BURKE SHIRE COUNCIL

Burketown Flood Risk Management Study

Report

April 2020

M7106_002-REP-001-2

www.engeny.com.au
P: 07 3221 7174
Level 7, 500 Queen St Brisbane QLD 4000 | PO Box 10183 Brisbane QLD 4000

DISCLAIMER

This report has been prepared on behalf of and for the exclusive use of BURKE SHIRE COUNCIL and is subject to and issued in accordance with BURKE SHIRE COUNCIL instruction to Engeny Water Management (Engeny). The content of this report was based on previous information and studies supplied by BURKE SHIRE COUNCIL

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of BURKE SHIRE COUNCIL or Engeny is not permitted.

JOB NO. AND PROJECT NAME: M7106_002 BURKETOWN FLOOD RISK MANAGEMENT STUDY

DOC PATH FILE: \\online.com\files\Management\Projects\M7000_Miscellaneous Clients\M7106_002 Burketown FRMS\07 Deliv\Docs\Report\M7106_002-REP-001-2-Burketown-FRMS.docx

REV	DESCRIPTION	AUTHOR	REVIEWER	PROJECT MANAGER	APPROVER / PROJECT DIRECTOR	DATE
Rev 0	Client Issue	Karl Umlauff	Mark Page	Karl Umlauff	Mark Page	20 March 2020
Rev 1	Client Issue	Karl Umlauff	Mark Page	Karl Umlauff	Mark Page	3 April 2020
Rev 2	Client Issue	Karl Umlauff	Mark Page	Karl Umlauff	Mark Page	8 April 2020
Signatures						

CONTENTS

Appendices

List of Tables

List of Figures

ABBREVIATIONS AND ACRONYMS

1D	One-dimensional
2D	Two-dimensional
AAD	Average Annual Damage
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
ATSI	Aboriginal and Torres Strait Islander
BoM	Bureau of Meteorology
CBA	Cost Benefit Assessment
CBR	Cost Benefit Ratio
CPI	Consumer Price Index
DAF	Department of Agriculture and Fisheries
DATSIP	Department of Aboriginal and Torres Strait Islander Partnership
DEHP	Department of Environment and Heritage Protection
DFE	Defined Flood Event
DFL	Defined Flood Level
DNRM	Department of Natural Resources and Mines
DTMR	Department of Transport and Main Roads
EY	Exceedances per Year
FIA	Flood Impact Assessment
FRMP	Floodplain Risk Management Plan

GIS	Geographic Information Systems
IFD	Intensity Frequency Duration
LiDAR	Airborne Light Detection and Ranging Survey
LDC	Local Disaster Co-ordinator
LDCC	Local Government Disaster Co-ordination Centre
LDMG	Local Disaster Management Group
NPV	Net Present Value
OFP	Overland Flow Path
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QRA	Queensland Reconstruction Authority
RFFE	Regional Flood Frequency Estimation
ROG	Rain on Grid
SES	State Emergency Service
WSE	Water Surface Elevation

Please note that technical terms are explained in the Glossary of Terms in Appendix A.

1. INTRODUCTION

Engeny Water Management (Engeny) was engaged to deliver the Burketown Flood Risk Management Study (Burketown FRMS) on behalf of Burke Shire Council (hereafter referred to as BSC or Council). The major stages of the study were:

I. Project Inception – collect and review updated data, review previous work, undertake site inspection and attend inception meeting.

II. Flood Risk Assessment

   a. Regional flood model and create local flood model

   b. Analysis of the flood behaviour and associated risks to the community and infrastructure using outputs from the flood study.

III. Flood Risk Management Measures

   a. Identification of measures to improve flood risk across emergency management, planning and engineering.

   b. Flood impact assessment, where required, of the selected engineering measures using flood model simulations.

IV. Development Planning – utilise the local and regional flooding characteristics to inform Council of the flood risks and stormwater management considerations relating to proposed development areas.

1.1 Previous Studies

The following studies focussed on Burketown have been undertaken by Engeny. The objectives of each study are provided below.

