1.07	2.98	1.62	-1.36	3.86	2.08	-1.77	4.67	2.54	-2.13
8	39.65	26.74	-12.91	66.27	40.85	-25.41	82.72	50.23	-32.49	106.40	66.37	-40.03	135.92	85.50	-50.42	162.83	101.33	-61.50
12	43.62	30.76	-12.86	69.39	47.79	-21.60	86.95	55.24	-31.71	114.79	73.30	-41.48	150.76	98.62	-52.14	180.09	118.99	-61.10
14	49.14	38.71	-10.43	80.75	62.08	-18.67	94.83	70.33	-24.50	123.12	92.37	-30.75	162.96	125.24	-37.72	196.38	149.73	-46.65
16	3.94	3.41	-0.52	7.20	6.14	-1.06	9.21	7.98	-1.23	12.43	10.50	-1.93	16.66	14.56	-2.10	20.14	17.66	-2.48
QC87	60.30	50.35	-9.95	104.10	87.07	-17.04	111.09	98.28	-12.81	149.94	132.30	-17.64	205.49	180.55	-24.94	250.54	214.26	-36.28

Table B5: Precinct 3 Peak Water Level

	Water Level (mAHD)*																	
	2 year ARI			5 year ARI			10 year ARI			20 year ARI			50 year ARI			100 year ARI		
Location	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.
4	19.58	19.52	-0.06	19.66	19.61	-0.05	19.71	19.66	-0.05	19.77	19.71	-0.05	19.88	19.79	-0.09	19.95	19.88	-0.06
9	22.77	22.73	-0.04	22.81	22.74	-0.07	22.83	22.78	-0.06	22.85	22.81	-0.04	22.88	22.84	-0.04	22.90	22.86	-0.04
A23	37.44	37.43	-0.02	37.46	37.44	-0.03	37.48	37.45	-0.03	37.53	37.46	-0.07	37.54	37.47	-0.07	37.56	37.48	-0.08
8	22.72	22.54	-0.18	23.01	22.73	-0.28	23.15	22.85	-0.31	23.30	23.01	-0.29	23.42	23.17	-0.25	23.52	23.28	-0.24
12	18.24	17.94	-0.30	18.72	18.41	-0.31	19.10	18.55	-0.55	19.29	18.84	-0.46	19.46	19.20	-0.26	19.57	19.32	-0.25
14	15.18	14.95	-0.23	15.63	15.40	-0.22	15.76	15.50	-0.26	15.98	15.73	-0.25	16.21	15.98	-0.23	16.35	16.12	-0.23
16	20.12	20.06	-0.06	20.28	20.24	-0.04	20.34	20.28	-0.05	20.38	20.36	-0.02	20.45	20.42	-0.03	20.49	20.46	-0.03
QC87	10.98	10.88	-0.10	11.39	11.24	-0.15	11.44	11.35	-0.10	11.73	11.62	-0.11	12.05	11.94	-0.12	12.28	12.11	-0.16

* Peak water level is representative of a single point in flowpath/channel only – refer to flood afflux maps for detail of variability of peak water level changes over full extent of flow paths

Table B6: Precinct 3 Peak Velocity

	Velocity (m/s)*																	
	2 year ARI			5 year ARI			10 year ARI			20 year ARI			50 year ARI			100 year ARI		
Location	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.	PRE	P3 DEV	Diff.
4	0.64	0.80	0.16	0.74	0.86	0.11	0.83	0.90	0.07	0.92	0.96	0.04	1.00	1.01	0.00	1.02	1.05	0.03
9	0.53	0.48	-0.05	0.63	0.50	-0.13	0.68	0.56	-0.12	0.75	0.64	-0.10	0.85	0.78	-0.07	0.86	0.79	-0.07
A23	0.80	0.63	-0.16	0.92	0.76	-0.16	0.99	0.83	-0.16	1.05	0.88	-0.17	1.16	0.99	-0.18	1.22	1.00	-0.22
8	1.49	1.42	-0.07	1.61	1.47	-0.14	1.65	1.50	-0.15	1.71	1.56	-0.15	1.74	1.61	-0.13	1.75	1.65	-0.10
12	1.26	1.49	0.24	1.37	1.30	-0.07	1.44	1.34	-0.10	1.52	1.48	-0.05	1.70	1.67	-0.03	1.74	1.75	0.02
14	0.91	0.83	-0.08	0.82	0.83	0.01	0.91	0.89	-0.02	1.31	1.03	-0.28	1.45	1.25	-0.20	1.47	1.28	-0.20
16	1.17	1.11	-0.06	1.43	1.32	-0.11	1.47	1.44	-0.03	1.49	1.51	0.02	1.63	1.63	0.00	1.64	1.63	-0.01
QC87	1.50	1.62	0.12	1.37	1.38	0.01	1.39	1.40	0.01	1.38	1.40	0.01	1.40	1.42	0.02	1.40	1.43	0.03

* Peak velocity is representative of a single point in flowpath/channel only and does not account for significant variation across channel and depth – refer to flood velocity maps for detail of variability

Table B7: Detention Basin Water Level

Location	Water Level (mAHD)							
	1 year ARI	2 year ARI	5 year ARI	10 year ARI	20 year ARI	50 year ARI	100 year ARI	100 year ARI Blockage Scenario
Flood 1	26.35	26.57	26.71	26.78	26.89	27.11	27.22	27.49
Flood 2	29.09	29.37	29.71	29.90	30.05	30.25	30.34	30.47
Flood 3	29.89	30.24	30.53	30.78	31.01	31.20	31.26	31.28
Flood 4	33.83	34.06	34.48	34.70	34.91	35.32	35.51	36.33
Flood 5	43.82	43.94	44.05	44.26	44.41	44.69	44.87	45.28
Flood 6	22.15	22.52	22.71	22.79	22.90	23.13	23.22	23.29
Wetland W2	22.24	22.53	22.71	22.79	22.90	23.13	23.22	23.30
Flood 9	25.58	25.95	26.33	26.44	26.54	26.73	26.83	26.97
Flood 15 [1]	26.36	26.87	27.36	27.43	27.72	28.06	28.28	28.35
Flood 16-INT [2]	*27.38*	*27.98*	*28.58*	*28.80*	*28.97*	*29.08*	*29.15*	*28.35*

Notes:

1. Flood 15 is only applicable to Precinct 3 total scenario and not staging of Precinct 3A
2. Flood 16-INT water levels apply to Precinct 3A development scenario only and is not required for the Precinct 3 total mitigation strategy
3. 1EY = probability of 1 exceedance per year

Table B8: Detention Basin Water Depth

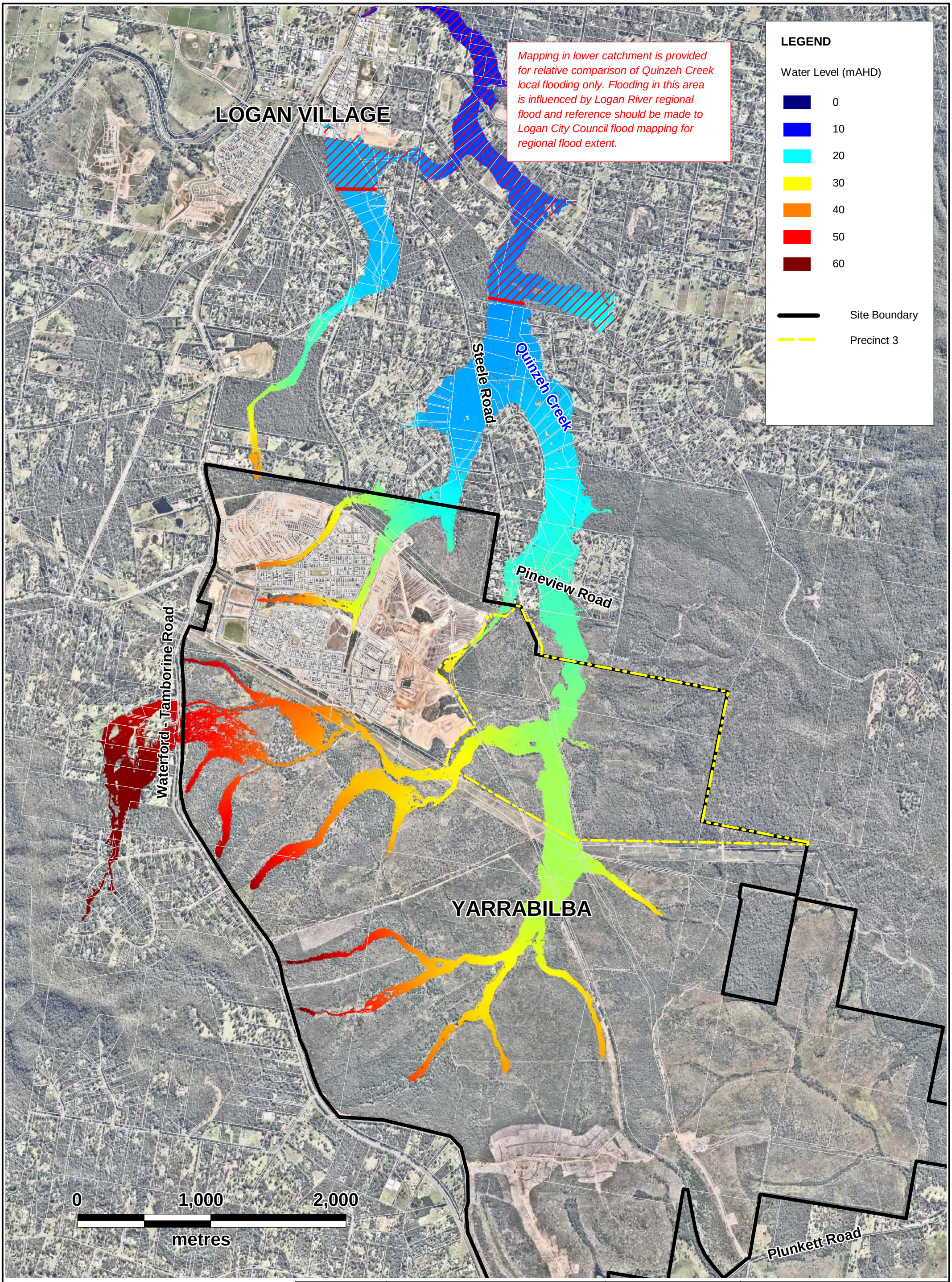
Location	Depth (mAHD)							
	1 year ARI	2 year ARI	5 year ARI	10 year ARI	20 year ARI	50 year ARI	100 year ARI	100 year ARI Blockage Scenario
Flood 1	2.35	2.57	2.71	2.78	2.89	3.11	3.22	3.49
Flood 2	1.04	1.32	1.66	1.85	2.00	2.20	2.29	2.42
Flood 3	1.03	1.38	1.67	1.92	2.15	2.34	2.40	2.42
Flood 4	1.03	1.26	1.68	1.90	2.11	2.52	2.71	3.53
Flood 5	0.82	0.94	1.05	1.26	1.41	1.69	1.87	2.28
Flood 6	1.65	2.02	2.21	2.29	2.40	2.63	2.72	2.79
Wetland W2	1.24	1.53	1.71	1.79	1.90	2.13	2.22	2.30
Flood 9	1.29	1.66	2.04	2.15	2.25	2.44	2.54	2.68
Flood 15 [1]	1.26	1.77	2.26	2.33	2.62	2.96	3.18	3.25
Flood 16-INT [2]	0.37	0.51	0.91	0.99	1.27	1.61	1.83	1.90

