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addendum to the north tralee local environmental study

urban planning
project management

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prepared for
Queanbeyan-Palerang Regional Council

prepared by

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executive summary

The North Tralee Local Environmental Study (December 2011) found that the land at North Tralee is generally suitable for employment, conservation, and open space uses subject to a number of recommendations. However, studies and reports to Council have identified that until the issue of Flood Prone Land can be resolved, rezoning of the entire Site, in accordance with the recommendations of the endorsed *Queanbeyan Residential and Economic Strategy 2031,* should not be supported.

This Report provides and addresses new information about Flood Prone Land at North Tralee. The Flood Planning Area (100 year ARI event plus 0.5m) at North Tralee has been confirmed by Council's consultant, WMAwater. This means that appropriate land use zones can now be delineated. The requirements of s.117 Direction No.4.3 (Flood Prone Land) as well as other site and strategic planning considerations has resulted in the following land use zones being recommended:

- the southern side of the Jerrabomberra Creek riparian corridor located within the Site to be zoned E2 – Environmental Conservation;
- the areas of the Site which are lower than the 100 year ARI event +0.5m freeboard to be zoned RU2 – Rural Landscape;
- areas of the Site which are higher than the 100 year ARI event +0.5m freeboard can be rezoned for Business and Industrial uses.

This Supplementary Report to the North Tralee Local Environmental Study should be read in conjunction with the December 2011 *North Tralee Local Environmental Study* and the August 2015 *Supplementary Report to the North Tralee Local Environmental Study,* prepared by Willana Associates.

1 introduction

1.1 The Client

This Supplementary Report to the North Tralee Local Environmental Study has been prepared for Queanbeyan-Palerang Regional Council.

1.2 Background

In December 2011, the North Tralee Local Environmental Study was reported to Queanbeyan Council. The Study found that the land at North Tralee is generally suitable for conservation, community and open uses but not for residential development. It also identified the need for further studies to be completed prior to finalisation of the boundaries of each land use zone within the North Tralee precinct. The Local Environmental Study found that demarcation of the employment and open space zones will largely be determined by:

- the need to protect the amenity of residents in the existing residential areas of Jerrabomberra to the east of the Site; and
- the extent of the flood zone.

In March 2014 Council resolved (Minute No. 054/14) to:

- progress a *Draft Local Environmental Plan (North Tralee);*
- defer consideration of the flood prone land located within the 1 in 100 ARI flood area; and
- seek a review by Council's consultants, of the proposed open space buffer in the eastern portion of the Site, to determine its final width. The main issue to be addressed was acoustic impact on residential areas to the east.

In May 2014, the Department of Planning issued a Gateway Determination for the public exhibition of a Planning Proposal for North Tralee. The Planning Proposal was for the rezoning of the Site from 1(a) (Rural A Zone) under the *Queanbeyan Local Environmental Plan 1998* to Employment Lands and associated uses.

In September 2015, Council considered a Supplementary Report to the North Tralee Local Environmental Study, prepared by Willana Associates. That report:

- provided information, analysis and land use recommendations as a result of acoustic assessment of potential industrial land uses and proposed bridge works at South Jerrabomberra;
- considered the findings of remodelling and assessment of an acoustic buffer zone proposed for the eastern portion of the Site;

- made recommendations in relation to the Heritage item (H3) Stone Façade Building; location and nature of buildings, planting and landscaped acoustic mounds;
- recommended that the areas of the Site which are subject to flooding be deferred from the zoning maps pending additional investigation; and
- informed the preparation of the draft Local Environmental Plan for the Site.

In October 2015, Council exhibited a Planning Proposal for the Site. The NSW Department of Environment and Heritage advised Council, as part of the government agency consultation process, that the flood data and extent of the flood affected land on the Site required review.

In November 2015, Queanbeyan Council engaged WMAwater to review the flooding components of earlier studies for North Tralee:

- Brown Consulting (2010) *Flood Study and Riparian Corridor Assessment Jerrabomberra Creek*
- URS Australia (2003) *Tralee LES Jerrabomberra Creek Flood Study*
- Northrop Consulting (2010) *North Tralee LES 2011 (Appendix B)*

The Brown Study (2010) is the only one of various flood studies which covers the entire North Tralee site as well as The Poplars. It was commissioned as part of the investigations during the preparation of the South Jerrabomberra Masterplan. The Brown Study includes flood maps for the 100 and 500 year ARI events and the Probable Maximum Flood (PMF). It also investigated options for on-site earthworks (cut and fill) to maximise developable land area. Bulk earthworks were subsequently not supported by Council or relevant Government agencies and, as such, the 2016 WMAwater review of the Brown Study is limited to only those parts of the Study which provide information in respect of the existing flooding behaviour.

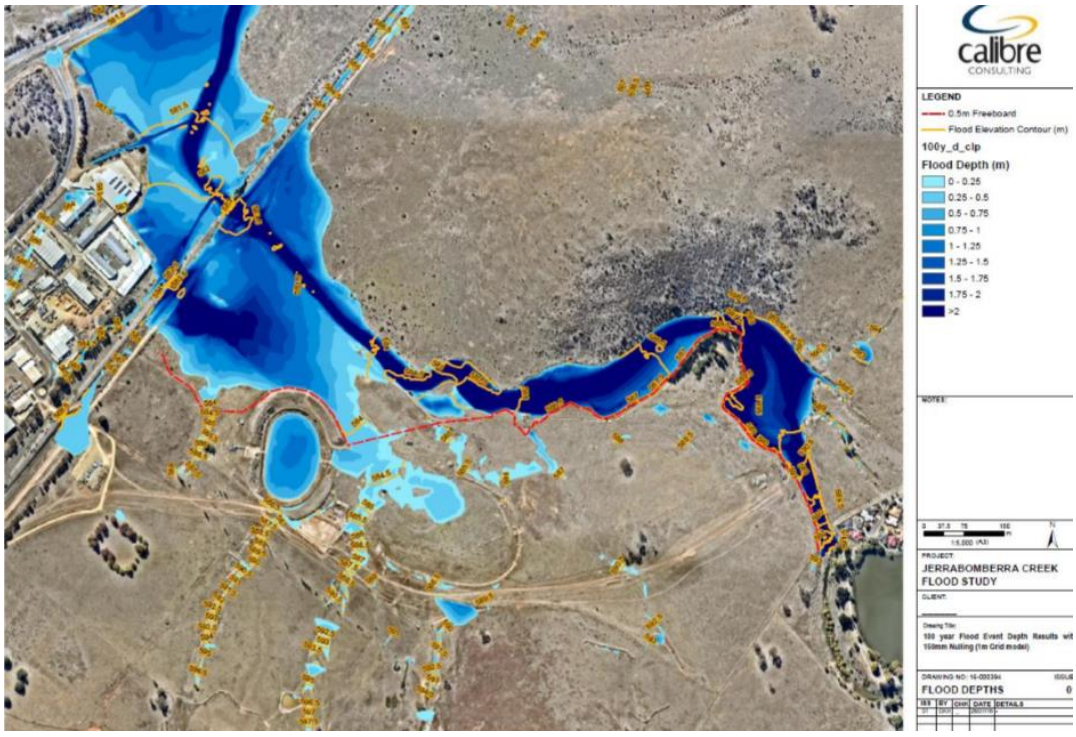
The aim of the WMAwater review was to determine the suitability of the Brown Study (2010) as the basis for determining the Flood Planning Level (FPL) for the Site. It is important that the Flood Planning Level is accurately determined as development is to be located only on land that is above the Flood Planning Level. The FPL is defined in Clause 7.2(5) of the *Queanbeyan Local Environmental Plan 2012* as the *'level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard'*.

The WMAwater review identified a need for the hydraulic model, which had informed the Brown Study, to be reviewed and additional survey work to be undertaken and incorporated into the hydraulic modelling of the Site.

Council advised the Proponent of the North Tralee rezoning, Village Building Co, of the outcomes of the WMAwater review. The Proponent then engaged Calibre Consulting to undertake the additional work recommended by the WMAwater review. In July 2016, Calibre Consulting completed the updates and provided their findings to Council.

In September 2016, WMAwater completed a peer review, on behalf of Council, of Calibre Consulting's work and provided Council with advice about the suitability of incorporating the Flood Planning Area as identified in the Calibre Study, into the draft Local Environmental Plan for North Tralee. WMAwater confirmed (refer Page 5, Appendix C) that the Flood Planning Area, as identified in the 2016 Calibre Study, is suitable for rezoning assessment purposes when used in conjunction with a 0.5m freeboard. Further, that the assumptions and modelling methods applied by Calibre were generally conservative.

Figure 1 Calibre Study (2016) FPA – 100 year ARI Event plus 0.5



In October 2016, Council considered a report in relation to the exhibition of a Planning Proposal to rezone land at North Tralee. The report included a draft land use map for the Site. Council resolved to place the Planning Proposal Report and supporting document, to rezone the land at North Tralee, on public exhibition for a period of 28 days.

1.3 Purpose of the Supplementary Report to the North Tralee Local Environmental Study

The purpose of this Supplementary Report to the North Tralee Local Environmental Study is to:

- Provide Queanbeyan-Palerang Regional Council with supplementary information about flooding as part of the North Tralee Local Environmental Study.
- Make recommendations in relation to land use at North Tralee as a result of confirmation of the Flood Planning Area (100 year ARI plus 0.5m freeboard)
- Inform the preparation of a Draft Local Environmental Plan for the Site by making recommendations about appropriate zonings and local provisions.

1.4 New Information

The following documents have been reviewed and provide updated information which has informed this Supplementary Report to the North Tralee Local Environmental Study:

- WMAwater (2016) *Review of North Tralee Flood Studies*
- Calibre Consulting (2016) Correspondence to Village Building Co. - *2016 North Tralee Flood Study Review*
- WMAwater (2016) Correspondence re – Calibre Consulting – *2016 North Tralee Flood Study Review*

The documents are available as Appendices to this Report.

1.5 This Report

Section 1 - This introduction

Section 2 - A description of the Study Area

Section 3 - A description of the strategic planning context

Section 4 – A description of the statutory framework

Section 5 – A summary of hydrological and flooding considerations

Section 6 – Land Use Strategy

Section 7 – Conclusions and recommendations

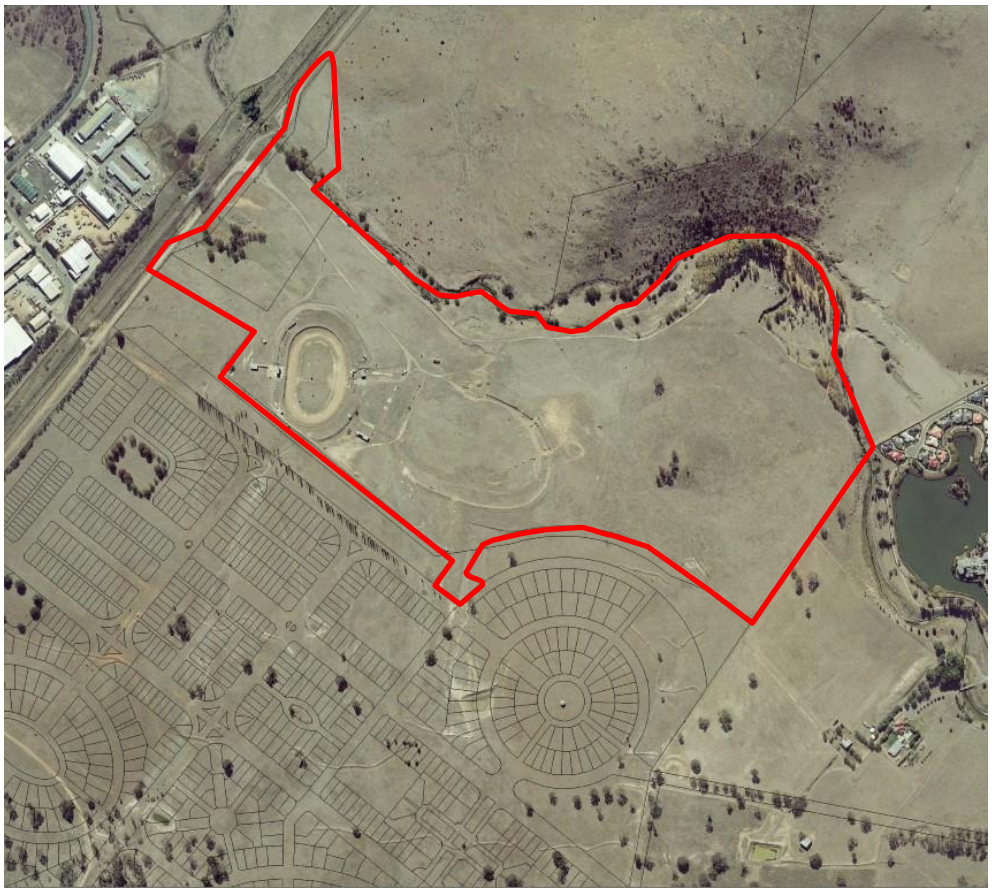
2 study area

2.1 Study area

The Queanbeyan-Palerang Local Government Area (LGA) is located in southern New South Wales approximately 180km south west from Sydney. It is adjoined by the Australian Capital Territory (ACT) to the north, west and south west.