- *Queensland Reconstruction Authority. Phase 2 Flood Mapping – Bundle 11. Burketown Flood Modelling by* Engeny Water Management dated April 2013.

The scope of the study was to develop a regional scale hydraulic model using inflow hydrographs provided by Queensland Reconstruction Authority to determine flood levels, velocities and hazard (and produce flood maps) in the vicinity of Burketown. The purpose of the study was to identify high level flood risks.

- *Burke Shire Council. Burketown Flood Mapping* by Engeny Water Management dated October 2015.

The scope of the study was to estimate the 1 % AEP peak discharge flood flow at Burketown using flood frequency analysis of DNRM gauges, flood frequency analysis of the Burketown

Airport gauge and broad scale rain-on-grid hydraulic modelling. The purpose of the study was to set flood planning levels for the Burketown area. The outcome of the study was that the 2011 flood event be adopted as the Defined Flood Event (DFE) for Burketown with additional freeboard set by Council in accordance with desired risk profiles. Flood maps were produced for Burketown based on the design flow estimates.

1.2 Study Area

Burketown is located on the Savannah Way in far North West Queensland and is considered a remote living community, being approximately an eight-hour drive (460 km via Gregory) or two-hour flight to the closest major city of Mount Isa. Burketown has a resident population of around 170 (Burke Shire Council, 2020). The Burketown locality is shown in Figure 1 (Appendix D).

The town is located on a remnant of the main channel of the Albert River and represents the most eastward extent of a very flat ridgeline that provides the highest ground (about 5 metres above sea level) on the western bank of the river in this area. A smaller channel bounds the southern side of the town centre, separating it from the airport just to the west where the land is of similar elevation. Areas to the north, east and west are low lying, with tidal flats and mangroves.

Burketown is susceptible to flooding from the Albert River floodplain as well as overland flow paths within the town area. Flooding of the Albert River could also occur from flood water breakout from the Nicholson or Gregory Rivers.

The Shire has a dry tropical climate with a clear wet and dry season. The wet season extends through the summer months from November to April, with most rain falling in late December to March. The remaining part of the year from May to October is generally dry with less than 15 mm of rain per month. Burketown has an average daily temperature range of 20.7°C to 33.4°C and an average annual rainfall of 803 mm ([2]Bureau of Meteorology, 2020).

1.3 Flood History

1.3.1 Flood Level Classification and Flood History

The Bureau of Meteorology has classified minor, moderate and major flood levels for Burketown at the Burketown Airport Gauge per Table 1.1.

Table 1.1 Flood Level Classifications for the Burketown Airport Gauge on Albert River

Flood level classification	Gauge flood level
First report height	4.5 m
Minor flood level	5 m
Moderate flood level	5.5 m
Major flood level	6 m

Historical flood levels at this gauge are presented below.

Table 1.2 Burketown Airport River Height Station Historical Flood Levels ([3]BOM, 2019)

Month and Year	Peak flood level at Burketown Airport	Flood Classification
December 2000	6.55	Major
January 2004	5.40	Minor
March 2006	5.90	Moderate
January 2009	6.50	Major
February 2009	6.00	Major
March 2011	6.78	Major

1.3.2 March 2011 Flood

The most recent major flood that has affected Burketown was in March 2011 with flood waters peaking at 6.78 metres at the Burketown Airport height gauge on 16 March 2011.

The Burketown Airport rainfall gauge recorded a total of 196 mm in January, 300 mm in February and 698 mm in March of that year ([2]Bureau of Meteorology, 2020).

The flood event required the relocation of residents in low-lying areas internally within town (ABC News, 2011).

Various news articles about the 2011 flood provide an insight into regional flooding characteristics that affect Burketown:

- Flooding was characterised at the time of the event by the Burke Shire CEO, Gary Letts, as a ‘very, very slow movement of water into the streets’, while the peak level remained steady for a few days (ABC North West QLD, 2011)

- The water was shallow and slow flowing in the town area (verbal correspondence during stakeholder meeting, 2019)
- Regional floods are unpredictable (ABC North West QLD, 2011)

It was stated at the time by Burke Shire Deputy Mayor, Ernie Camp, that 450 residents were facing up to eight weeks of isolation (Courier Mail, 2011). Advice from Council was that this isolation was not only for Burketown residents but also people at remote properties due to regional roads being inundated and not passable to traffic.