Notes:

1. Flood 15 is only applicable to Precinct 3 total scenario and not staging of Precinct 3A
2. Flood 16-INT water levels apply to Precinct 3A development scenario only and is not required for for the Precinct 3 total mitigation strategy

APPENDIX C – FLOOD ELEVATION MAPS

Pre-development, Precinct 3A Interim (mitigated) and Precinct 3 total (mitigated)



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

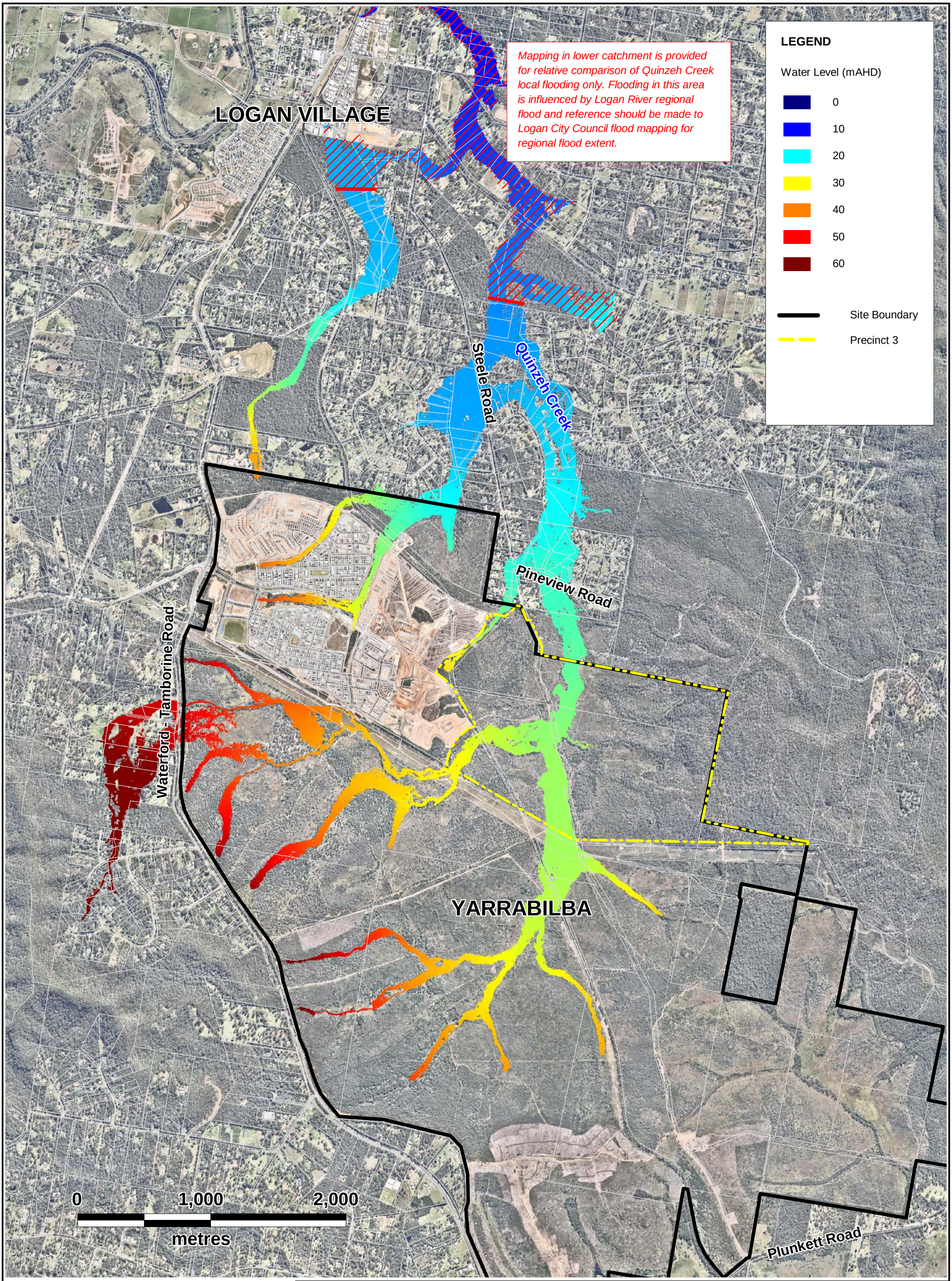
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

FIGURE C01

Pre-development 100 year ARI Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

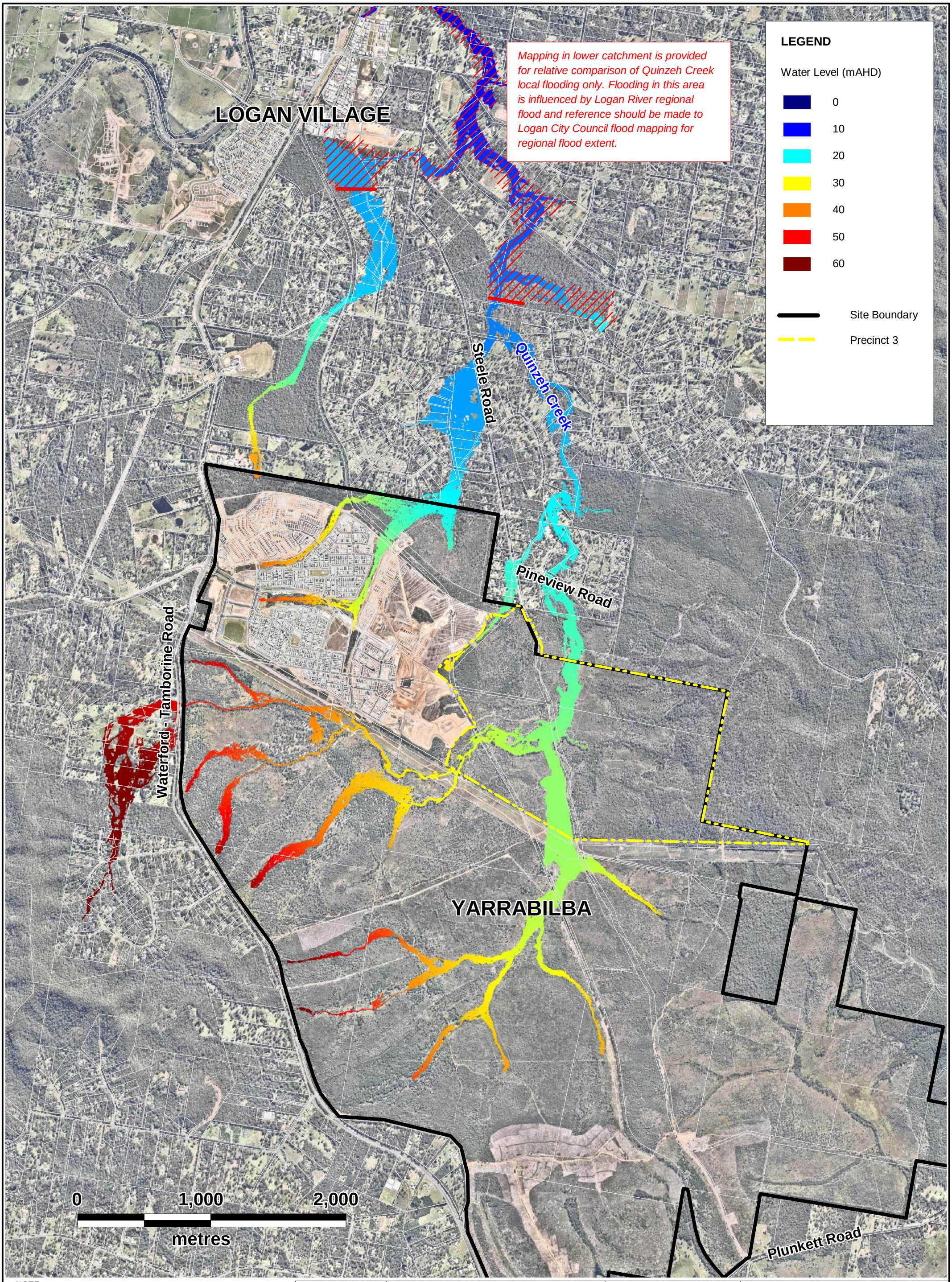
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

FIGURE C03

Pre-development 20 year ARI Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

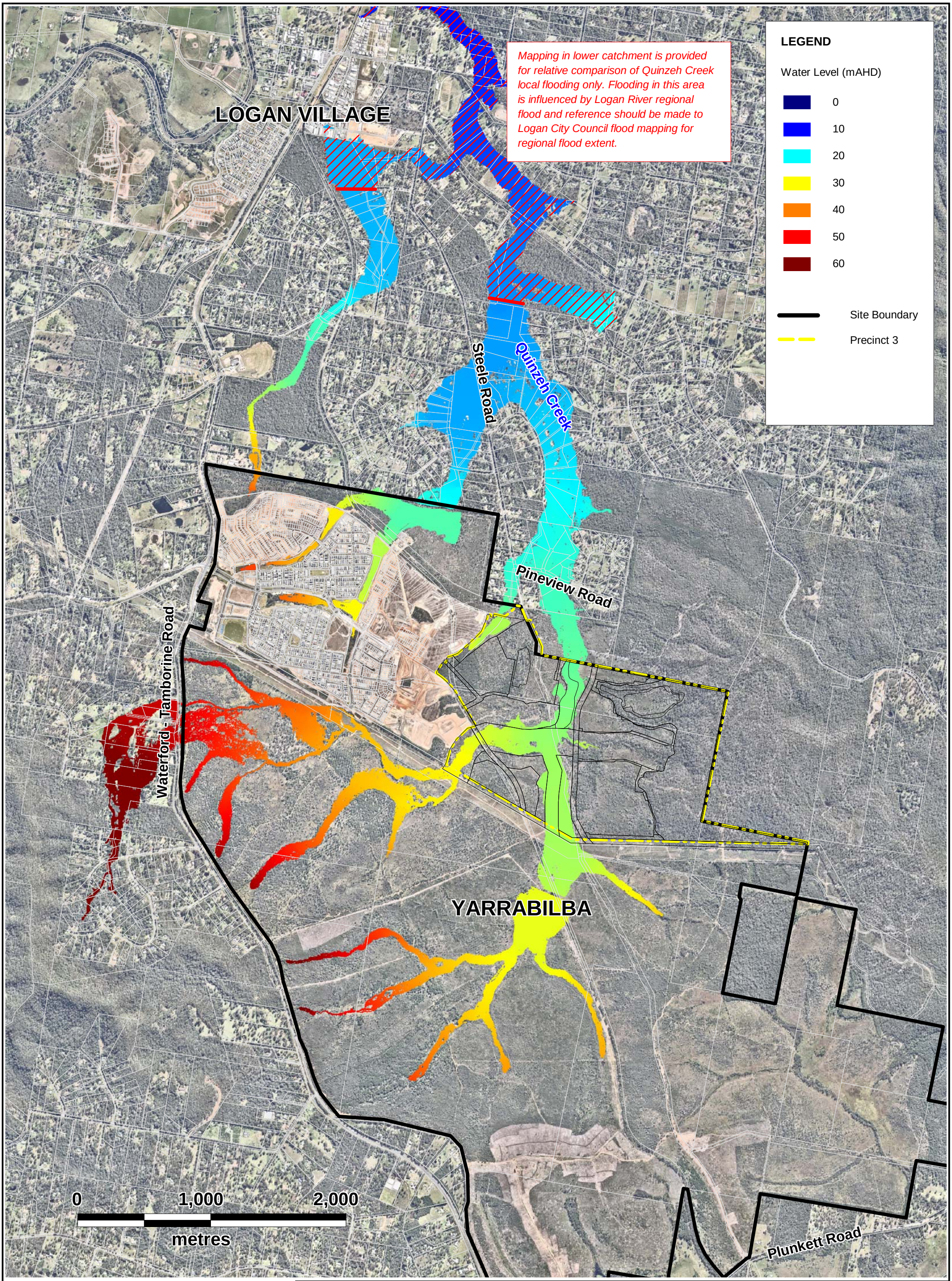
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