The Site is situated south west of Queanbeyan, adjacent to the ACT/NSW border, south of the proposed 'Poplars' release area and west of the existing Jerrabomberra residential development (**Figure 2**). North Tralee covers 55.64ha and is the site of the old Fraser Park Speedway.

Figure 2 – North Tralee (the Site)



Source: Six Maps 2016

Subject site: North Tralee

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North Tralee is located within the Jerrabomberra Creek catchment immediately upstream of the NSW/ACT border. The Jerrabomberra Creek catchment, upstream of North Tralee, is approximately 82 square km of predominantly rural and natural land uses.

2.2 General description of the Site

Jerrabomberra Creek runs through the Site, forming the boundary to the north east. The Goulburn-Bombala railway line (which is no longer in operation), which forms the ACT/ NSW border, runs along the western boundary and the rural property known as Environa is situated along the southern boundary. To the west is the Hume Industrial Estate which is within the ACT. The Hume Industrial Estate is accessible from Queanbeyan via Tompsitt Drive and Tharwa Road. Urban residential development, within the suburb of Jerrabomberra, is to the east of the Site and represents the existing limits of urban development in the south west of Queanbeyan.

Photograph 1: North Tralee viewed from Territory Parade

2.3 Land ownership and zoning

North Tralee is legally described as:

- Lot 1 DP 313299
- Lot 6 DP 239080
- Lot 3 DP 239080
- Lot 1 DP 323002
- Lot 1 DP 333443

The Site is principally owned by the Village Building Company Pty Ltd (VBC) and two members of the Morrison family.

The Site is currently zoned 1(a) (Rural A Zone) under *Queanbeyan Local Environmental Plan 1998.*

3 strategic planning context

The strategic planning framework for the Site, as outlined in Chapter 3 of the North Tralee LES (December 2011), remains relevant. A summary of new or updated strategic planning documents is provided below.

3.1 Regional Growth Plans

In June 2014, the NSW Government released new draft regional boundaries for NSW. Once the boundaries are finalised for each region, they will provide the basis for a new generation of strategic plans called Regional Growth Plans. Queanbeyan LGA falls within the South East and Tablelands regional area.

The new Regional Growth Plan will guide future planning and investment decisions covering housing; economic development and jobs; open space and the transport to connect our homes; jobs, education and recreation facilities. The Draft South East and Tablelands Regional Plan was on exhibition until 23 August 2016.

Until the Regional Growth Plan is prepared, the *Sydney-Canberra Corridor Regional Strategy 2006* continues to apply to the region.

3.2 Additional Strategic Documents

Further strategic documents considered (but not limited to) during the preparation of the Supplementary Report to the North Tralee Local Environmental Study include:

- *Queanbeyan Residential and Economic Strategy* (updated December 2015)

4 statutory framework

4.1 NSW Legislation

4.1.1 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* is the principle Act that guides development in NSW. As outlined in previous North Tralee Local Environmental Study reports, the Local Environmental Plan needs to be prepared under the former s.54 of the Act as the Director General of the NSW Department of Planning received notification of Councils' resolution to prepare a draft LEP prior to 1 July 2009.

4.2 Other NSW Legislation and policies

4.2.1 Section 117 (2A) Directions

Section 117 of the *Environmental Planning and Assessment Act 1979* requires that a series of criteria, prepared by the NSW Department of Planning and Environment, must be considered when undertaking a Local Environmental Study and preparing the draft Local Environmental Plan. The criteria address a range of items including environmental sensitivities and form or function of new urban areas and are called s.117 Directions. The Department must be satisfied that the LES process has implemented the intentions of each of the Directions. The s.117 Direction which is of relevance to this Supplementary Report is:

Direction 4.3 Flood Prone Land

Direction 4.3 applies because Queanbeyan-Palerang Regional Council, as the Relevant Planning Authority (RPA), is considering the preparation of a Planning Proposal that will create, remove or alter a zone or provision that affects flood prone land. The objectives of this Direction are:

a) To ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the *Floodplain Development Manual 2005, and*
b) To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

As Direction 4.3 applies to North Tralee, Council is required to ensure that strategic planning for the Site:

- gives effect to and is consistent with the:
  - NSW Flood Prone Land Policy
  - *Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas*);
- does not result in rezoning of land within the Flood Planning Area (FPA) from Rural to Residential, Business, Industrial, Special Use or Special Purpose Zone;
- does not permit development in floodway areas; and
- does not permit development that will result in significant flood impacts to other properties.

4.3 Local Environmental Plans

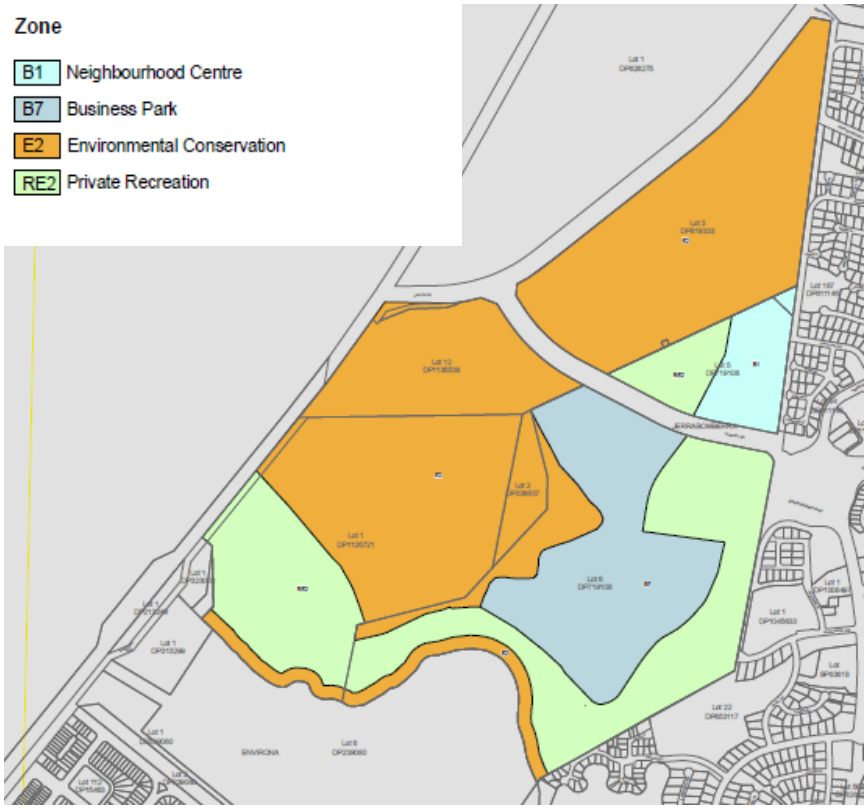
4.3.1 Queanbeyan Local Environmental Plan 1998 (LEP)

The *Queanbeyan Local Environmental Plan 1998* is the principle environmental planning instrument influencing development in North Tralee. It identifies a range of land uses which can take place in each of the zones. It also includes a number of performance based objectives and development standards influencing the form and intensity of development. The study area is currently zoned 1(a) (Rural "A" Zone) under Queanbeyan LEP 1998. The objectives of the zone encourages small scale agricultural and related land uses.

<u>'The Poplars'</u>

'The Poplars' is an area located at the south western edge of the Queanbeyan LGA and immediately north of the North Tralee site. 'The Poplars' site was rezoned in accordance with *Queanbeyan Local Environmental Plan (Poplars) 2013* (refer to Figure 3). The northern side of the Jerrabomberra Creek riparian corridor was rezoned to E2-Environmental Conservation and directly interfaces with North Tralee.

Figure 3 | Queanbeyan LEP (Poplars) 2013 – Land Zoning Map



4.4 Development Control Plans & Developer Contributions Plans

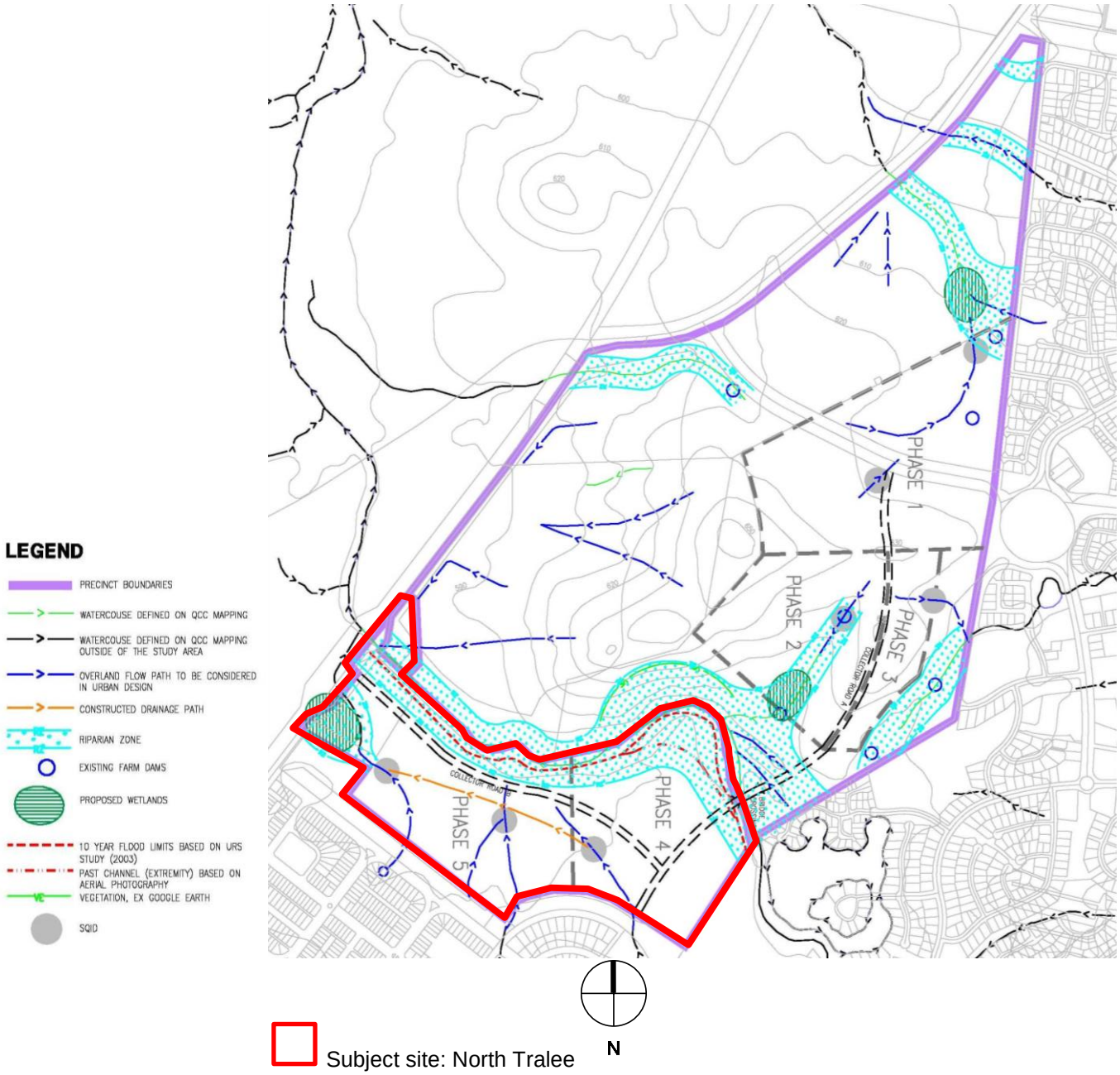
The Queanbeyan Development Control Plan (DCPs) supplements the *Queanbeyan Local Environmental Plan* by providing development controls of greater detail and tailored for the primary forms of development taking place in the LGA as well as locality specific characteristics.

5 natural environment

5.1 Hydrology, drainage and flooding

In 2010 Northrop Engineers were engaged by Council to undertake a hydrology assessment, review the drainage characteristics of the Site. Figure 4 illustrates the key hydrological characteristics of the Site and 'The Poplars', immediately to the north. Figure 4 shows the drainage paths and riparian zones based on the topography, hydrology and ecology of the Site, not the existing or planned land use.