2. STUDY APPROACH

The approach to floodplain risk management in this study is in general alignment with *Managing the Floodplain: a Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017). The guideline is part of the Australian Emergency Management Handbook Series and provides a structure within which the flood risk management study has been delivered.

An excerpt from the guideline, the flood risk management framework, is depicted in Figure 2.1.

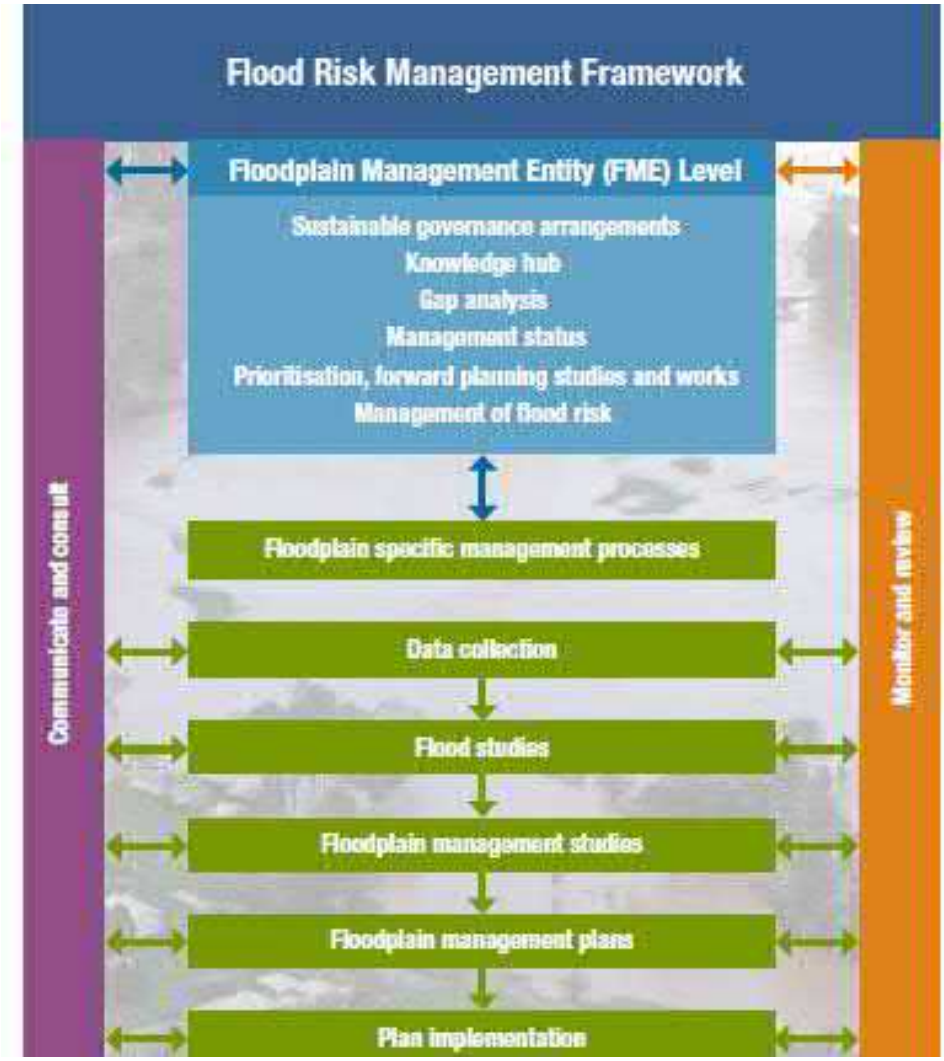


Figure 2.1 Flood Risk Management Framework

The study approach has been based on the objectives defined in section 2.1 and the scope is presented in section 2.2.