FIGURE C06

Pre-development
2 year ARI
Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

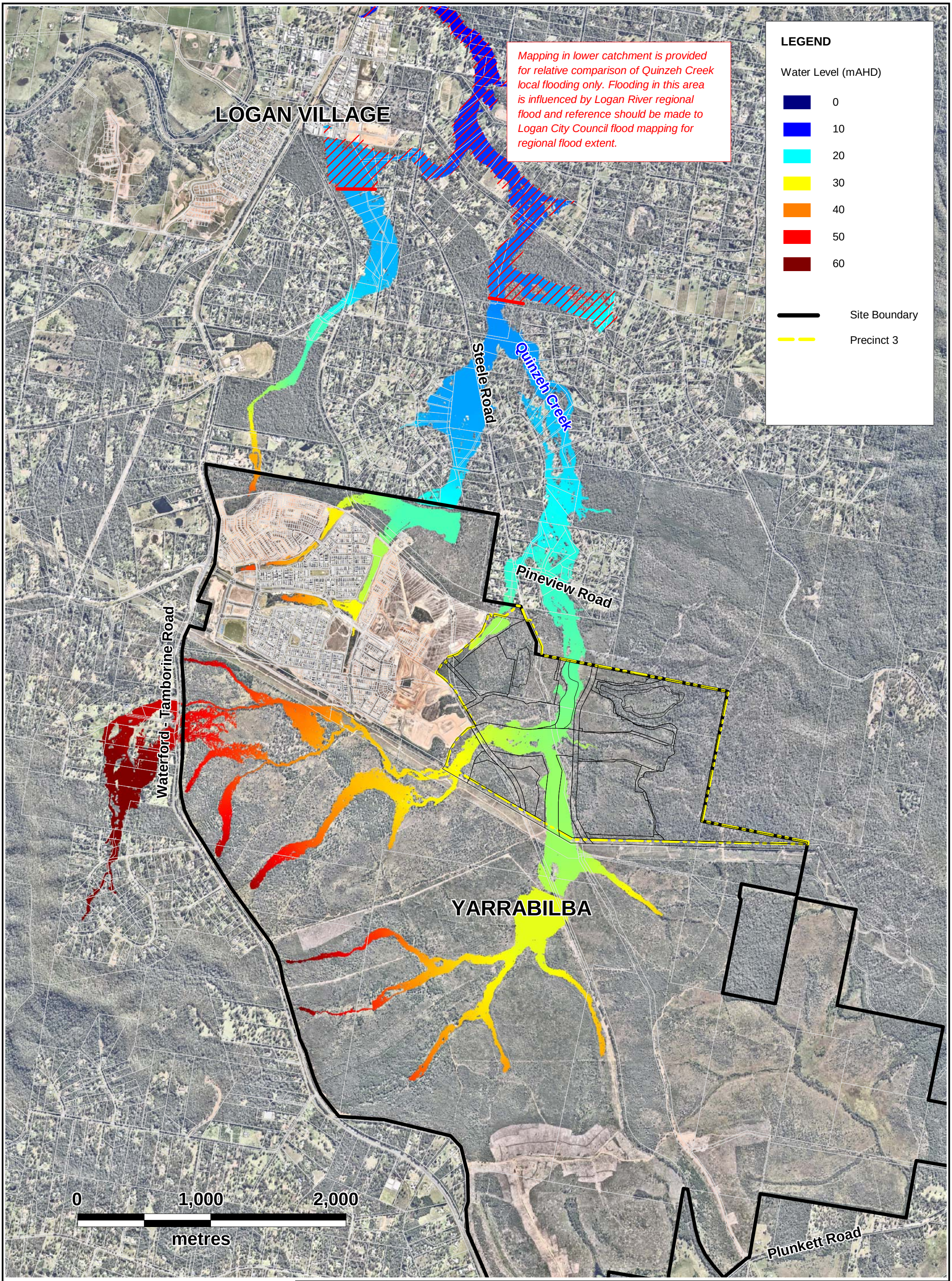
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

FIGURE C07

Precinct 3A Interim (Mitigated)
100 year ARI
Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

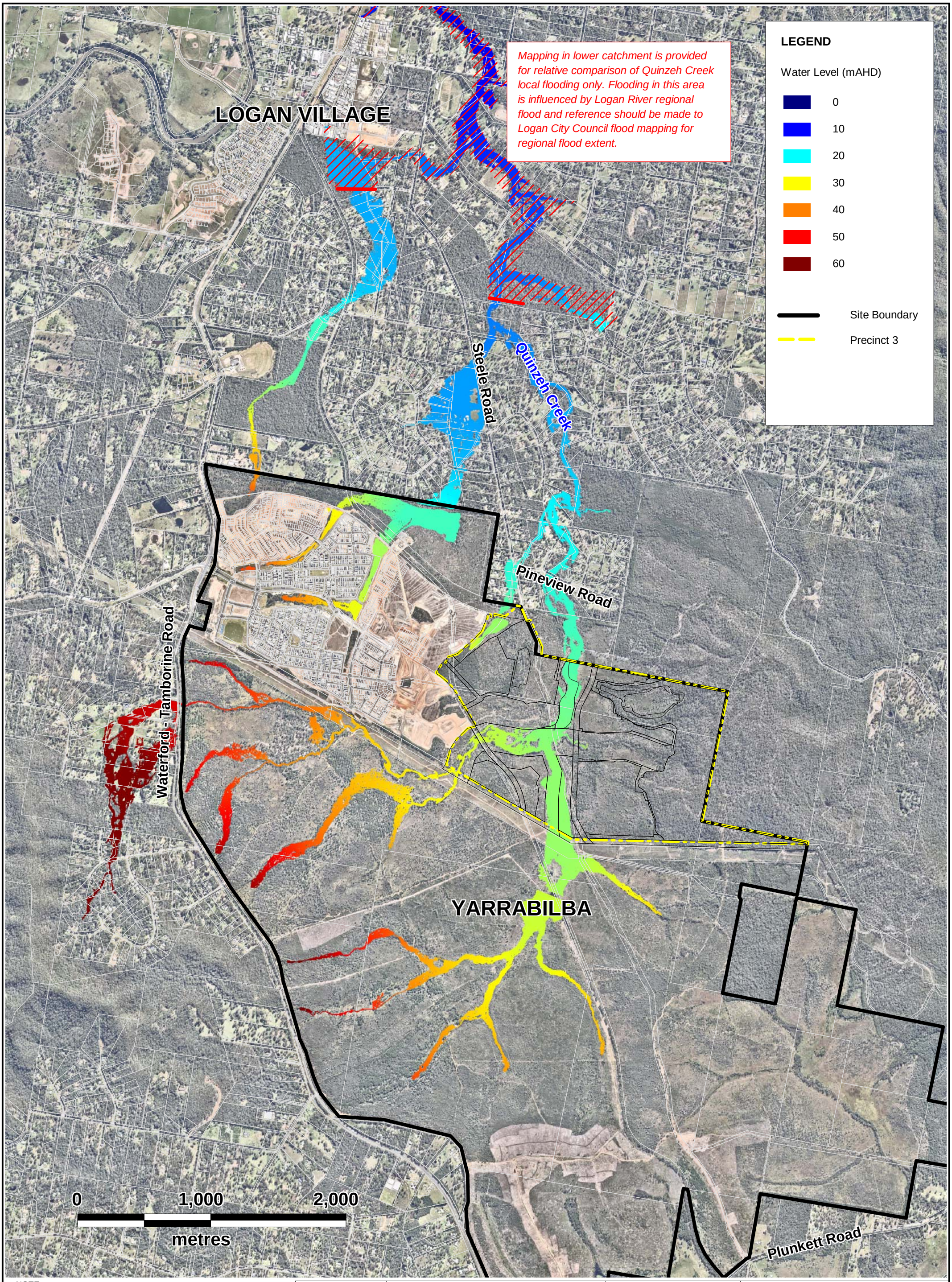
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

FIGURE C09

Precinct 3A Interim (Mitigated)
20 year ARI
Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

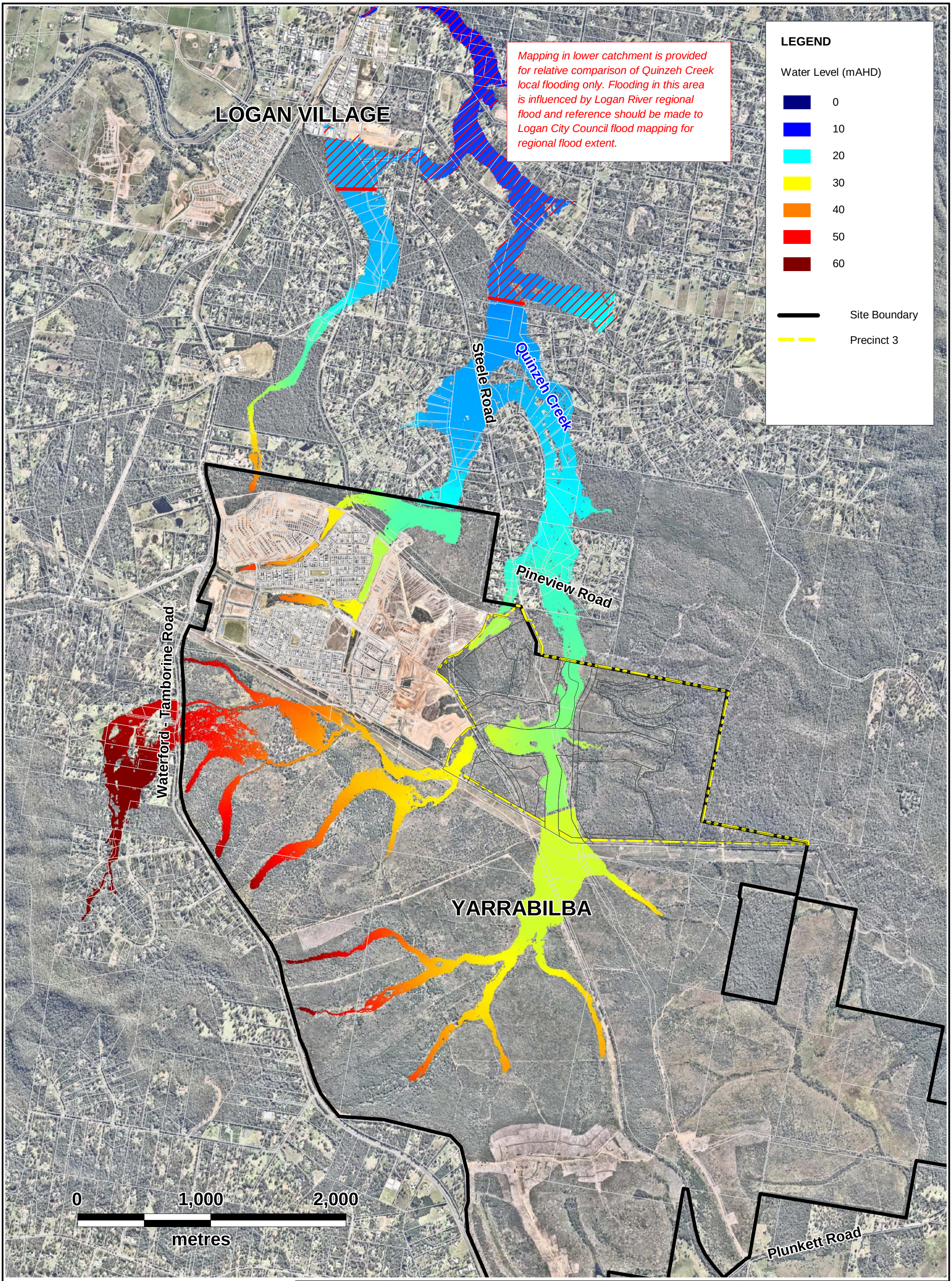
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 14 July 2016