Figure 4 – Drainage Paths and Riparian Zones (Source Northrop Engineers 2010)



Northrop Engineers also investigated three land use scenarios which were reported to Council in September 2015:

- Filling of the flood plain to at least the flood planning level (FPL, equivalent of the 100-year ARI (average recurrence interval) flood) with a maximum potential area for employment land uses of 28.9ha (as envisaged in the Queanbeyan Residential & Economic Strategy 2031 (2008) The filling of the floodplain was not supported by Council or government agencies.
- Reduce the proposed employment land uses to areas outside the flood prone land on the basis that the flood issue cannot be resolved in the short term with the proposed employment land uses equating to approximately 15 – 16ha. The impacts of the reduced employment area were investigated, particularly in terms of how this might impact on thresholds and phasing for infrastructure services, traffic, etc.
- Maintain 28.9ha of land for employment uses, outside of the flood prone land, and extending towards the south east boundary of the Site towards the existing Jerrabomberra residential area. Appropriate buffer zones with the existing Jerrabomberra suburb would need to be determined to ensure the amenity of the suburb is not adversely impacted by the development. This option has been the subject of further investigation.

The Northrop Study found that:

- North Tralee occupies the southern overbank of Jerrabomberra Creek, which represents the upper limits of the greater floodplain.
- Development of North Tralee is constrained by its proximity to and relationship with the Jerrabomberra Creek riparian zone and the potential consequences of filling the land to above the flood planning level.
- The development of the western portion of North Tralee would require filling of the flood plain to at least the estimated 100-year ARI flood level. Although the volume of flood storage lost through filling represents less than 1% of the greater Jerrabomberra Creek floodplain, it would contribute to cumulative losses and change the hydraulic characteristics of the adjoining creek during larger flood events.
- Jerrabomberra Creek appears to have commenced stabilising in form and further disturbance of the riparian zone should be avoided to facilitate this stabilisation processes.

The Study also found that there have been several hydrologic studies which have built on previous work and make simplifying assumptions that may not simulate flood conditions as accurately as would be desirable. The Study recommended that an independent extended flood model should be developed to more broadly simulate the potential impact of the filling floodplain. Any broader model should take into consideration:

- the stream being in a stabilisation phase and susceptible to renewed degradation if disturbed to enlarge the waterway area;
- the proximity of both Lanyon Drive and the railway embankment as potential constraints on stream flow;
- the Site is within Jerrabomberra Creek's transition zone from a valley-confined creek to a broad floodplain form;
- the impact on the greater floodplain of the loss of just under 1% of the storage capacity; and
- the impact on the upstream channel of the loss of a proportion of the conveyance zone at the edge of the fill.

Riparian Zones

A Riparian zone is land located adjacent to a creek, stream, gully, river or wetland. These areas are important as they can support diverse vegetation and fauna and assist with maintaining bank stability. Riparian zones are typically defined as the interface between the terrestrial and aquatic habitats of the stream, which in the case of ephemeral streams by necessity includes the waterway itself. This leads to the broader definition of the stream itself plus all of the vegetation on the banks.

Riparian zones are difficult to delineate for a range of reasons including:

- major streams and rivers are dynamic in character changing position with each major flood event;
- the boundary condition can be hydrologic, topographic, geologic or ecologic or any combination of these at any particular location. In disturbed reaches the relevant extent of these parameters can be difficult to assess; and
- the order of accuracy of defining the boundary can be quite low.

In defining the riparian zones for this report, account has been taken of the ecology of the area, connectivity potential, geomorphology of the stream, the identified existing watercourse and the extent of flooding.

For the purpose of this report, the Riparian zone has been defined by:

- The extent of the 10-year ARI flood event as determined by URS (2003), but excluding the floodplain on which the speedway was constructed.
- The vegetated southern hill slope of the knoll on 'The Poplars' site.
- The historic Jerrabomberra Creek channels in the pocket opposite 'The Poplars' knoll, as identified from satellite photography. As the creek has historically taken these courses there is the real possibility that under a future major flood event the channel may relocate to anywhere within the area defined by these historic channels.
- The erosion gullies immediately west of Bayside Court Jerrabomberra.
- Identifiable 1st Order waterways across the sites.
- A buffer zone of 20m for 1st Order and 40m for 3rd Order waterways. Jerrabomberra Creek is a 3rd Order waterway.

The Report noted that whilst changing the land use may have limited effect on the overall peak flood pattern of Jerrabomberra Creek it will alter the local hydrology and water quality creating issues that will require management. The key issues that need to be addressed through comprehensive planning and design of water sensitive urban design are outlined below.

Hydrology

Converting the existing, relatively permeable grasslands to a relatively impermeable industrial use will alter the parameters that control the local stormwater runoff and discharge to the creek. To manage the potential impacts of concentrated high-energy flows through piped systems, stormwater detention and infiltration should be used to reduce the effect of the increased impermeability of the ground surface.

Groundwater

Sealing of ground surfaces will reduce infiltration to the soil and therefore groundwater recharge. Increased evaporative losses will also result further reducing infiltration to soil and groundwater recharge.

Loss of vegetation

The removal of grassland would reduce a key mechanism for stormwater quality improvement as grasslands extract nutrients, trap suspended solids and support communities of organisms that contribute to the process of water quality improvement.

Increase in pollutant load

A commercial or industrial environment would be expected to have a higher and more diverse pollutant load than natural grasslands. Stormwater contaminants can cause harm, have long term effects or create collateral impacts which can affect wildlife, vegetation and humans.

Northrop Engineers indicated that a change in land use is likely to impact on the environment of the land, the hydrology and morphology of Jerrabomberra Creek and the amenity of the area. However, if appropriate planning and design is implemented the impacts can be managed. More detail is provided in section 6.2 of this report.

6 land use strategy

6.1 Land use zones

Confirmation of the Flood Planning Area (100 year ARI event plus 0.5m) at North Tralee means that the extent of areas which are affected by the relevant s.117 Direction can now be translated into land use zones.

As outlined in section 4.2 of this report strategic planning for the Site:

- must not result in rezoning of land within the Flood Planning Area (FPA) from Rural to Residential, Business, Industrial, Special Use or Special Purpose Zone;
- must not permit development in the Flood Way Area;
- must not permit development that will result in significant flood impacts to other properties.

The area located along either side of Jerrabomberra Creek requires a zone that will protect the riparian corridor and prevent incompatible development. The *Queanbeyan Local Environmental Plan (Poplars) 2013* zoned the northern side of the Jerrabomberra Creek riparian corridor to E2 – Environmental Conservation. The southern side of the Jerrabomberra Creek riparian corridor located within the Site should also be zoned E2 – Environmental Conservation.

Areas of North Tralee which are lower than the 100 year ARI event +0.5m freeboard are also within the Flood Planning Area (refer Figure 1) and cannot be rezoned from Rural to Residential, Business, Industrial, Special Use or Special Purpose Zone and no development is permitted. A land use that is compatible with the flood characteristics of the Site is recommended. In 2014, Council resolved to defer the rezoning of land at North Tralee that is within the Flood Planning Area and retain the 1(a) Rural A Zone under the *Queanbeyan Local Environmental Plan 1998.* However, now that the Flood Planning Area has been confirmed it is preferable to identify and apply land uses under the new Local Environmental Plan, for the entire North Tralee Site.

The land use which is most suitable is RU2 – Rural Landscape as the zone makes provision for the ongoing use of the Site for primary industry and the maintenance of the rural landscape. Some recreation uses may also be permissible subject to the requirements of the *Floodplain Development Manual 2005* (including the *Guideline on Development Controls on Low Flood Risk Areas*).

Areas of North Tralee which are higher than the 100 year ARI event +0.5m freeboard can be rezoned for Residential, Business and Industrial uses. As outlined in the *North Tralee Local Environmental Study (2011)* the site is unsuitable for residential purposes due to its affectation by the ANEF contours generated by Canberra Airport. The *Queanbeyan Residential and Economic Strategy 2031* (as

updated in December 2015) identified North Tralee for employment land uses. Employment lands are generally considered to be those accommodated by 'Business' or 'Industrial' land use zones.

It is recommended that a Flood Planning clause and Flood Planning Map be included in the draft North Tralee Local Environmental Plan. Clause 7.2 of the *Queanbeyan Local Environmental Plan 2012* is recommended:

"7.2 Flood planning

(1) *The objectives of this clause are as follows:*

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) *This clause applies to:*

(a) land identified as "Flood planning area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

(3) *Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:*

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) *A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.*

(5) *In this clause:*
flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard."

6.2 Stormwater Design Principles and Policies

It is noted that any development of the Site will lead to increased stormwater runoff volumes and flow-rates. This will result from an increase in impervious areas on the Site. Stormwater runoff should be managed to minimise the effect of development on downstream waterways, habitats and landform. The key measures to manage stormwater runoff within the Site are:

- Stormwater Collection – capturing surface runoff to minimise the potential for overland flow to affect people and property (e.g. stormwater drainage pits).
- Stormwater Conveyance – directing stormwater runoff to safe points of discharge, so as not to affect people and property (e.g. stormwater drainage pipes/culverts, open channels, swales).
- On-site Stormwater Detention (OSD): Allows for storage and controlled release of stormwater runoff. OSD facilities can be provided to service individual lots, or at a local catchment level. Facilities are best located toward the downstream end of sites, outside areas susceptible to flooding (up to 100-year ARI), and so that connections are not susceptible to backwater from downstream drainage systems. On-site detention and infiltration mechanisms are required to ensure that there is no increase, over pre-development, in either the peak discharge rate or total discharge volume from storms between the 2-year and 100-year ARI events. Increased runoff volumes and rates from North Tralee site will not necessarily affect peak flooding off Jerrabomberra Creek. However, the Creek formation, habitats and ecosystems associated with the watercourse may be vulnerable to increased runoff. It is recommended site discharge is adequately managed so as not to adversely affect these systems.
- Stormwater Retention: Reduces runoff discharging to the downstream drainage system. Runoff is captured to provide an alternative water supply, thereby reducing potable water consumption. Retained stormwater can be consumed in the same manner as potable if it is subject to the required level of treatment

- Stormwater Quality Improvement Devices and constructed wetlands. (About 2% of the developed area needs to be set aside to accommodate the constructed wetlands. The option to direct stormwater towards the existing wetland area upstream of the culverts under the railway embankment should be investigated.) The provision of Stormwater Quality Improvement Devices (SQIDs) within the private space should also be addressed through appropriate development control regulations. Concentration of both stormwater and the contaminants that it may be carrying for treatment in the public space should be avoided.

An effective Water Sensitive Urban Design (WSUD) strategy can reduce the impact of development on water quality, quantity and supply and demand. The principles and guidelines recommended by Northrop Engineers target those outcomes. They were developed around the basic principles of WSUD and tailored to suit the anticipated geographic and climatic conditions at the site. The basic principles include:

- value water quality;
- view stormwater as a resource;
- promote at-source water recovery, treatment and reuse to reduce the consumption of potable water;
- require at-source stormwater detention and treatment to reduce the need for public facilities at discharge points;
- detain, infiltrate and consume stormwater within the drainage system rather than convey it rapidly to a point of discharge;
- harvest excess stormwater, with particular emphasis on use of irrigation and for groundwater recharge;
- give priority to low-tech passive management and treatment practices;
- integrate stormwater management and treatment into the landscape;
- adopt landscape practices that reflect the climatic conditions of the site; and
- protect water-related ecosystems.

General Design Principles and Policies

In the event of rezoning an overall Stormwater Management System for the Site should be developed and implemented in accordance with the following principles:

- An Integrated Water Cycle Plan should be prepared for the entire Site.
- Pollutant levels for the post-development scenario must not exceed pre-development levels. (at a minimum).
- A Stormwater Impact Assessment should be provided with each Development Application (on a per lot basis).
- Approximately 2% of the developable area should be set aside to accommodate constructed wetlands and stormwater quality improvement devices (SQIDs).

- The provision of Stormwater Quality Improvement Devices (SQIDs) within the private space should also be addressed through appropriate development controls.
- Concentration of both stormwater and pollutants in public space should be avoided.
- Treatment of stormwater on individual lots should achieve at least the following:
  - 90% reduction in litter;
  - 60% reduction in suspended solids; and
  - 60% reduction of insoluble liquid contaminants.
- Water Sensitive Urban Design should be implemented across the Site to assist in the management of stormwater runoff pollution/quality.