2.1 Study Objectives

The key objectives of the Burketown Flood Risk Management Study were to:

- Develop modelling and mapping products to identify flood risks spatially within and around Burketown.
- Establish an understanding of the existing flooding behaviour of the Albert River floodplain and local catchment using the output from the flood study to map key flood risk characteristics.
- Define the flood risks to existing and future development areas and increase the community's awareness and resilience.
- Identify and recommend potential improvements to emergency response systems, property and flood behaviour modification and development planning.
- Provide advice to BSC as to the suitability of previously identified development areas.

2.2 Study Scope

The scope of works for the Burketown Flood Risk Management Study were as follows:

- Stage 1: Project Inception
  - Data collection and review
  - Review existing flood studies
  - Inception meeting
  - Site inspection
- Stage 2: Flood Risk Assessment
  - Update regional flood model previously developed by Engeny with latest data to define flooding behaviour and characteristics for the Albert River floodplain based on current conditions
  - Develop coupled hydrologic/hydraulic model to define flooding behaviour and characteristics for the local catchment area
  - Assess and map flood characteristics (depth, velocity, hazard)
  - Assess current emergency response measures (flood warning, evacuation and response).
- Stage 3: Flood Risk Management Measures
  - Identify potential modifications to emergency response measures (flood warning, evacuation and response)
  - Prepare and assess a list of potential property and flood behaviour modification measures
  - Assess Council defined development areas
  - Identify potential stormwater management planning options.

3. PROJECT INCEPTION

3.1 Inception Meeting

A workshop was held at the Burke Shire Council administration building on Wednesday 25 September 2019 to discuss the priorities regarding flood risk management for Burke Shire Council.

The attendees were Clare Keenan (Chief Executive Officer), Cr Ernie Camp (Mayor), Cr Paul Poole (Deputy Mayor), Cr John Clarke, Cr Tonya Murray, Cr John Yanner, Philip Keirle (Executive Manager Strategic Projects), Karl Umlauff (Principal Engineer, Engeny Water Management).

Council advised that major earthworks for flood mitigation, new roads or drainage structures are not preferred or considered necessary.

3.2 Data Collection

Council provided the following information, which was utilised in the flood models:

- Digital elevation model overlays including erosion gully, Moungibi Oval design surface, Firefly Street precinct survey, Moungibi Oval and Cemetery corridor survey, Moungibi Oval and Raw Water Pipe corridor survey, AusNorth Consultants survey database, Gregory Street drainage channel survey
- Cross drainage culvert configurations and invert levels undertaken by AusNorth Consultants.

Council also provided subdivision plans for West Burketown and South Burketown (Appendix G).

3.3 Site Inspection

A site inspection of areas of interest around Burketown was undertaken by Karl Umlauff of Engeny on Wednesday 25th to Friday 27th September 2019. The following areas were visited, and information obtained:

- Confirmation of locations of critical and vulnerable infrastructure around Burketown, including photographs
- Measurements of selected culvert crossings
- Measurements of the Albert River traffic bridge
- Historical flood levels at a property on Bowen Street
- South Burketown and West Burketown areas.

4. FLOOD RISK ASSESSMENT

4.1 Introduction

A flood risk assessment has been undertaken for the purpose of assisting BSC to understand existing flood risks posed to community, property and infrastructure, and whether or not Council's land-use planning intentions are appropriate, given the level of risk posed by flooding. Additionally, the flood risk assessment forms the basis upon which mitigation measures have been identified.

4.2 Flood Sources

Generally, there are two key mechanisms of flooding that affect Burketown township; regional flooding in the Albert River floodplain and local flooding (overland flow) from localised catchments. This chapter describes the regional and local flood behaviour and impacts on critical or vulnerable infrastructure and facilities. The key flood risks from local flooding have been summarised to inform future drainage studies for mitigation of this flooding.