FIGURE C12

Precinct 3A Interim (Mitigated)
2 year ARI
Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

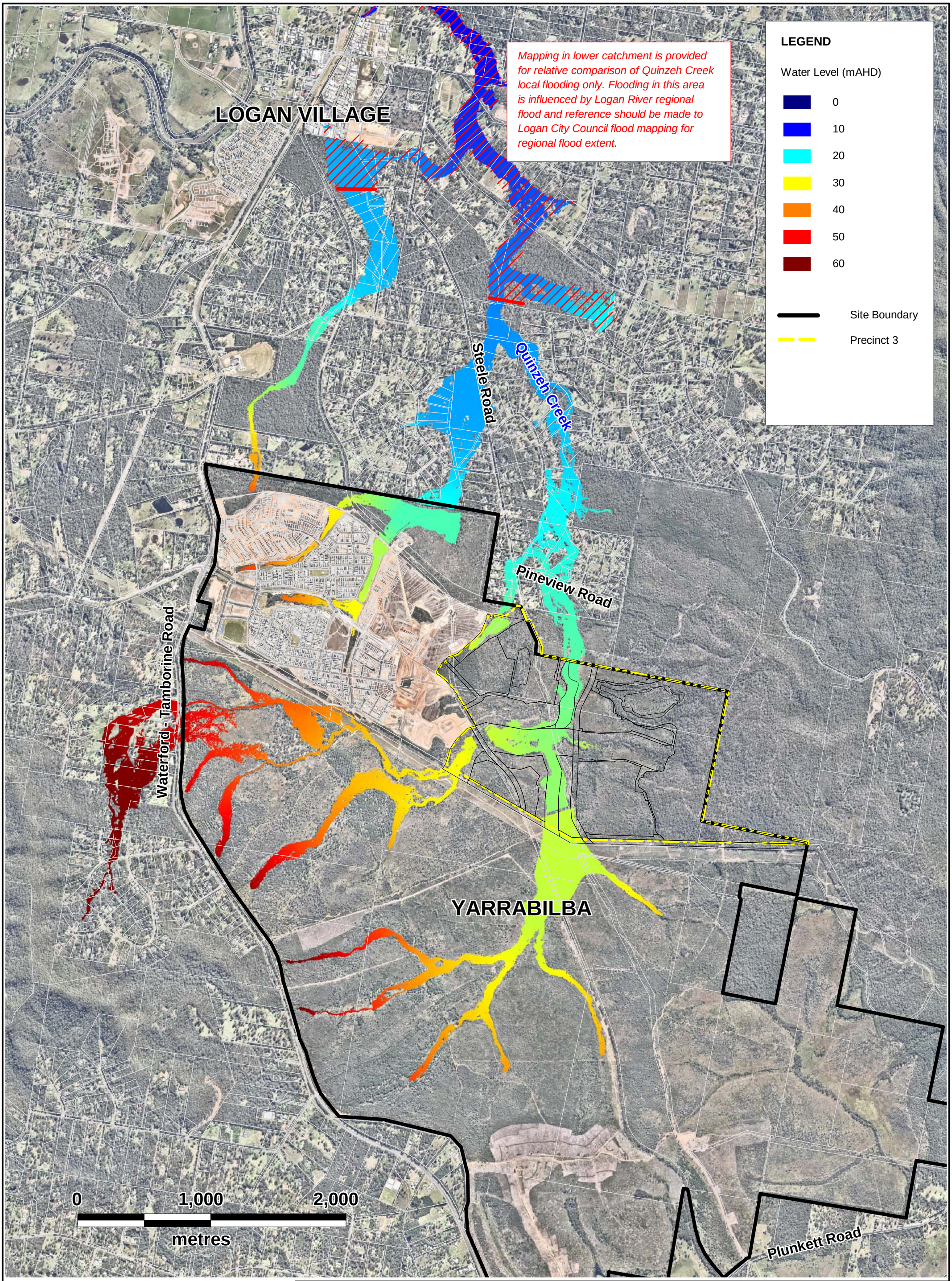
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 14 June 2016

FIGURE C13

Precinct 3 Total (Mitigated)
100 year ARI
Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

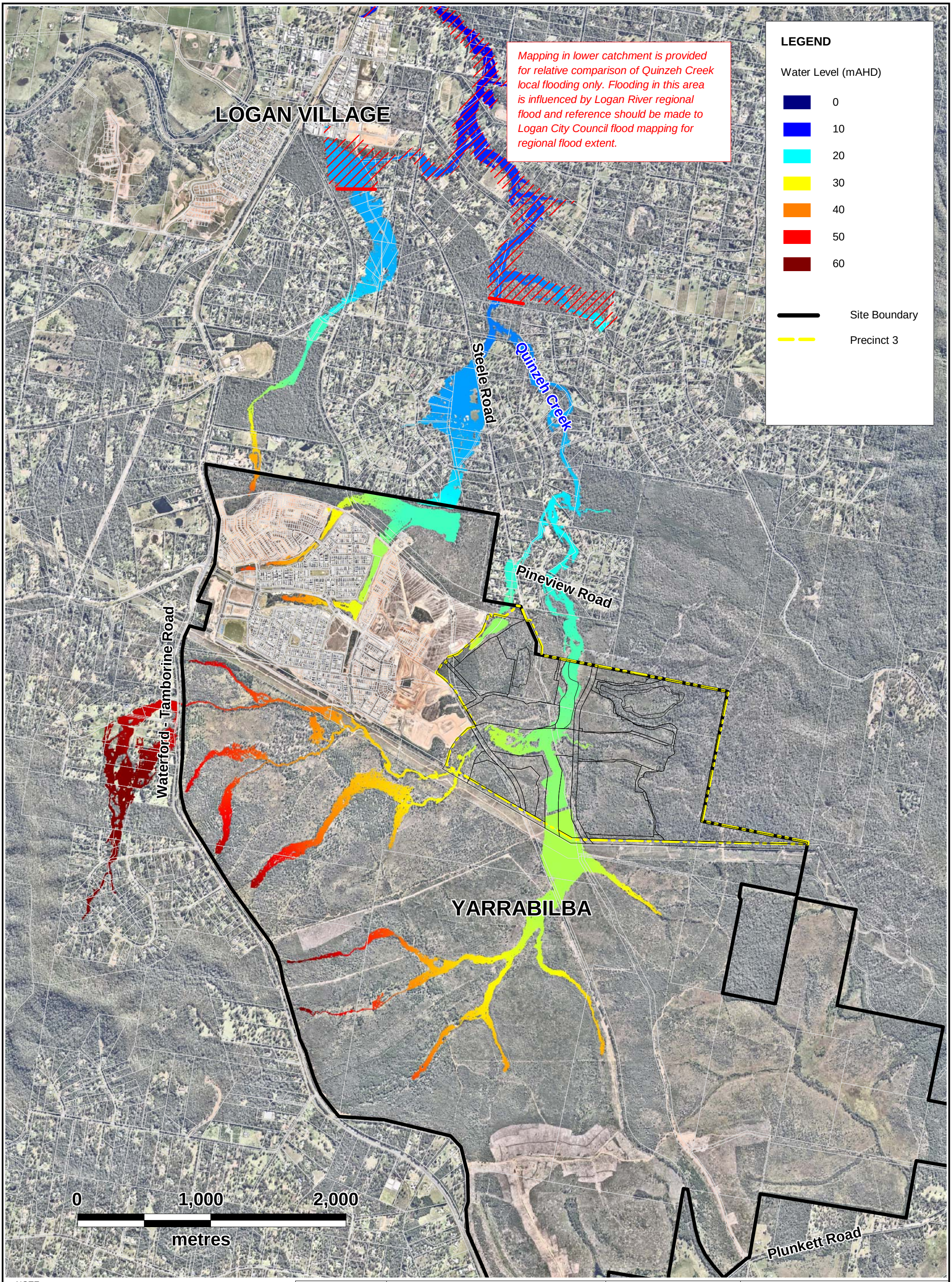
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 14 June 2016

FIGURE C15

Precinct 3 Total (Mitigated)
20 year ARI
Flood Elevation



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

Scale: 1 : 25,000 (A3)