Employment land – Design Principles

The southern portion of the Site is proposed to be zoned IN2 – Light Industrial and B7 Business Development. Industrial sites can have high impervious area ratios which may result in significant runoff volumes and increased pollutant load. The capacity of existing downstream drainage systems to receive the changed runoff volumes and patterns whilst maintaining appropriate flows to support habitats must be taken into consideration. Mechanisms to achieve this include:

- Water cycle management within the private spaces of employment lands is to include the following mechanisms and be required as part of the site and building design and approval process:
  - Water efficient equipment and appliances.
  - Water efficient plumbing.
  - Rainwater harvesting and storage for use on site.
  - Climate attuned landscaping, irrigated with harvested rainwater or treated site-water only.
  - On-site treatment of the entire first-flush runoff from impervious areas.
  - On-site stormwater detention to at least 50% of the requirement for the local drainage system.
  - Infiltration areas capable of absorbing at least 50% of the natural infiltration capacity of the entire allotment.
  - Porous pavement in non-vehicle traffic areas.
- In areas of public domain the following mechanisms for water cycle management should be required as part of the site and building design and approval process:
  - Signage on inlets to stormwater drainage pipes.
  - Neighbourhood advisory signs about Jerrabomberra Creek; the function of the various works and the contribution that the community is making to the health of the ecosystem.
  - Porous pavements for any hard areas that do not carry heavy vehicle traffic.

  - Gross pollutant traps to remove litter and sediment from stormwater.
  - Detention basins to attenuate the peak flows, to enable fine sediments to settle out and to facilitate infiltration to the soil. (Detention basins need not be large affairs requiring large open spaces. Multiple small basins can turn left-over spaces and difficult corners into useful lands and build in system flexibility).
  - Bioretention areas with climate sensitive vegetation to reduce the level of soluble and immiscible contaminants.
  - Constructed wetlands as the final treatment prior to release into Jerrabomberra Creek. Indicatively, constructed wetlands for each site would need to be in the order of 5000m^2, subject to detail design.
- The use of vegetated swales in lieu of formal kerb and gutter is not recommended as it will be difficult to protect them from frequent and heavy vehicle traffic associated with employment land uses resulting in loss of vegetation.
- Consideration should be given to the issue of spill management. This element of the public space works should be examined more closely as the details of the urban design emerge.

Management of runoff should maintain existing (environmental) stormwater flows to support habitats. The following measures can be considered as part of an overall stormwater management system:

- The system should ensure existing site flows are maintained, while minimising the effects of excessive runoff rates and volumes.
- Final locations and sizes of stormwater management measures are subject to an integrated stormwater management system being developed – considering the recommendations outlined above.
- The stormwater management system should also include a number of engineered solutions which have been discussed by Northrop to overcome potential water quality impacts. The ultimate strategy for site stormwater quality management will incorporate a suite of these measures to achieve the water quality objectives for Jerrabomberra Creek.

7 conclusions and recommendations

The Flood Planning Area (100 year ARI event plus 0.5m) at North Tralee has been confirmed by Council's consultant, WMAwater. This means that appropriate land use zones can now be delineated. The requirements of s.117 Direction No.4.3 (Flood Prone Land) as well as other site and strategic planning considerations has resulted in the following land use zones being recommended:

- The southern side of the Jerrabomberra Creek riparian corridor located within the Site to be zoned E2 – Environmental Conservation;
- The areas of the Site which are lower than the 100 year ARI event +0.5m freeboard to be zoned RU2 – Rural Landscape
- Areas of the Site which are higher than the 100 year ARI event +0.5m freeboard can be rezoned for Residential, Business and Industrial uses.
- The inclusion of a Flood Planning clause and Flood Planning Map in the draft North Tralee Local Environmental Plan is recommended.

Appendix Sheets

Appendix (A) WMAwater (2016)
Review of North Tralee Flood Studies

Appendix (B) Calibre Consulting (2016) Correspondence to Village Building Co. – (2016)
North Tralee Floor Study Review

Appendix (C) WMAwater (2016 Correspondence re – Calibre Consulting – (2016)
North Tralee Flood Study Review

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REVIEW OF NORTH TRALEE FLOOD STUDIES

FINAL REPORT

FEBRUARY 2016

Project Review of North Tralee Flood Studies	**Project Number** 115070
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Date 1 February 2016	**Verified by** 

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1. INTRODUCTION

This study has been prepared by WMAwater on behalf of Queanbeyan City Council (Council) and serves as an independent peer review of a number of studies undertaken for the North Tralee site (the site).

The site is proposed to be developed for employment, open space and conservation purposes, however parts of the site are known to be subject to flooding.

This study provides Council with independent advice as to the suitability of previous studies prepared for the site, in regards to flood related information and the accuracy of the Flood Planning Level (FPL) for the subject land.

1.1. Objectives

The aim of this study is to review the flooding components of the following studies undertaken for the North Tralee Study Area:

- *Flood Study and Riparian Corridor Assessment Jerrabomberra Creek - Brown Consulting, Jan 2010* (the Brown Study);
- *Tralee LES Jerrabomberra Creek Flood Study - URS Australia, Aug 2003* (URS Study)*; and*
- *North Tralee LES 2011 (Appendix B) – Northrop Consulting, 2010*

In particular, advice is sort as to the suitability of the Brown Study being used as a basis to inform a FPL for the North Tralee site consistent with relevant NSW legislation and policy requirements. The Brown Study produced a hydraulic model of the site to model flood behaviour which extended some distance both upstream and downstream of the site. This region is defined throughout this report as 'the study area'.

1.2. Background

The site is part of a larger parcel of land known as 'Tralee' that was considered for residential rezoning in the early 2000's. A Local Environmental Study (LES) was prepared for the entire site at that time (comprising land known as North Tralee and South Tralee). However due to the close proximity to Canberra Airport, the site at North Tralee is no longer being considered for residential development. Instead, the site is now proposed to be developed for employment, open space and conservation purposes as noted earlier.

A planning proposal to rezone the land at North Tralee for employment/light industrial uses was submitted to the NSW Department of Planning in May 2014 and a Gateway determination was issued to Council on 28 May 2014.

A number of studies have been prepared for Council and by various proponents to investigate flood behaviour at Tralee. Not all of these studies have covered the entire site with a number investigating only parts of the site.

The Brown Study (2010) was prepared by Brown Consulting for the proponents and covers the entire area subject to the rezoning proposal. Study findings include flood maps for the 100 and 500 year ARI events and the Probable Maximum Flood (PMF).

Council wish to determine to suitability of the Brown Study (2010) for determining the sites FPL and have sought independent advice in respect to the flood liability of the site. Development is proposed to only occur where land is located above the flood planning level, and it is important this level be accurately defined. The 'flood planning level' as defined under Council's local environmental plan is the 1:100 ARI (average recurrent interval) plus a 0.5 metre freeboard.

In addition to the Brown Study (2010), other studies (see Section 1.1) have been made available for review to help inform Council of the site's flood liability.

1.3. Study Area

The Study Area is located in the south western corridor of Queanbeyan NSW within the Jerrabomberra Creek catchment immediately upstream of the NSW/ACT border. The Jerrabomberra Creek catchment upstream of the Study Area is approximately 82 km² of predominately, rural and natural land uses. The Study Area follows Jerrabomberra Creek from Lake Jerrabomberra in the upstream to Lanyon Drive in the downstream.

The disused Goulburn-Bombala Railway and its embankment form a significant hydraulic feature at the downstream end of the site. A wooden trestle bridge forms the Railway crossing of Jerrabomberra Creek. This bridge was noted in the Brown Study to be supported by six sets of three wooden piers and approximately 38 metres long. A second break in the railway embankment is located approximately 200 metres south of this bridge.

2. STUDY REVIEWS

2.1. Brown Consulting Study (2010) - Study Review

Brown Consulting were commissioned to undertake an investigation of the flood behaviour of Jerrabomberra Creek at Tralee for the proposed Tralee North and The Poplars development areas. The investigation was part of the South Jerrabomberra Masterplan.

The objectives of the Brown Study were:

- Review of available existing information;
- Review and assessment of previous investigations into Jerrabomberra Creek and the development areas;
- Determine current flooding situation for the 100 and 500 year Average Recurrence Interval (ARI) storm events and the Probable Maximum Flood (PMF);
- Determine limitations on the proposed development due to flooding;
- Investigate cut and fill options to maximise developable area and minimise impact on Jerrabomberra Creek and minimise flooding impacts.

As mentioned above the Brown Study was commissioned to investigate options with regard to cut and fill measures to maximise the developable land area. These measures were not supported by Council or the relevant Government agencies and were therefore not undertaken. Accordingly, it is only those parts of the Brown Study that provide information in respect of the existing flooding behaviour of the subject land that require review as part of the current study.

2.1.1. Hydrology

The Brown Study investigated using Flood Frequency Analysis (FFA) for stream gauge (410743) to determine design flows for the study area, however concluded that the total record period (26 years) is too short to provide an accurate 100 year flow estimate. Whilst this is a reasonable assumption, it failed to mention that the 2 year to 20 year ARI design flow estimates are likely reasonable and could be used for hydrologic model calibration. FFA is the preferred method of determining design flows where available data allows for it.

Instead of FFA, the Brown Study (2010) utilised the hydrologic model XP-Rafts (Version 7) with typical regional model parameters to determine design flows. Details on selected model parameters indicate that reasonable hydrologic parameters have been used. Model parameters include:

- ARBM loss model with parameters recommended in the ACT Planning and Land Authorities Water Sensitive Urban Design Code (March 2008);
- Reasonable percent imperviousness;
- Reasonable catchment slopes; and
- Typical Manning's values for both impervious and pervious land uses.

However, the Brown Study (2010) does not provide information on how catchment routing was modelled which can significantly impact on peak flows.

2.1.1.1. Hydrology Results

The Brown Study (2010) hydrologic model design flows have been compared to the FFA undertaken as part of the Tralee LES study (2003). As mentioned previously, FFA performed on a 26 year record period, likely provides reasonable flow estimates for design flows up to and including the 20 year ARI. Table 1 presents a comparison of flows from these two studies. Comparison of the Brown Study (2010) hydrologic model flows to the Tralee LES (2003) FFA derived design flows for the 10 and 20 year ARI events indicates that flows are similar. This provides confidence in the Brown Study (2010) hydrologic model design flows.

Table 1: Comparison of design flows at the NSW/ACT boarder (m^3/s)

	10 year ARI	20 year ARI	50 year ARI	100 year ARI
Brown Study (2010) XP-Rafts Model Flow	165	213	270	322
FFA - Tralee LES (2003)	152	212	317	423
PRM	145	186	254	305

To add further robustness to the design flow estimates the Brown Study (2010) calculated design flows via the Probabilistic Ration Method (PRM) for comparison. The PRM flows were found to be similar to the flows determined from the hydrologic model for all examined ARI. This comparison can be seen in Table 1.

As the 10 and 20 year ARI Tralee LES study (2003) FFA flows and the PRM flows are similar to the hydrologic model design flows, WMAwater conclude that the Brown Study hydrologic assessment and design flows are reasonable and suitable for use in design flood hydraulic modelling. Hence, they are also suitable for determining FPLs.

2.1.2. Hydraulic Modelling

The Brown Study (2010) utilised a two-dimensional hydraulic model (SOBEK) to define design flood behaviour for the study area. The model was not calibrated.

The model grid cell size has not been specified in the report, and two models with varying grid cell sizes (5 m and 10 m) were made available for the study review. Selection of grid cell size is important for the definition of in-bank conveyance. A 10 m model grid would likely lack the definition required to accurately model the Jerrabomberra Creek in-bank for the study area.

Model inflow boundaries were situated downstream of Jerrabomberra Lake and on the small tributaries within The Poplars and Tralee North development areas. The downstream model boundary was modelled as a constant water level boundary upstream of Lanyon Drive.

Roughness coefficients were determined from Section D5.06.9 of Queanbeyan City Council – Development Design Specification D5 Stormwater Drainage Design and from Hydraulic Design of Flood Control Channels, Engineer Manual published by the US Army Corps of Engineers. A roughness coefficient of 0.04 was used in the modelling for the in-bank area and overbank overland flow. WMAwater notes that a Manning's of 0.04 is towards the lower end of what would

be considered acceptable and a higher roughness (0.05) should be considered if no hydraulic model calibration is undertaken. The URS study indicated that '*Vegetation in the main creek channel largely comprises grasses and shrubs with scattered trees along the banks'* (see Section 2.2) which would indicate a higher roughness than that selected. Selection of a higher roughness would be considered conservative and best practise for an uncalibrated model.