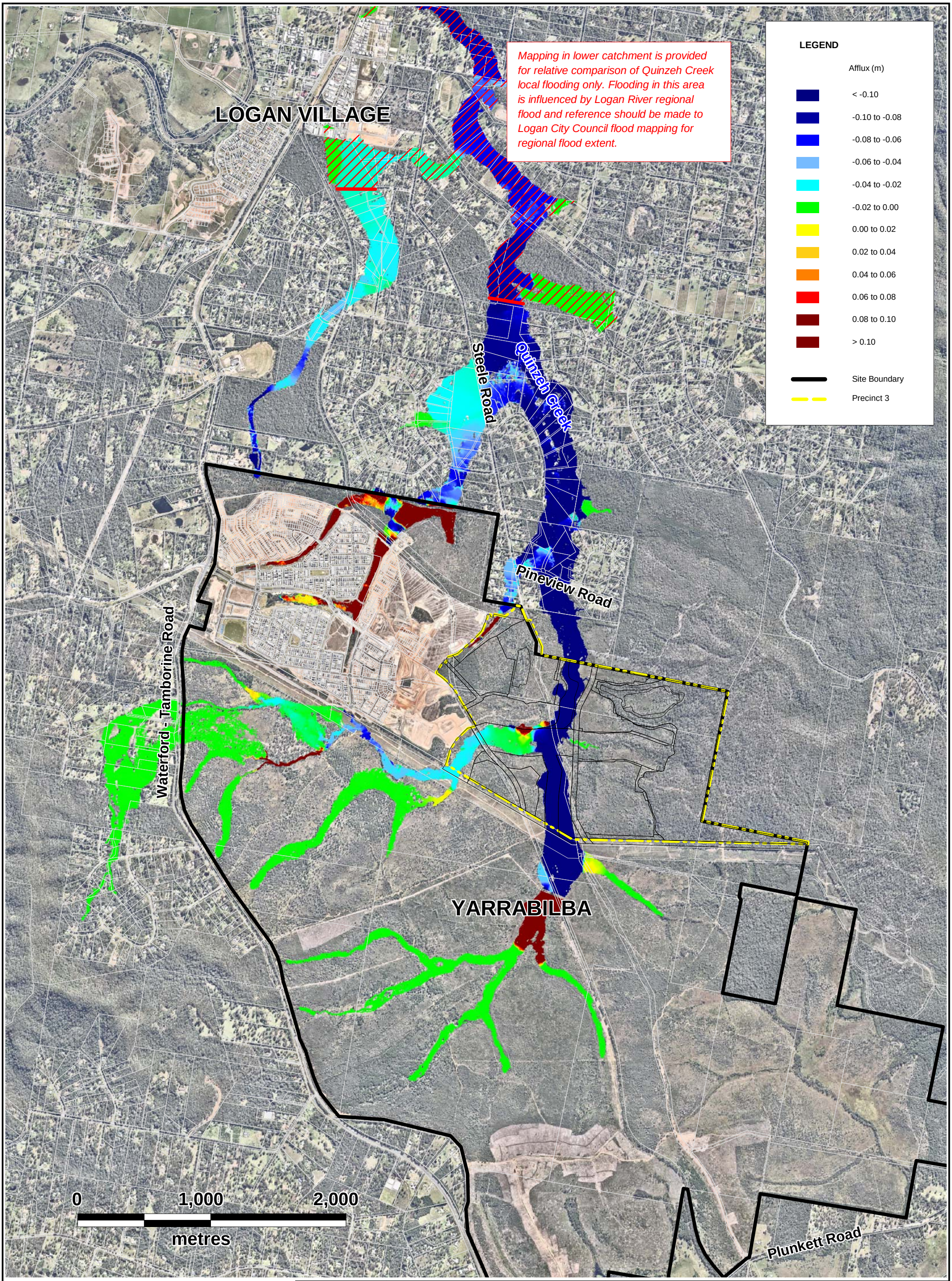
Date: 14 June 2016

FIGURE C18

Precinct 3 Total (Mitigated)
2 year ARI
Flood Elevation

APPENDIX D – FLOOD AFFLUX MAPS

Precinct 3A Interim (mitigated) and Precinct 3 total (mitigated)



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 14 June 2016

FIGURE D01

Precinct 3A Interim (Mitigated)
100 year ARI
Flood Afflux

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Flooding in this area is influenced by Logan River regional flood and reference should be made to Logan City Council flood mapping for regional flood extent.

LOGAN VILLAGE

YARRABILBA

Steele Road

Quinzeh Creek

Pineview Road

Waterford - Tamborine Road

Plunkett Road

LEGEND

Afflux (m)

- < -0.10
- -0.10 to -0.08
- -0.08 to -0.06
- -0.06 to -0.04
- -0.04 to -0.02
- -0.02 to 0.00
- 0.00 to 0.02
- 0.02 to 0.04
- 0.04 to 0.06
- 0.06 to 0.08
- 0.08 to 0.10
- > 0.10
- Site Boundary
- Precinct 3

0 1,000 2,000

metres

NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

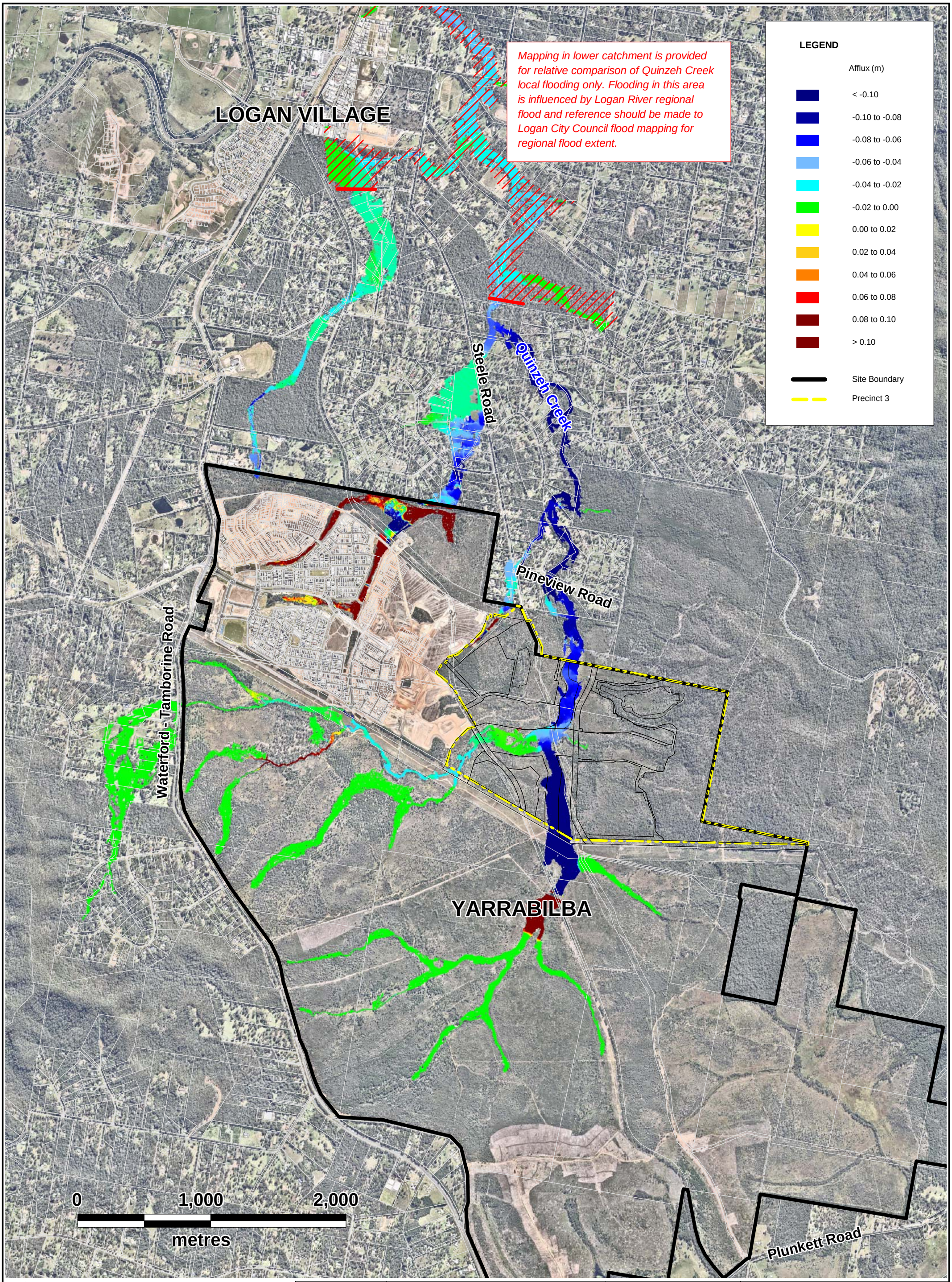
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 14 June 2016

FIGURE D3

Precinct 3A Interim (Mitigated)
20 year ARI
Flood Afflux



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

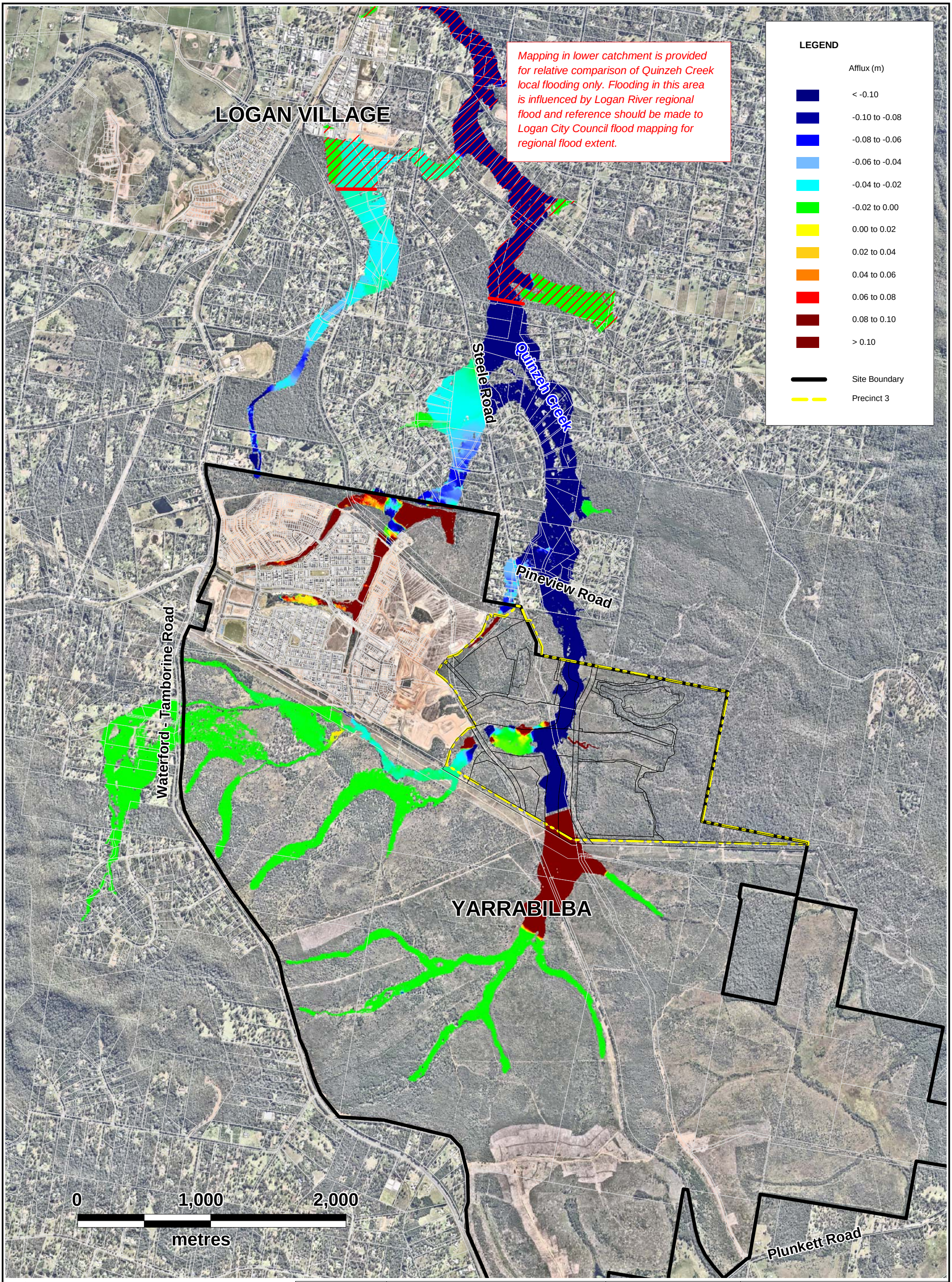
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 14 June 2016

FIGURE D6

Precinct 3A Interim (Mitigated)
2 year ARI
Flood Afflux



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

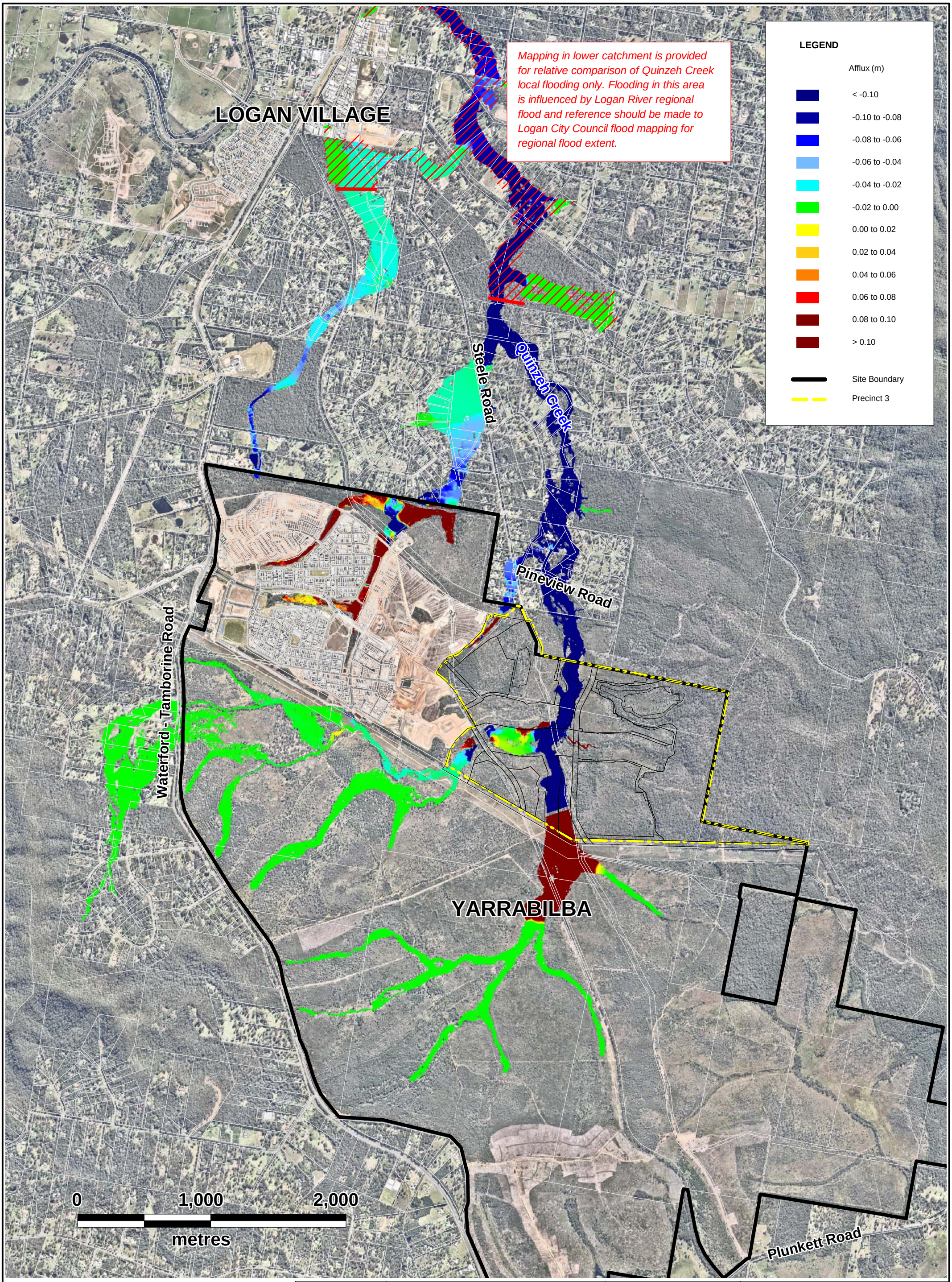
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11July 2016

FIGURE D07

Precinct 3 Total (Mitigated)
100 year ARI
Flood Afflux



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

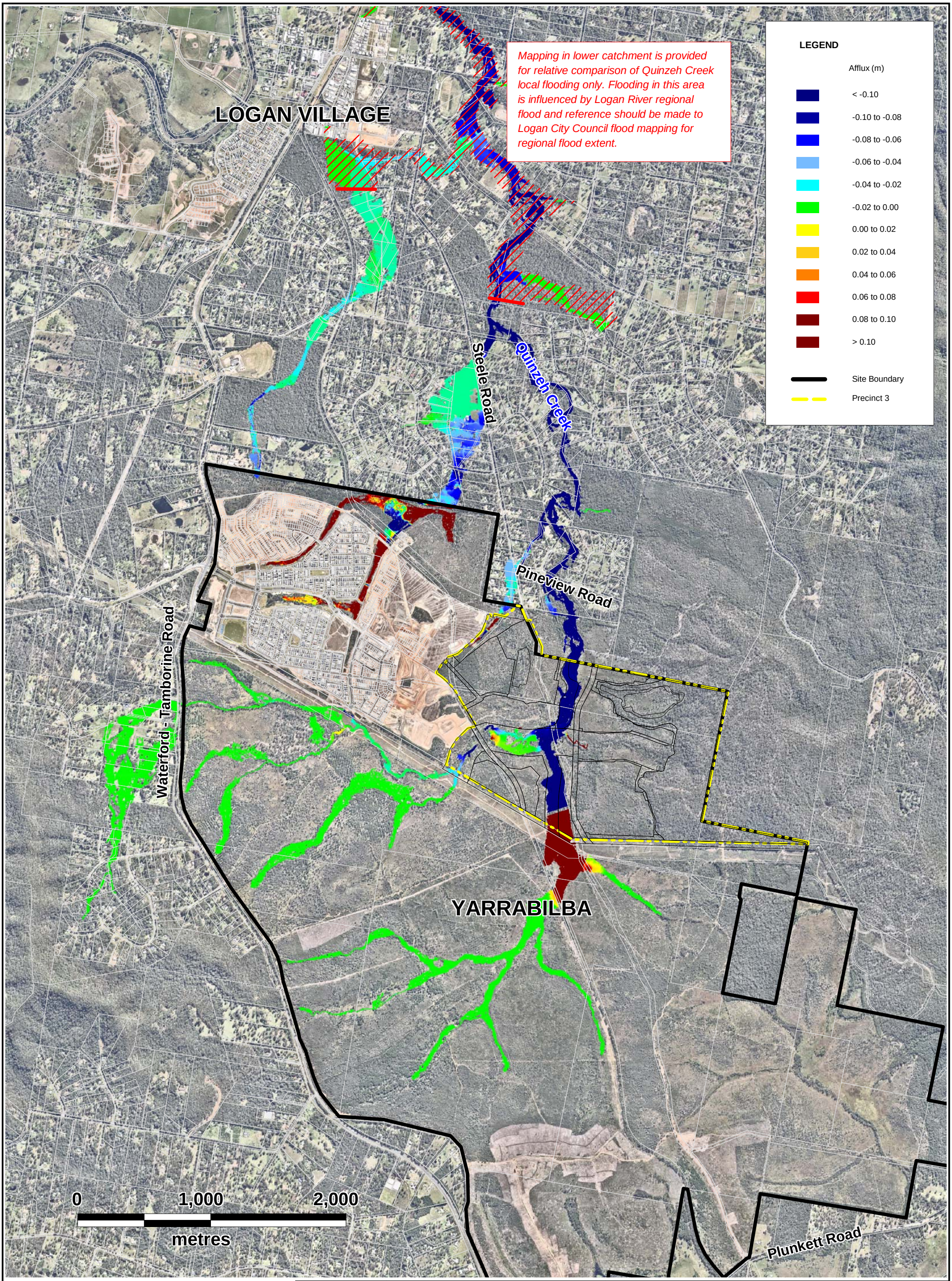
Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

FIGURE D09

Precinct 3 Total (Mitigated)
20 year ARI
Flood Afflux



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

Scale: 1 : 25,000 (A3)

Date: 11 July 2016

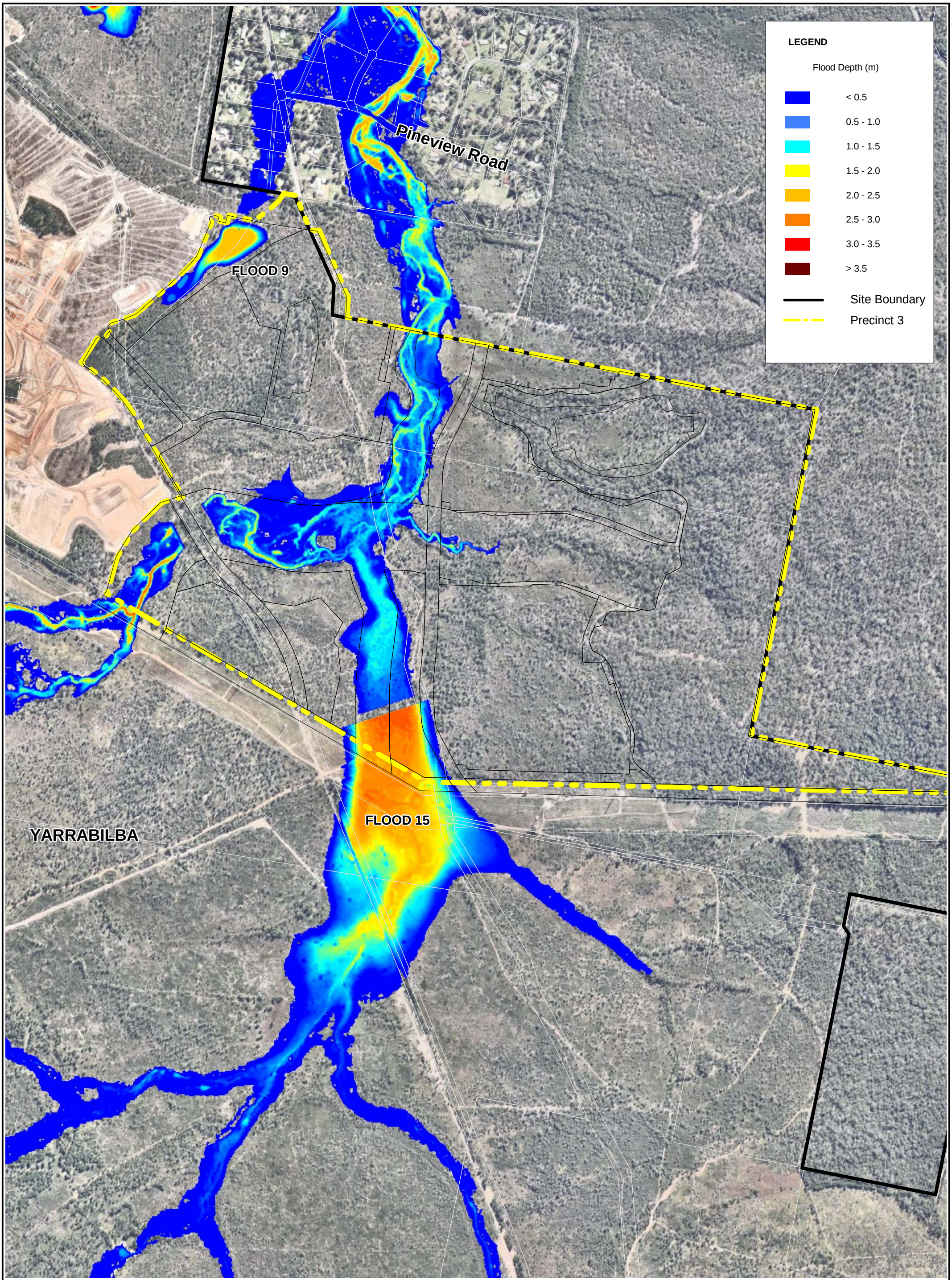
FIGURE D12

Precinct 3 Total (Mitigated)
2 year ARI
Flood Afflux

APPENDIX E – FLOOD DEPTH MAPS

Precinct 3 total mitigated only

(Precinct 3A has the same depths within Flood 9, while Interim Flood 16-INT does not lie within or adjacent to any urban areas and therefore not mapped).