2.1.2.1. Topographical and Survey Data

The Brown Study notes that topographical and survey data for the study area was obtained from various sources throughout the history of the site. The Brown Study (2010) notes, that 'detailed survey of the creek will be undertaken for the detailed design stage of the development with flood extents to be recalculated.' This indicates that Brown Consulting themselves anticipate revision of the study's 100 year flood level, and associated FPL (100 year ARI level + 0.5m). Furthermore, the quality of the Aerial Laser Scanned (ALS) ground survey is not known with the Brown Study (2010) noting that the ALS data had been 'manually adjusted', with no mention of confirming the ALS data with survey data made. It is common practise to ensure the accuracy of the ALS with survey data.

Also of note is the lack of information related to detailed survey of the disused Goulburn-Bombala Railway and associated infrastructure. The Railway forms a significant hydraulic feature at the downstream end of the site, and likely is a control influencing the site's flood levels. Correct modelling of this structure is essential to the accurate modelling of flood behaviour and in particular, peak flood levels, from which the FPL is derived.

A key feature of the Railway infrastructure is a wooden trestle bridge that forms the Railway crossing of Jerrabomberra Creek. This bridge was noted in the Brown Study (2010) to be supported by six sets of three wooden piers and 'approximately' 38 metres long, however, the Brown Study (2010) has modelled this structure (in 1D) as 31 m long. There is also an error with modelling of the southern bridge span, with the 1D invert modelled as higher than the crest level of the railway. This removes flow conveyance through this significant bridge span (modelled as 15 m x 2 m) until the level of the Railway embankment is overtopped, which, once this occurs, does not require a 1D model element as flow can pass freely over the embankment in 2D.

Additionally, no detail has been given about a 'second break' in the railway embankment mentioned in the Brown Study (2010) which is located approximately 200 metres south of the bridge. This structure is modelled in 1D as two 5 m wide non-enclosed flow paths through the Railway. The URS Study (2003) provides details of this structure (see Section 2.2) which are in conflict with that modelled as part of the Brown Study (2010) which would over estimate flow conveyance through this structure.

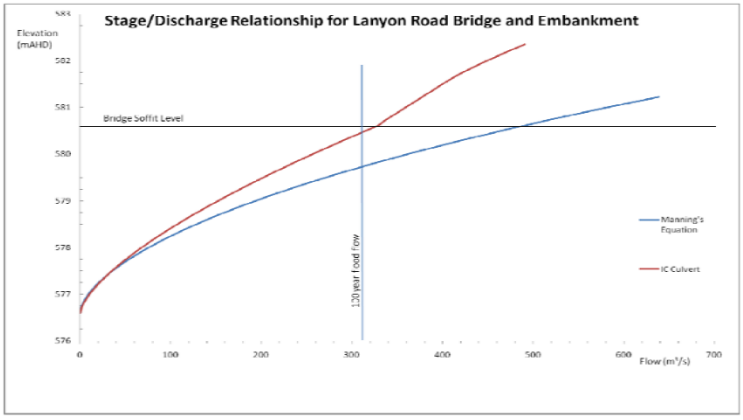
Due to the importance of these structures on flood behaviour, it is recommended that detailed survey be undertaken for the bridge, the railway embankment crest level within the flood extent, and for the southern 'break in the railway'. The railway embankment has been modelled as overtopped in various locations, the occurrence of which could significantly impact on upstream flood levels.

2.1.2.2. Model Boundaries

The upstream inflow boundaries are positioned in suitable locations so as to not impact on results in the area of interest at the site.

The downstream model boundary was modelled as a constant water level boundary upstream of the Lanyon Drive Bridge, which along with the Goulburn-Bombala Railway, likely forms an important flow control. The bridge was reported in the Brown Study (2010) as not being modelled for the following reasons:

- *The bridge at Lanyon Drive was not included in the model due to a lack of data downstream of the road embankment and the assumption that the bridge was designed to accommodate the 100 year peak flood flow;*
- *The flow capacity of the bridge and embankment was calculated from pencil-drawn hand measurements were provided on 10 September 09 by Brown Consulting (ACT);*
- *A simple stage/discharge relationship based on the sketched details of the Lanyon Drive Bridge was developed using Manning's Equation – the channel under the bridge deck was found to have capacity of 487 m³/s, well in excess of the 313 m³/s developed in XP-RAFTS and used in the SOBEK modelling;*
- *Culvert entrances were also modelled using the program IC Culvert –this program calculated that the bridge has the capacity to accommodate the 100 year flow below the soffit level of the bridge;*
- *A graph showing these calculated stage/discharge relationships is presented below;*



- *The flow elevation was not estimated at the bridge, however it was calculated at 581.0 m AHD approximately 50 metres upstream of the bridge – this would result in a water level at the bridge of below the soffit of 580.6 m AHD which would not result in backwater effects, which is in line with the assumption that the bridge is designed to allow passage of the 100 year flood;*
- *The stage discharge relationship at the bridge was approximated using a normal depth boundary condition upstream of the bridge in both existing and developed model runs for consistency;*
- *The SOBEK model has the limitation that the boundary condition to the flow must be in line with the model cells. Incorporation of the bridge did not allow this without additional downstream ALS data; and*
- *Given the level of accuracy of the ground surface data used in the hydraulic modelling*

(which was not based on actual survey data but estimates based on elevation modifications made in 12d) the minor inaccuracies to the flow downstream of the site caused by modelling the Lanyon Drive Bridge and embankment in this manner will not impact on the accuracy of the results.

Point six (6) above mentions that because water levels are determined not to reach the bridge soffit, no backwatering upstream of Lanyon Drive will occur. However, it is not the case that flood levels must reach the level of the bridge soffit for backwatering to occur as expansion/contraction losses and various other losses associated with bridges and their embankment can cause significant backwatering upstream.

It is recommended that additional survey data of Lanyon Drive Bridge and downstream be obtained and incorporated into the hydraulic model.

2.1.2.1. Model Calibration

The hydraulic model has not been calibrated. It is best practise to calibrate a hydraulic model, particularly when determining design flood levels used to develop FPLs.

It is recommended that the hydraulic model be calibrated using available historic flood information to ensure accuracy of the selected parameters and model results.

2.2. Tralee LES Jerrabomberra Creek Flood Study – Study Review

The Tralee LES Jerrabomberra Creek Flood Study by URS Australia (2003) has been reviewed.

Of note is Section 10.2.2 – Infrastructure and Other Issues which is reproduced below:

- *The main railway crossing over the Creek comprised an old wooden bridge, approximately 38 m long with six sets of three wooden piers, of which three sets are located within them channel. The Creek was not flowing at the time of the inspection by URS.*
- *Pipe culverts (4 x 2.35 m diameter) have also been recently installed within the railway embankment, approximately 170 m south of the bridge. It is understood that Railway Infrastructure Corporation (RIC) installed the culverts to replace a bridge structure previously at that location, and the culverts were designed to provide similar flood discharge capacity to the original bridge (pers. comm. Stuart McCarthy). These culverts act to provide additional waterway opening areas within the embankment during extreme flood events.*
- *The Creek channel banks within the Tralee North site comprises near vertical batters, frequently as much as 4 m high, resulting from on-going erosion during high flow events. It is reported that considerable volumes of silt have been deposited within areas of the creek downstream (Dept. Housing, 1984).*
- *Vegetation in the main creek channel largely comprises grasses and shrubs with scattered trees along the banks. The floodplain overbank areas generally comprise grasses and low shrubs.*

The report indicates a 100 year ARI peak flood level at the Goulburn-Bombala Railway of 583.95 mAHD. This is higher than the 100 year ARI level determined in the Brown Study (2010) which likely relates to a number of the issues highlighted in Section 2.1.

2.3. North Tralee LES 2011 (Appendix B) – Study Review

Appendix B of the North Tralee LES study by Northrop Consulting (2010) has been reviewed. The study provides little additional relevant information from a flooding perspective.

3. CONCLUSIONS

After reviewing the Brown Study (2010) hydrology, WMAwater conclude that the design flows, including the 100 year flow, determined as part of the Brown Study (2010) are suitable for use in design flood modelling.

Review of the Brown Study (2010) hydraulic model indicates that the model requires review and that detailed survey of the disused Goulburn-Bombala Railway and associated infrastructure should be undertaken for incorporation into the model. In particular, the Jerrabomberra Creek bridge crossing, the southern 'break in the railway', and the railway crest over the width of the floodplain should be surveyed and incorporated into the model.

Additionally, survey of Lanyon Drive Bridge and downstream should be undertaken so that the hydraulic model can be extended further downstream to model the potential impacts of Lanyon Drive on upstream flood levels.

The hydraulic model should then be calibrated using available historic flood information to ensure accuracy of the selected parameters and model results.

4. REFERENCES

Brown Consulting

1. **Flood Study and Riparian Corridor Assessment Jerrabomberra Creek**
   Queanbeyan City Council, January 2010.

URS Australia

2. **Tralee LES Jerrabomberra Creek Flood Study**
   Queanbeyan City Council, August 2003.

Northrop Consulting

3. **North Tralee LES 2011 (Appendix B)**
   Queanbeyan City Council, September 2010.

Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

	redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers

	the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For

	an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models — The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach — The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding — Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures — Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge — The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) — The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete

	protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

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ABN 30 109 434 513

Our Ref: 16-000394 - Jerrabomberra Creek Flood Study - Additional Modelling.docx
Your Ref: North Tralee
Contact: Anthonie Lambert/Philip Bellard

26 July 2016

Village Building Co.
Argyle Corner
92 Hoskins Street
Mitchell ACT 2911

Attention: John Kenworthy

Dear John

North Tralee – Jerrabomberra Creek Flood Study – Update to 2010 Flood Modelling

This letter report has been prepared to accompany the *Flood Study and Riparian Corridor Assessment Jerrabomberra Creek*, prepared by Brown Consulting (now Calibre Consulting) in January 2010. This additional flood modelling has been undertaken to assist with the re-zoning application for the site and incorporates the recommendations of a peer review of the 2010 study by WMA Water, dated December 2015. The recommendations by WMA were that the hydrologic investigation in the 2010 flood study was appropriate, with additional ground survey required for the flood model, in particular the railway embankment and the area downstream of the site, incorporating Lanyon Drive and the new bridge on Lanyon Drive, which was constructed after the 2010 report.

This letter outlines the updated flooding investigation, referred to as the 2016 modelling, describing the additional survey data obtained, along with changes to the flood modelling methodology and software.

Data Sources

Flow rates used in the 2016 modelling were the hydrographs developed for the 2010 modelling. This approach was taken after 'WMA water concluded that the design flows, including the 100 year flow, determined as part of the Brown Study (2010) are suitable for use in design flood modelling.'

Additional survey data was obtained for the project by MMB Consulting Surveyors.

Survey of the floodplain and main channel of Jerrabomberra Creek was obtained by incorporating ground survey data with aerial survey undertaken by an unmanned remote control vehicle (drone) with LiDAR remote sensing. This drone survey has been provided as an attachment to this letter and has an accuracy of 1.0 metre horizontal and 0.15 metre vertical.

Survey of the bridge on Lanyon Drive has also been supplied by MMB, with ground survey taken on site. A copy of the survey of the bridge is provided as an attachment to this letter.

These survey data sources were used in the modelling, along with the flow rates and surface topography used in the 2010 flood modelling (discussed in Section 4.1 of the 2010 report).

Methodology

The 2010 investigation used the two-dimensional hydraulic modelling software package *SOBEK* (Version 2.11.002). The 2010 model was constructed using a 5.0 metre grid, with inflow boundaries from sub-catchments of Jerrabomberra Creek entered as discrete flow boundaries within the two-dimensional model. This approach to flows entering the model was used for upstream boundary conditions and for local flows within the development site.

The 2016 investigation has been developed using the two-dimensional modelling software package *TUFLOW* flood modelling software (Build: 2013-12-AC), using the *SMS* interface (Version 11.2.5). This model has been constructed with the additional survey data provided by MMB, on a 1.0 metre grid size. Flows entering the main channel of Jerrabomberra Creek from upstream of the site were used from the 2010 modelling, with flows generated on the site calculated using the application of rainfall directly onto the grid of the two–dimensional hydraulic model within the TUFLOW flood modelling software. This methodology is known as the direct rainfall approach or 'rainfall on the grid'. This approach removes the need for a separate hydrological modelling package.

In traditional flood modelling, separate hydrological and hydraulic models are constructed. The hydrological model has inputs of rainfall, area losses and roughness within a lumped or partially distributed sub–catchment, calculating runoff hydrographs for modelled storm events. This hydrograph is then applied to the hydraulic model, which performs flow calculations based on hydraulic features to develop estimations of flood behaviour across the study area.