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

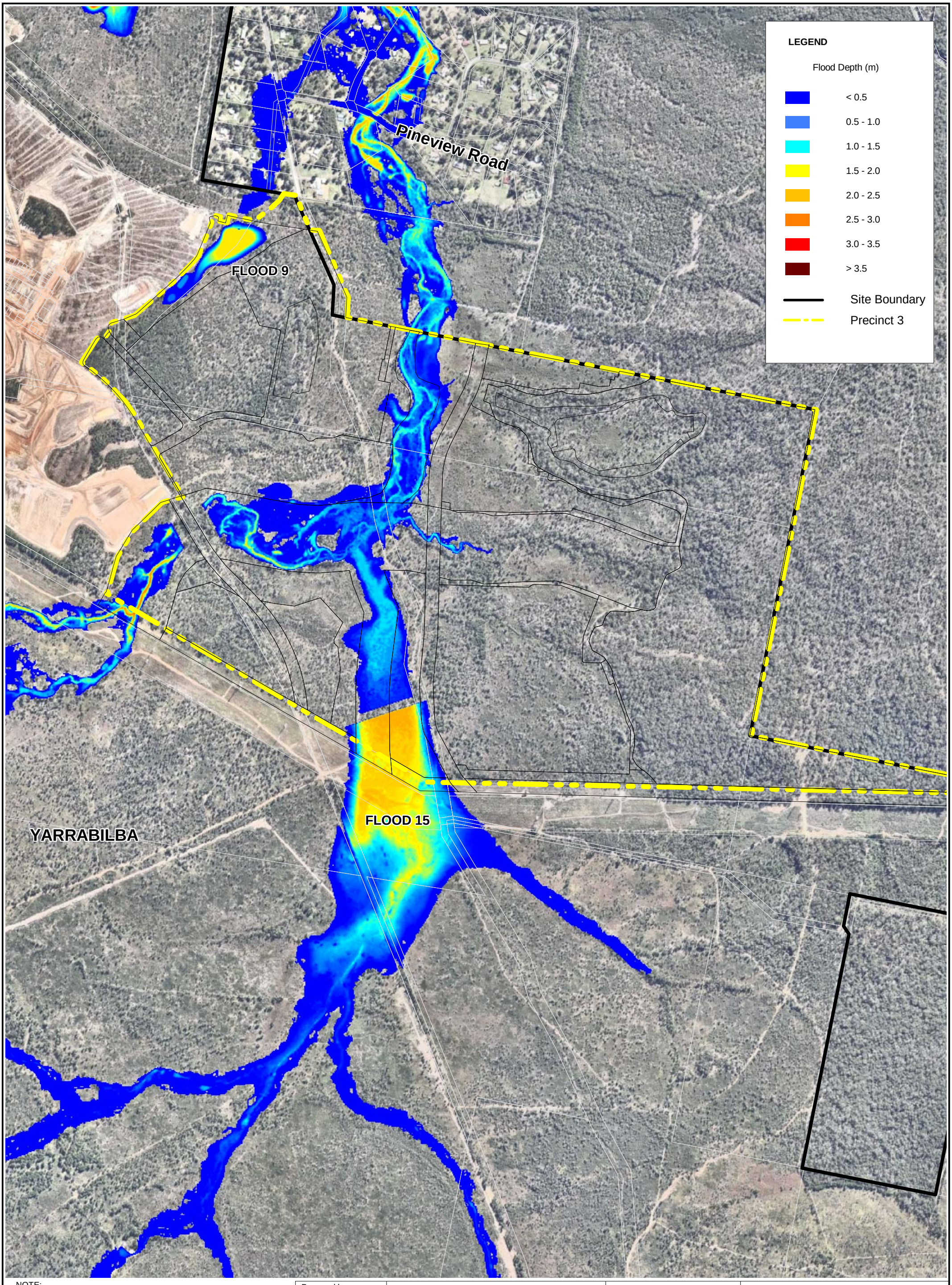
Client: Lend Lease

Scale: 1 : 10,000 (A3)

Date: 11 July 2016

FIGURE E01

Precinct 3 Total (Mitigated)
100 year ARI
Flood Depth



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

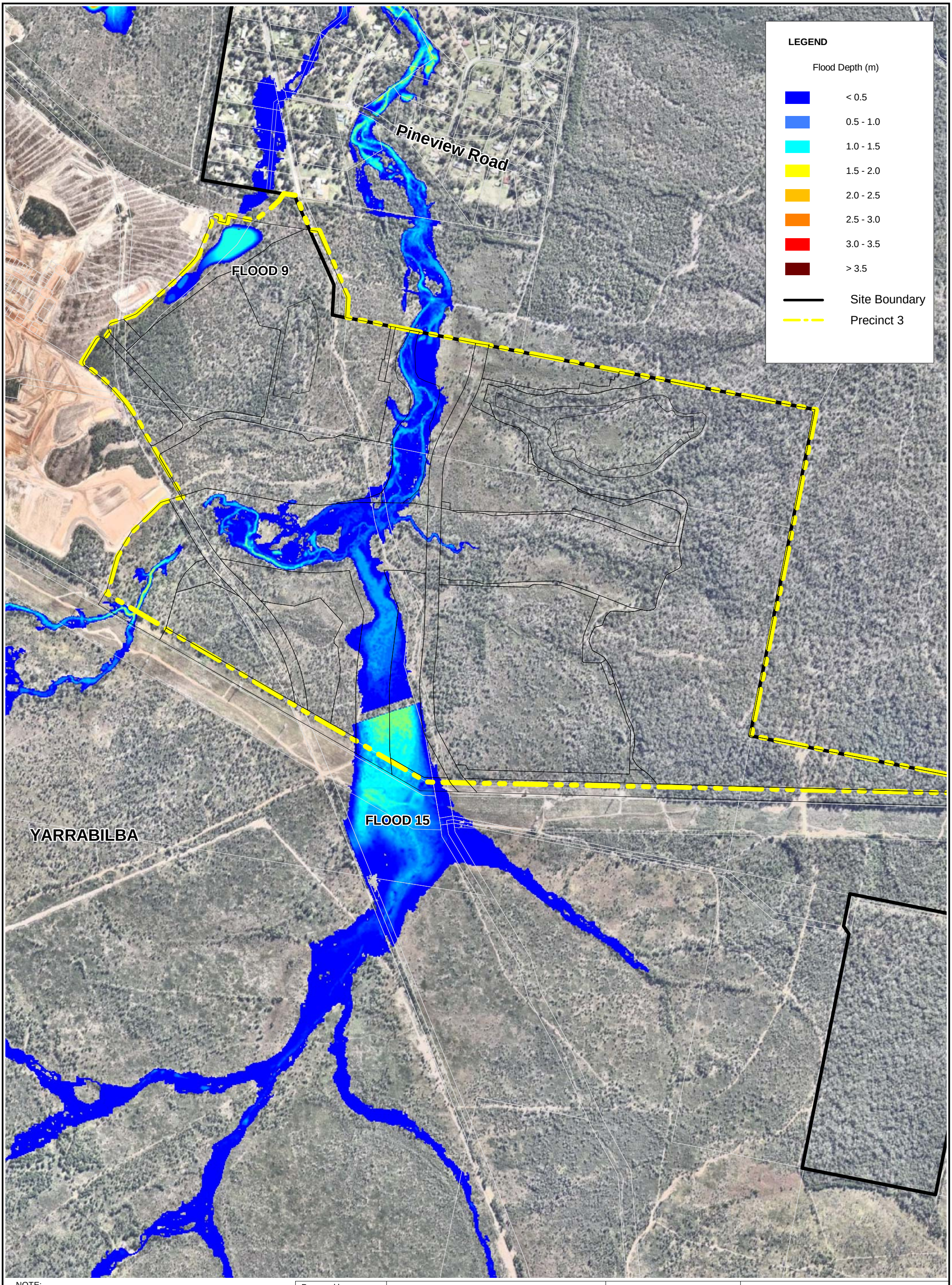
Client: Lend Lease

Scale: 1 : 10,000 (A3)