In the direct rainfall approach, the hydrological model is either partially or completely removed from the process. The hydrological routing is undertaken in the distributed two–dimensional model, rather than in a lumped hydrological package.

This approach was adopted for this investigation in order to more accurately model flows within the development area.

Results

The results of the modelling are provided in *Drawing 16-000394 — 100 year Flood Event Depth Results with 150mm Nulling (1m Grid model)* Issue 2 Dated 26/07/16, provided as an attachment to this letter. The results of this modelling are of a finer resolution when compared with the results of the 2010 modelling. The inflow boundaries shown by the straight line boundaries in Figure 0.7 in the 2010 report have been replaced by a flood extent that has resulted from the distributed rainfall modelling.

Flood extents developed for the previous modelling did not extend upstream into the site along the drainage lines shown on *Drawing 16-000394 — 100 year Flood Event Depth Results with 150mm Nulling (1m Grid model)*. Overland flow shown in these small tributaries will be managed in the development by the trunk drainage network. The 2016 modelling also indicates that a localised flooded area occurs within the former Tralee Speedway embankment.

Recommendations

The results of the flood modelling are to be used to prepare development zoning and flood planning elevations. The 100 year flood extents of Jerrabomberra Creek main channel (fluvial flows) are intended to be used for mapping the flood affected zone that will be unsuitable for development. A mark-up showing the boundary between main channel and site tributary flows has been provided for this letter in Figure 1.

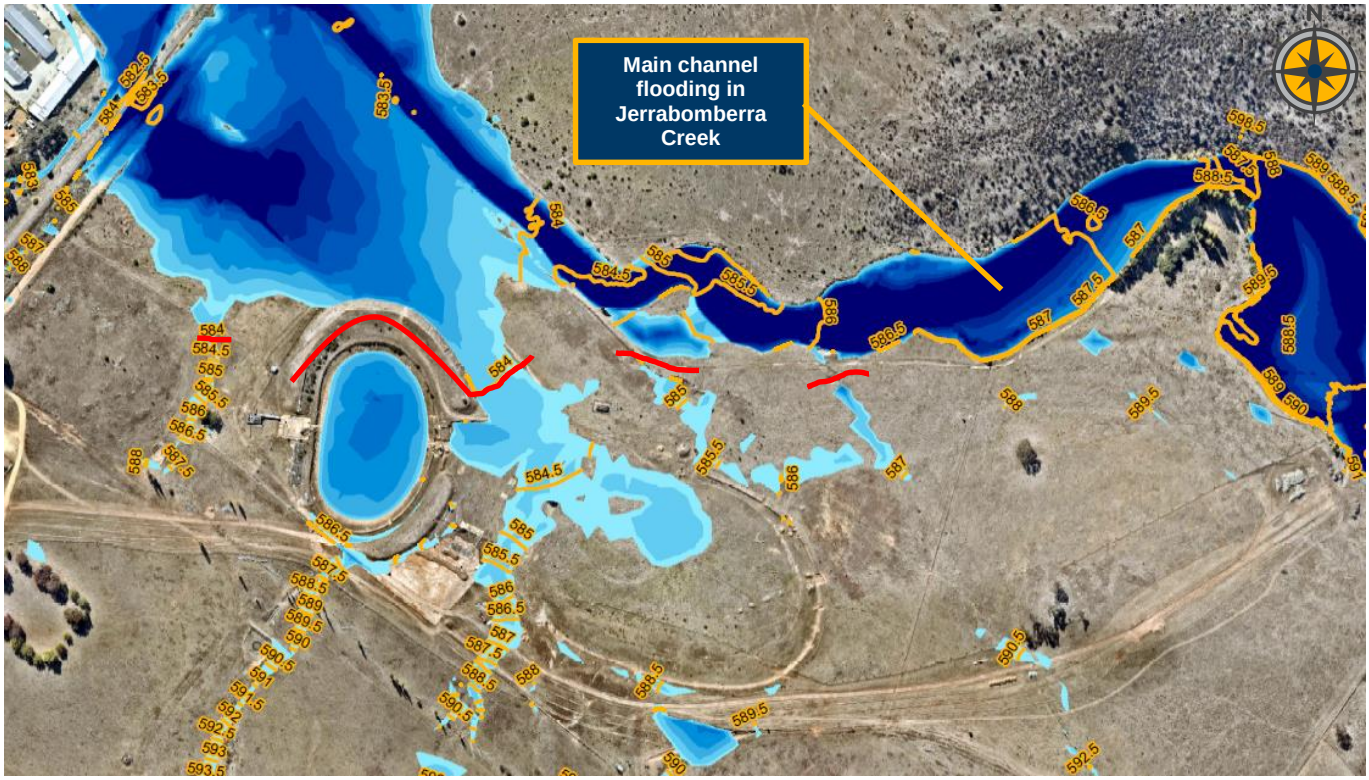


Figure 1 – Flood zoning recommendation

The results of the flood mapping shown on Figure 1 have been marked with a red line indicating the area of main channel flooding. Areas to the north (creek side) are recommended to be zoned as drainage area, with areas to the south of the red lines to be zoned for land development, with flows to be managed by the trunk drainage network once developed.

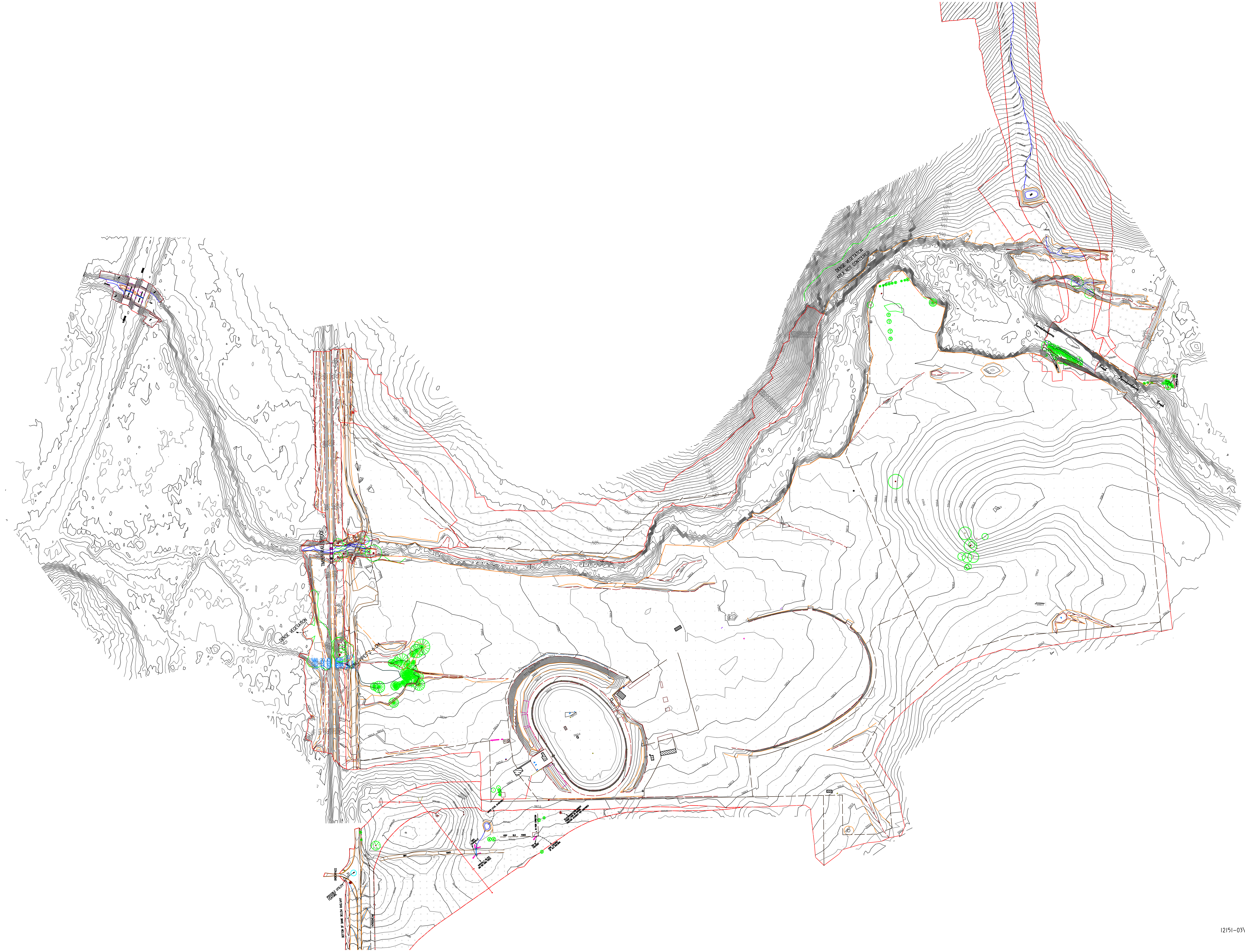
If you have any queries regarding the information in this letter report or require additional clarification of the information provided, please call me on 8808 5000.

Yours sincerely
Calibre Consulting

Nigel Bosworth
Principal Engineer - Water and Environment

ATTACHMENTS

1. Drawing 12151–03\12151–03_drone_160616.dwg Dated 16/06/16
2. Drawing 12151–03 Lanyon Drive Bridge Dated 16 June 2016
3. Drawing 16-000394 — 100 year Flood Event Depth Results with 150mm Nulling (1m Grid model) Issue 2 Dated 26/07/16



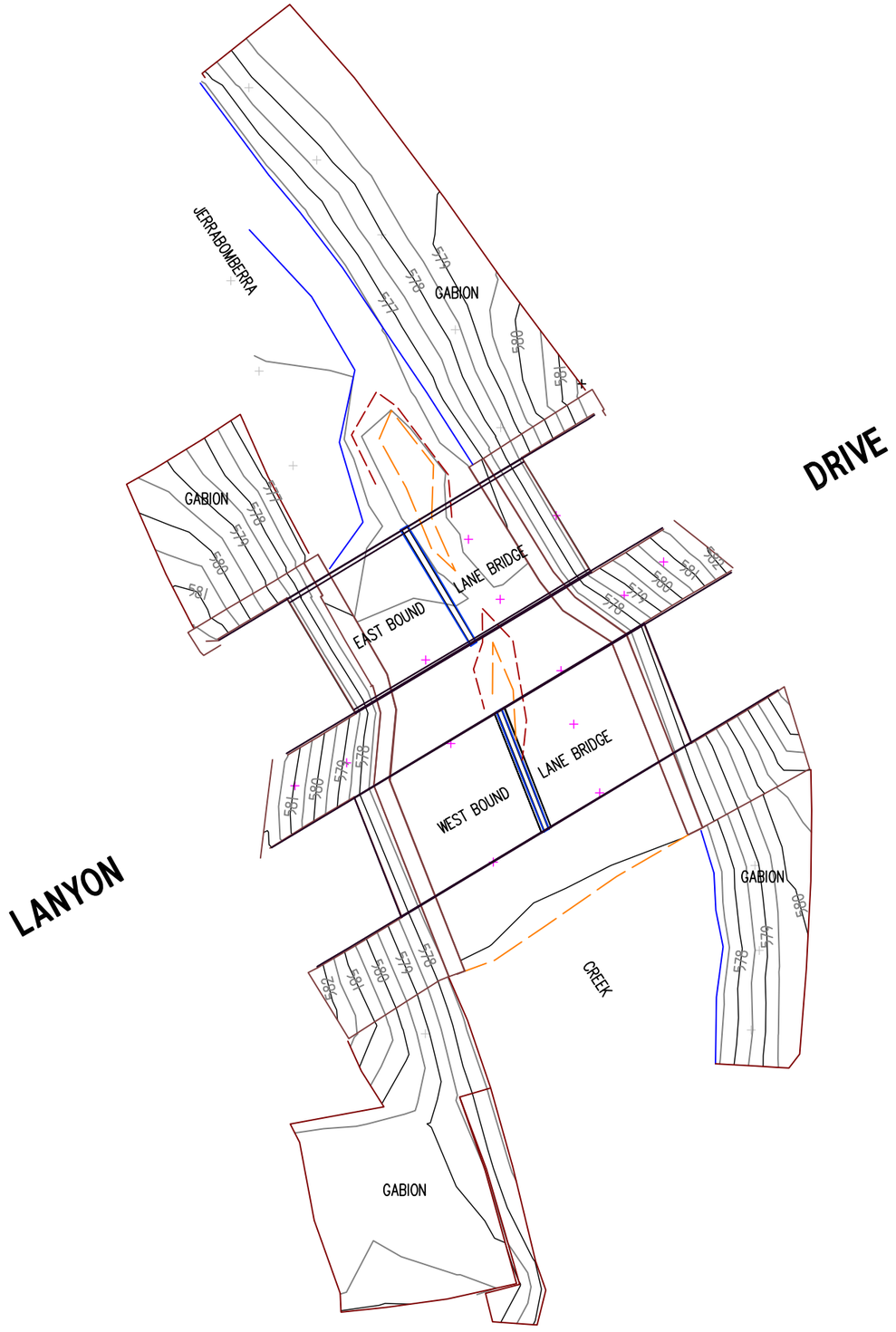
DVIEW=40°

0 25 50 75 100

SCALE 1:2500 (A1) MTRS
SCALE 1:5000 (A3)