Date: 11 July 2016

FIGURE E03

Precinct 3 Total (Mitigated)
20 year ARI
Flood Depth



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

N W E S

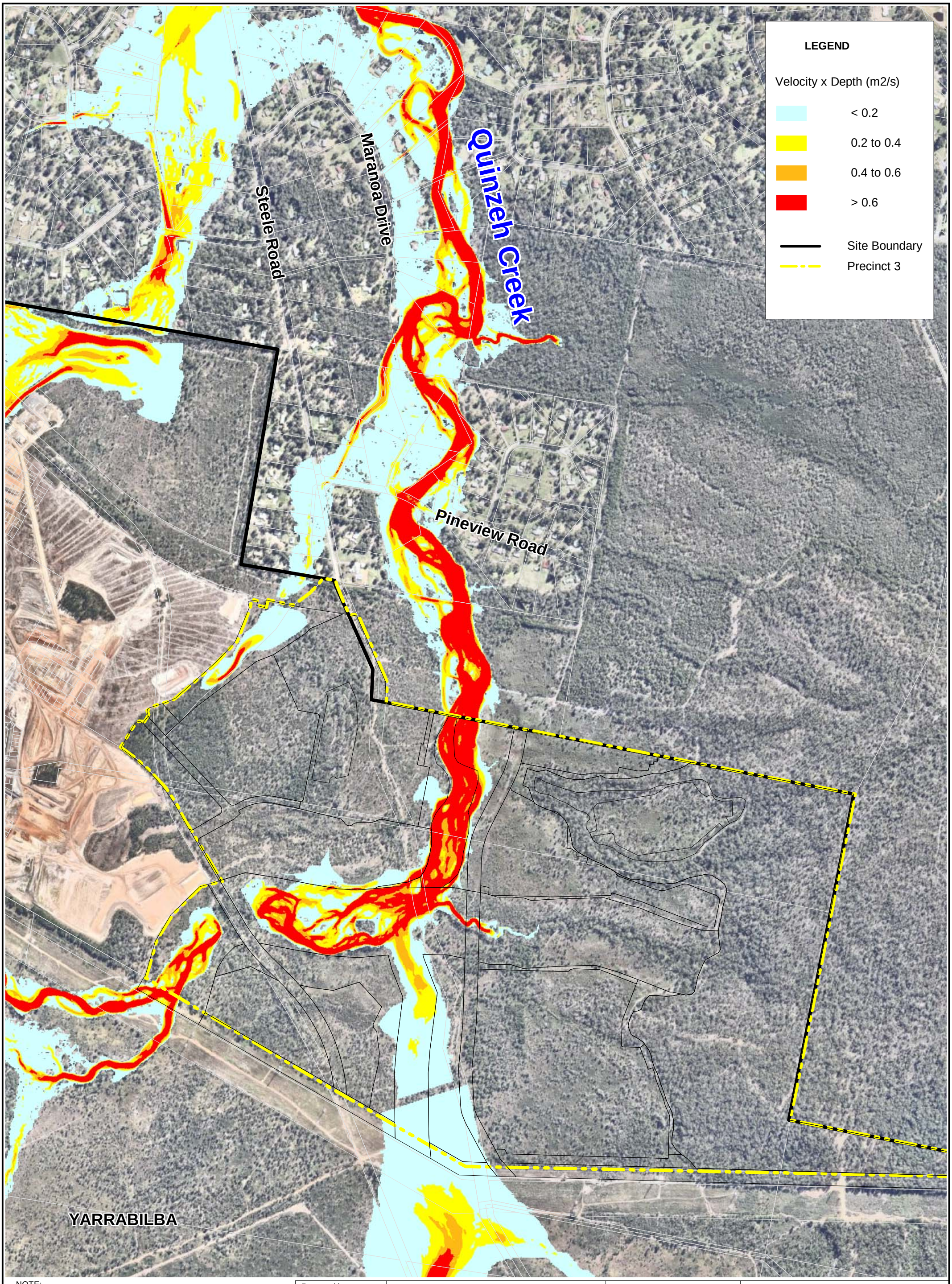
Scale: 1 : 10,000 (A3)

Date: 11 July 2016

FIGURE E06

Precinct 3 Total (Mitigated)
2 year ARI
Flood Depth

APPENDIX F – FLOOD SAFETY MAPS



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

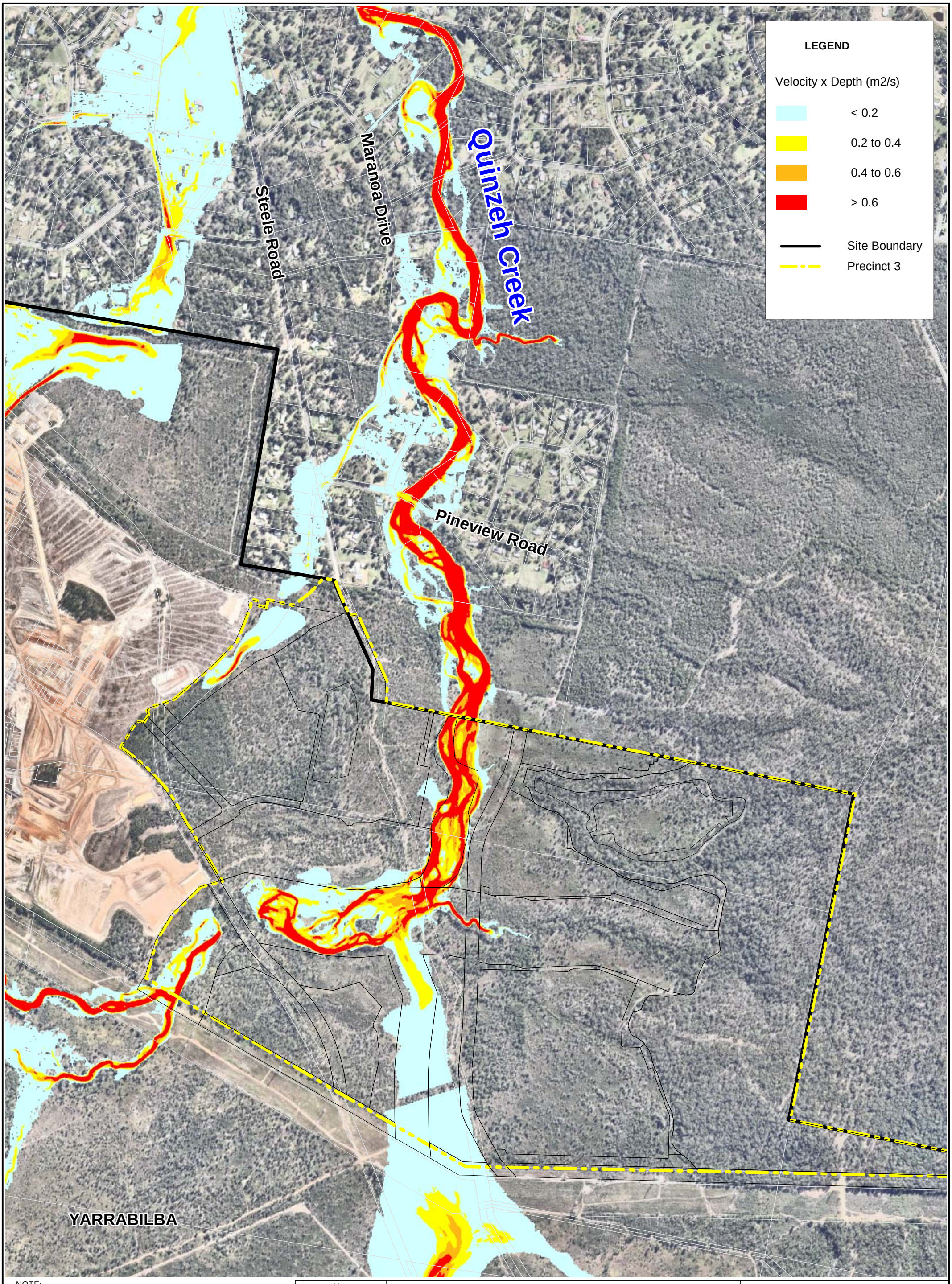
N W E S

Scale: 1 : 10,000 (A3)

Date: 11 July 2016

FIGURE F01

Precinct 3 Total (Mitigated)
100 year ARI
Velocity x Depth



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

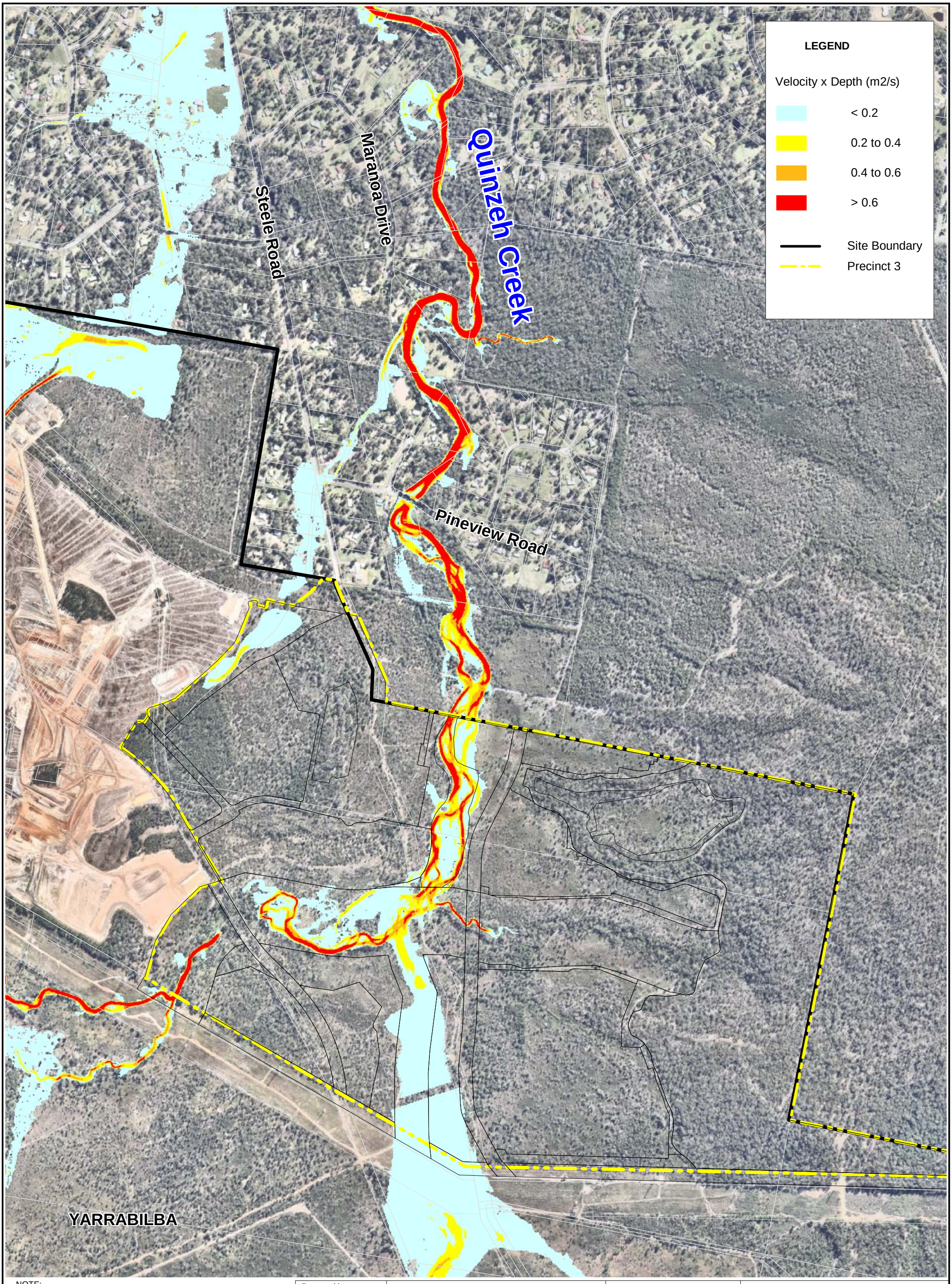
N W E S

Scale: 1 : 10,000 (A3)

Date: 11 July 2016

FIGURE F03

Precinct 3 Total (Mitigated)
20 year ARI
Velocity x Depth



NOTE:
These plans are not intended to be used for flood regulation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 3 Flood Study (Version 1) (DesignFlow, 2016).

Aerial Photograph: Nearmap (Image Date: 23 April 2015)

Prepared by: DesignFlow

For: lendlease

Project: 4284

Yarrabilba Precinct 3

Client: Lend Lease

Scale: 1 : 10,000 (A3)

Date: 11 July 2016

FIGURE F06

Precinct 3 Total (Mitigated)
2 year ARI
Velocity x Depth