16 June 2016

12151-03\12151-03_drone_160616 ·dwg
XRef: \ ·dwg
Field: 12150-03\Field\ ·scp



NOTES:

- DRAWING TO BE USED FOR PLANNING PURPOSES ONLY
  NO RESPONSIBILITY IS TAKEN FOR THE ACCURACY OF THIRD PARTY DATA
- INFORMATION ON THIS PLAN MAY BE LIMITED TO THAT REQUESTED BY THE CLIENT
  IT IS INTENDED FOR THE USE OF THE CLIENT & SHOULD NOT BE USED FOR ANY OTHER PURPOSE
- UNDERGROUND SERVICES HAVE NOT BEEN LOCATED – APPROPRIATE AUTHORITIES SHOULD BE CONTACTED FOR THE LOCATION OF UNDERGROUND SERVICES PRIOR TO DESIGN & CONSTRUCTION
- EXCEPT FOR VISIBLE SURVEYED POINTS ON SERVICE LINES ie: PITS, HYDRANTS etc, ANY LINES DEPICTED SHOULD BE CONSIDERED DIAGRAMMATIC ONLY AND IF ANY CONSTRUCTION IS TO IMPINGE ON UNDERGROUND SERVICES ALL PLANS SHOULD STATE THAT THEY BE EXPOSED PRIOR TO CONSTRUCTION
- MMB CANNOT GUARANTEE THAT ALL SERVICES PRESENT HAVE BEEN LOCATED
- PLEASE NOTE THAT THIS DRAWING WAS PREPARED FOR THE PURPOSES OF A GRAPHICAL REPRESENTATION DIMENSIONAL INFORMATION SHOULD NOT BE EXTRACTED FROM THE DIGITAL ELEMENTS

NOTE: SYMBOLS DENOTE POSITION OF OBJECT & ARE NOT NECESSARILY TRUE SIZE OR SHAPE

MMB PTY LTD
SURVEYORS
ABN 43 008 502 949
P: 02 6251 4976
W: mmbsurveyors.com.au
E: survey@mmbsurveyors.com.au

CLIENT: The Village Building Co.

PROJECT:
LANYON DRIVE BRIDGE OVER JERRABOMBERRA CREEK

LEGEND:
- MISC (GAS)
- FINISHED SURFACE LEVEL
- TOP OF BANK
- BOTTOM OF BANK
- EDGE OF CONCRETE
- EDGE OF GABION
- EDGE OF WATER

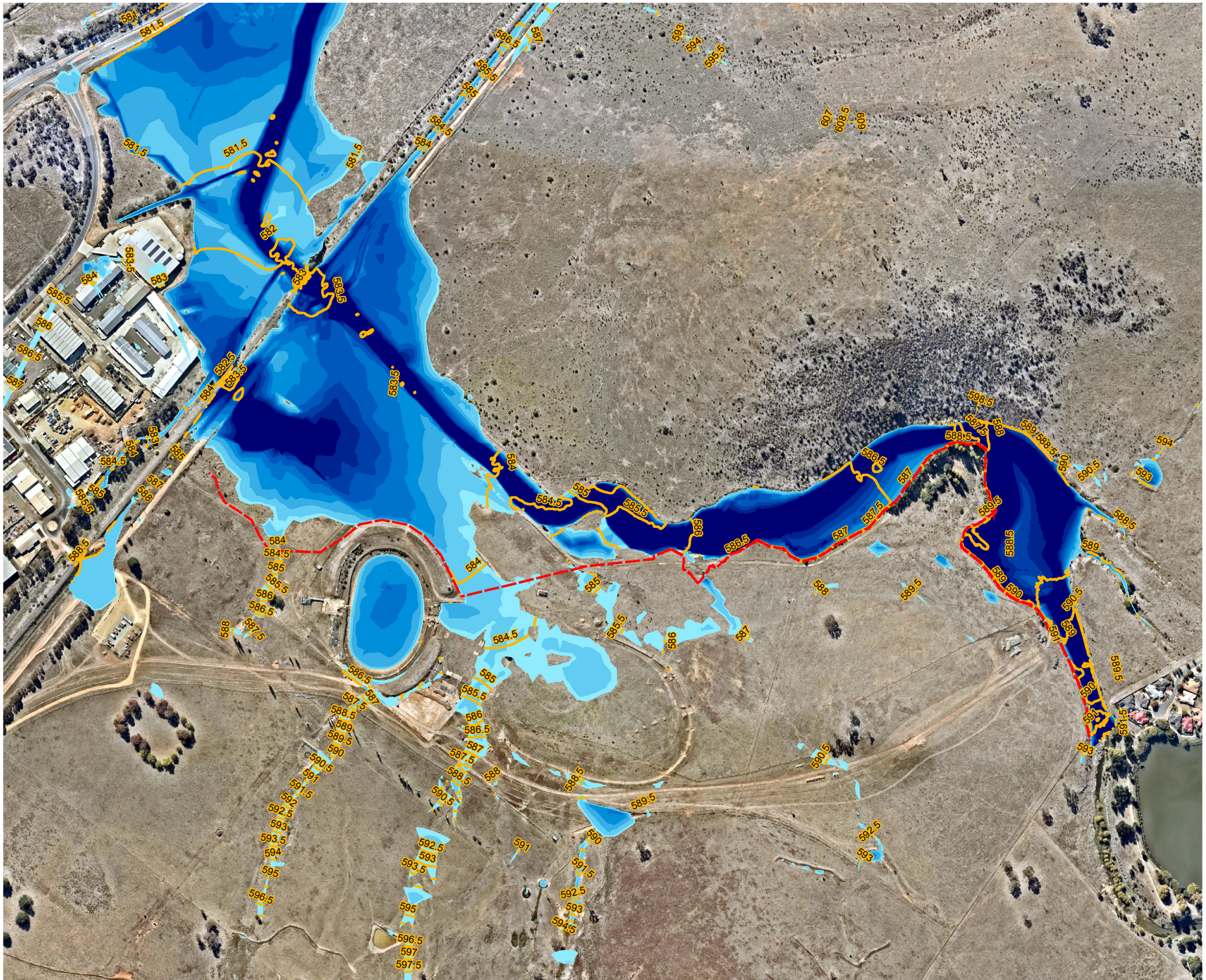
DATUM: AHD LEVELS BASED ON TG 180 RL 614·345

DRAWING TITLE:
DETAIL SURVEY

DRAWING NAME:	DRAWN:	CHECKED:	DATE:
12151-03 LANYON DRIVE BRIDGE	TD	JW	16 JUNE 2016

SCALE 1:500 AT A3

0 5 10 15 20 25 METRES



W:\Projects\16-000394\Flood Depths.mxd

Coordinate System: GDA 1994 MGA Zone 55 Datum: GDA 1994

calibre CONSULTING

LEGEND

- 0.5m Freeboard
- Flood Elevation Contour (m)

100y_d_clp

Flood Depth (m)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- >2

NOTES:

0 37.5 75 150 m

1:5,000 (A3)

N

PROJECT:

JERRABOMBERRA CREEK FLOOD STUDY

CLIENT:

Drawing Title:

100 year Flood Event Depth Results with 150mm Nulling (1m Grid model)

DRAWING NO: 16-000394 ISSUE:

FLOOD DEPTHS **01**

ISS	BY	CHK	DATE	DETAILS
01	DKH	_	26/07/16	-

Queanbeyan-Palerang Regional Council
PO Box 90
Queanbeyan
NSW 2620

J:\Jobs\115070_01\Admin\L13092016_Tralee_Review

15 September 2016

Attention: Beate Jansen

Dear Beate,

Re: Calibre Consulting – 2016 North Tralee Flood Study Review

In February 2016, WMAwater carried out a peer review of the North Tralee Flood Studies (Brown Consulting, 2010) on behalf of Queanbeyan City Council. This review concluded that the 100 year ARI flow estimate determined as part of the Brown Study (2010) was suitable for use in design flood modelling. However, the review suggested that hydraulic model should be reviewed and additional survey work be carried out to incorporate into the model. This work has now been carried out and an update has been provided by Calibre Consulting in July 2016. This letter details a review of the Calibre Study (2016), undertaken by WMAwater on behalf of Queanbeyan-Palerang Regional Council.

It is worth mentioning that the Calibre Study (2016) report contained insufficient information to undertake a detailed assessment which necessitated WMAwater to request available survey, models and model results to assist in the review. Whist this data was forthcoming, it was generally incomplete and difficult to assess due to the unusually large file sizes associated with the selection of a 1 m grid (see below for further details).

HYDROLOGY REVIEW

The hydrology was examined by WMAwater as part of the Brown Study (2010) review. The Calibre Study (2016) indicates that the same design flows have been applied and accordingly review of the hydrology has not been revisited.

HYDRAULIC MODEL REVIEW

The Brown Study (2010) investigation used the hydraulic modelling software package SOBEK whilst the Calibre Study (2016) used TUFLOW. Accordingly, the hydraulic models used for these studies have changed and a full review of the Calibre Study (2016) hydraulic model was required.

WMAwater Pty Ltd

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Model Domain and Grid Size

The Calibre Study (2016) used a 1 m grid for modelling of the 2D domain (5.3 million cells). This resulted in extraordinarily long model run times and large output files. Some of the check files and result files were so large that they could not be examined using WMAwater's GIS programs.

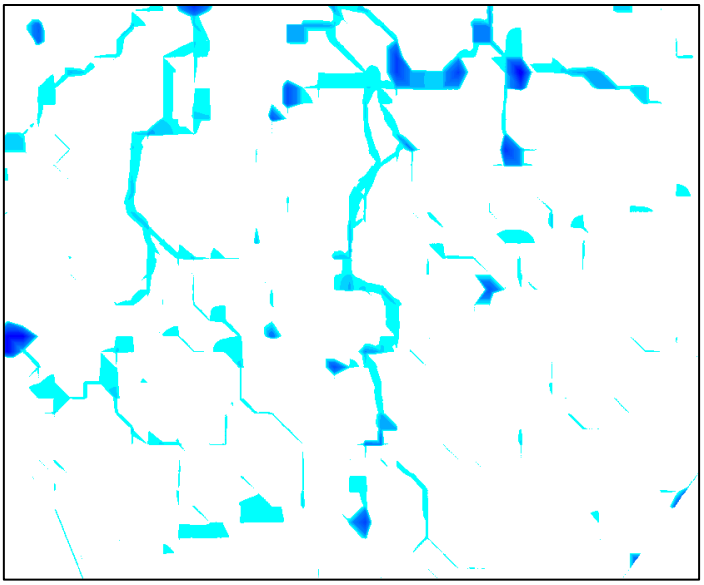
The selection of grid size for use in a hydraulic model is based on ensuring hydraulic features are adequately defined whilst not creating excessively long model run times. Of most importance is that sufficient detail of the creek channel is available. Typically, 3 to 4 cells is required to accurately model a creek channel.

TUFLOW calculates hydraulic flood behaviour based on Shallow Water Equations of which some of the assumptions that TUFLOW makes during calculation become ambiguous when the flood depth is many times greater than cell size. The Calibre Study (2016) frequently has flood depths four times greater than the selected cell size within the creek channel, with flood depths increasing to over five times the selected cell size near the Railway Bridge. TUFLOW notes that whilst this is typically not an issue, modelling of complex flow patterns (such as those experienced at the Railway Bridge) on very fine grids with deep water may lead to some issues (Reference 1).

Preliminary investigation by WMAwater indicates that a 3 - 5 m grid would be more suitable for use to determine the mainstream flood extent in the Calibre Study (2016).

It was also noted that the Calibre Study (2016) modelled overland flow to the south of the Site. The overland flow results have not been reviewed extensively, however it is noted that on preliminary examination the results appear to be unusual, particularly in the upper reaches (see Image 1). It was noted that the flow paths appear to be gridded in a semi-linear/parallel fashion. This may indicate that there may be issues with the available DEM, presumably due to the employed tinning process. Whilst this is of only minimal issue with the current study's modelling of mainstream flood behaviour, for subsequent studies focusing on overland flow the DEM should be examined in detail and validated.

Image 1: Overland Flow Flood Modelling Results (Depth)



Breaklines

Flow paths, and rail and road embankments, are hydraulic features that can have a significant impact on flood behaviour. Such features should be represented in the model by breaklines with crest and invert heights determined by ground survey.

The Railway embankment is not overtopped and accordingly, a breakline is not required to define the crest level of this structure. Additionally, no breakline has been modelled for the creek invert, however this has meant higher flood levels and is therefore conservative.

Roughness Values

Roughness estimates impact on hydraulic characteristics such as peak flood level. The Manning's 'n' values for each grid cell should be based on vegetation and other obstructions at each location. The Calibre Study (2016) has used roughness values similar to those used in established references and other nearby studies. However, the spatial distribution of more dense vegetation types have not been modelled. In particular, riparian vegetation and vegetation close to the two railway underpasses (see Image 2) has not been considered. WMAwater have examined the vegetation density at these locations and estimate that a Manning's 'n' of 0.08 should be applied.

However, as the above mentioned vegetation is generally quite localised, it is expected that failing to model these features would not lead to widespread impacts on flood behaviour.

Image 2: Dense Vegetation

Bridges and Culverts

Three major bridges and culverts exist in the study area. These are:

1. Railway Bridge (at main creek channel);
2. Railway Culverts (160 m south-east of the main creek channel; and
3. Lanyon Drive Bridge.

A summary of how these bridges have been modelled is presented in the following sections.

Railway Bridge

The Railway Bridge is situated on the main creek channel. The bridge has been modelled in 2D using methods that are not considered best practise. The bridge piers have been modelled by nulling the cells to not allow flow to pass through the areas where the piers are situated. When using this approach care needs to be taken to ensure that the predicted afflux is representative. Modelling carried out using a variety of 2D software tends to show that blocking out cells/elements for bridge piers will overestimate the afflux (Reference 2). It is recommended that for modelling of bridges in 2D, TUFLOW's 2d_lfsch layer be used to model blockage due to piers and the associated form losses.

Additionally, the deck of the Railway Bridge has not been modelled. Liaison with Calibre Consulting indicates that survey obtained of the Bridge shows that the 100 year ARI flood level is below the level of the bridge obvert and therefore will not impact on the flood behaviour. If the flood level was at or above the level of the bridge deck obvert, this would lead to an increase in peak flood level. The 2d_lfsch layer mentioned above can also be used to model the bridge deck if required.

Assuming that the bridge deck obvert is above the level of the 100 year ARI flood as reported by Calibre Consulting, then the methodology used likely produces higher peak flood levels and is therefore conservative and suitable for use to determine the 100 year ARI flood level for the Site.

Railway Culverts

The Railway Culverts have been modelled as 1D features. The individual culvert details are reasonable and match available survey. However there are a number of issues with the application of these culverts as described below:

- The culvert dimensions are 4 x 2.6 m diameter culverts. Each of the four culverts are applied to a single 1 m cell which is not the best practise method of modelling the 1D/2D interface. It is recommended that each culvert is applied to three cells so that the culvert is modelled as the flow control, not the upstream and downstream cells.
- The stability and performance of these culverts has not been checked as insufficient information was available for this review.

Without having access to the complete model results (_PO.csv, _TS.mif etc.), WMAwater postulate that the conveyance of these structures are unlikely to be overestimated. Accordingly, upstream flood levels are likely to be conservative.

Lanyon Drive Bridge

The bridge on Lanyon Drive has been applied as a 2d_lfsch layer, however no form losses have been applied to this structure. Applying no form loss leads to lower flood levels upstream. The form losses recommended in the TUFLOW manual should be applied in the absence of calibration data.

It is considered unlikely that this bridge would impact on flood levels at the Site due to Lanyon Drive Bridge been situated 500 m downstream of the Railway Bridge. Additionally, the Railway forms a major control which would not likely be significantly affected by downstream flood behaviour.

Structure Blockage

Structure blockage can significantly affect peak flood levels both upstream and downstream of a structure. Blockage of hydraulic structures can occur with the transportation of materials by flood waters, which in the vicinity of Tralee is most likely vegetation such as logs and fallen trees but may also be sedimentation or urban debris such a wheelie bins.

It is recommended that a conservative approach to incorporate potential structure blockage in accordance with the ARR Blockage Guidelines (Reference 3) be incorporated into flood modelling of all design events for all culverts. Bridges with diagonal spans exceeding 6 m are not likely to block during a flood event (Reference 3) and therefore do not need to be blocked for design runs.

As the diagonal spans of both the Railway and Lanyon Drive Bridges exceed 6 m, modelling of structure blockage is not required for design events. However, the modelling of blockage for the Railway Culverts would be considered best practise.

The Railway Culverts convey a smaller portion of the total flow when compared to the Railway Bridge and accordingly have less of an impact on upstream flood levels. As mentioned previously, the flow in these culverts could potentially be restricted due to the culverts being linked to only one cell much

smaller than the size of the culvert. This is therefore unlikely to be a major issue when considering design flood levels for the 100 year ARI flood event.

Boundary Conditions

The upstream boundary was modelled as a time varying hydrograph using TUFLOW's QT boundary. The downstream boundary was modelled using a HQ boundary. These methods of modelling boundaries are suitable for use in the current study.

Hydraulic Model Calibration

The Floodplain Development Manual requires that numerical models be calibrated and validated. The calibration process consists of adjusting appropriate parameter in the model to obtain agreement between recorded and simulated water levels during a major flood. No calibration/validation of the hydraulic model has been undertaken as part of the Calibre Study (2016).

As typical model parameters have been used in the Calibre Study (2016) a detailed calibration of the hydraulic model may not be required depending on what the model results are to be used for. The model is not suitable for determining finished flood levels for residential properties, however is likely suitable for undertaking a rezoning assessment for the reasons described below.

DISCUSSION

The Site is situated upstream of the Railway embankment which forms a major control for flows upstream. The 100 year ARI flood level is typically 0.2 – 0.3 m below the railway embankment crest height dependant on location. If the crest height of the embankment was to be overtopped by flow, any further increase in flow would lead to a comparatively minor increase in peak flood level compared to before the Railway embankment crest height is overtopped. This indicates that above the threshold created by the Railway embankment, peak flood levels are relatively insensitive to the assumptions made in the hydraulic model.

Furthermore, due to the steep terrain on either side of the creek floodplain, any increase in flood level leads to a relatively minor increase in flood extent. For example, assuming the 100 year ARI flood level estimate was to increase by 0.4 m, thus overtopping the Railway embankment, the average increase in flood extent at the Site would be approximately 10 m (maximum of ~15 m).

It is noted that a freeboard of 0.5 m is to be applied to the 100 year ARI flood level. This freeboard should sufficiently account for any error associated with the hydraulic modelling techniques.

CONCLUSIONS AND RECOMMENDATIONS

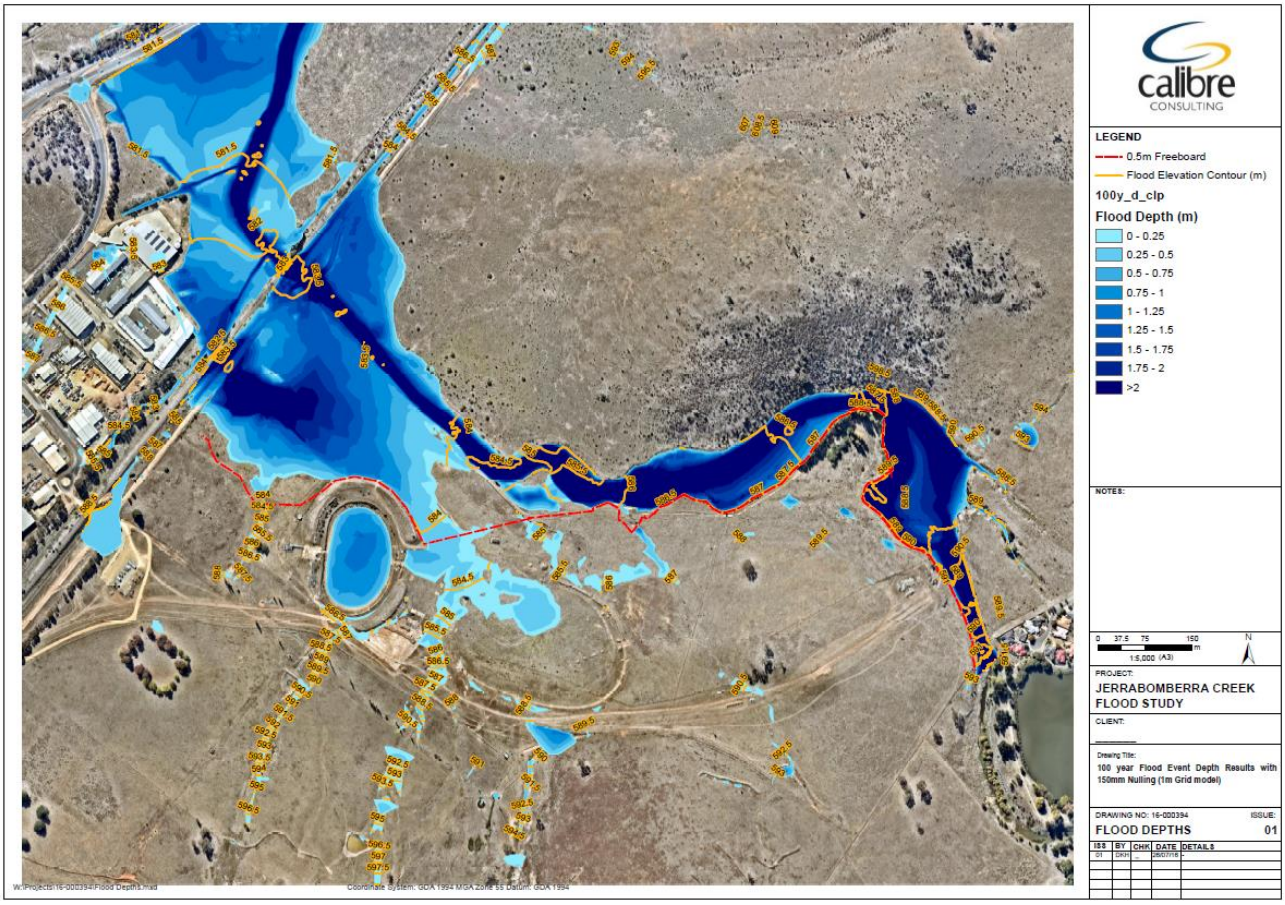
The Calibre Study (2016) hydraulic model was found to have a number of issues making it unsuitable for determining finished floor levels for residential properties and other outputs that are required as part of a Flood Study performed under the NSW Floodplain Management Program.

However, the assumptions and modelling methods applied have been determined to be generally conservative. This coupled with the characteristics of the control formed by the Railway embankment and the steep terrain on the surrounding floodplain, indicates that the model results are suitable for rezoning assessment purposes when used in conjunction with a 0.5 m freeboard.

Council have requested that the Calibre Study (2016) FPA (as derived using the 100 year ARI event + 0.5 m freeboard) be examined to investigate the suitability for incorporation of this information into the draft plan for Council's LEP. The FPA extent as presented as the red line on the final page of the Calibre Study (2016) and recreated herein as Image 3, has been determined as representative of the 100 year ARI event + 0.5 m freeboard. However it should be noted that the FPA extent may need to be extended further to the north-west until the Railway embankment is met, depending on the

proposed rezoning area. Additionally, it should be noted that the FPA extent has not been determined for the northern floodplain which may be a requirement of Council.

Image 3: Calibre Study (2016) FPA – 100 year ARI Event plus 0.5 m



It is recommended that for future studies, a more detailed hydraulic model be derived that addresses the issues highlighted throughout this letter. The model should also be calibrated if possible.

No comment is made as part of this letter as to the accuracy of the overland flow results to the south of the Site.

REFERENCES

TUFLOW

1. **TUFLOW Forum**
   http://www.tuflow.com/forum/index.php?/topic/785-purely-2d-river-model-is-this-suitable/

TUFLOW

2. **Modelling Bridge Piers and Afflux in TUFLOW**
   http://www.tuflow.com/Download/Technical_Memos/Modelling%20Bridge%20Piers%20in%202D%20using%20TUFLOW.pdf

Engineers Australia

3. **Australia Rainfall and Runoff, Project 11: Blockage Guidelines for Culverts and Small Bridge**
   February 2015

Yours Sincerely,

WMAwater

Zac Richards

Associate