4.3 Regional Flood Risk Assessment

4.3.1 Albert River Catchment Context

For the purposes of this regional flood risk assessment, the Albert River catchment is the source of flood water that affects Burketown. The Albert River catchment is difficult to define as water could enter the catchment from flood water breaking out of the Gregory River or the Nicholson River.

The Nicholson River catchment extends far west and into the Northern Territory. The Gregory River catchment extends to the south and west into the Northern Territory. The combined catchment extent (Queensland part), the Nicholson, Gregory and Albert Rivers relative to Burketown are shown on the figure ([1]Bureau of Meteorology, 2019) in Appendix C.

The upstream reaches of the Albert River source flows from Beames Brook and One Mile Creek, and Running Creek and the Barkly River, which are considered to be part of the Gregory River floodplain in large flood events. These breakout locations from the Gregory River to the upper Albert River catchment are generally considered to be north of Wills Road and Gregory township.

One Mile Creek and Barkly River are inflow tributaries to the Albert River and are adjacent and east of the confluence of the Nicholson River and Gregory River as shown in Figure 4.1. The Nicholson River and Gregory River upstream of their confluence share floodplains and it is considered that in large flood events flood water from the upper Nicholson River catchment could enter the Gregory River system and subsequently the Albert River's inflow tributaries.

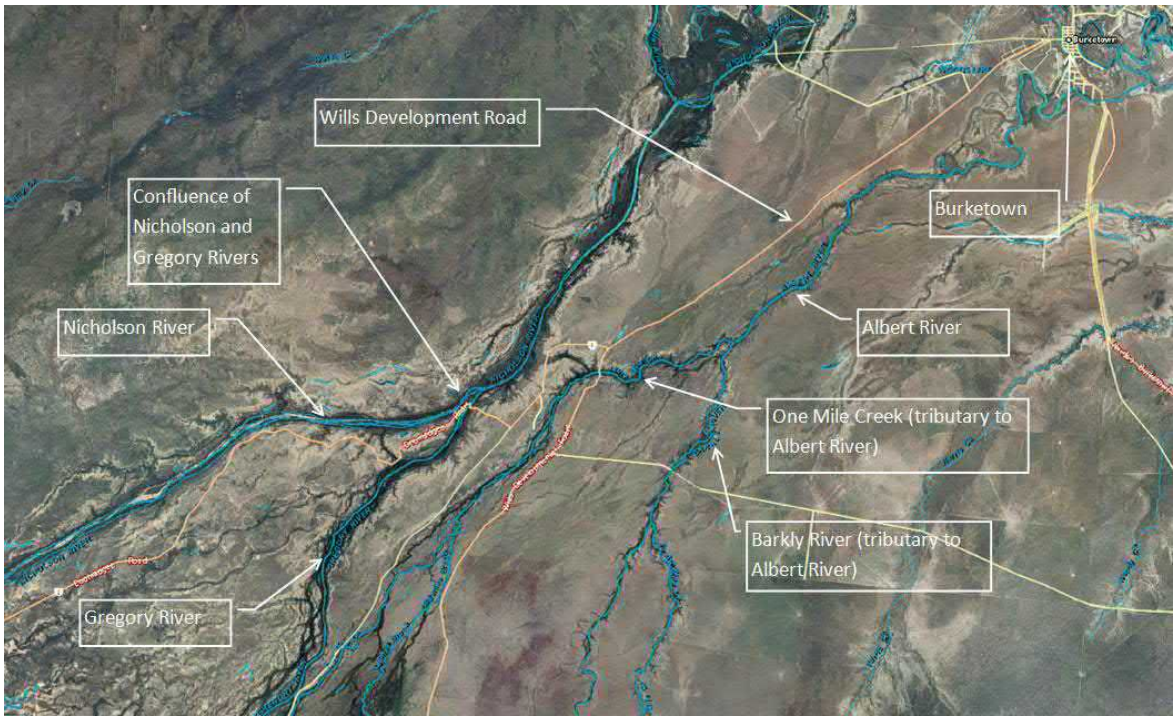


Figure 4.1 Location of Albert River Tributaries Relative to Gregory River and Nicholson River (Image sourced from QLD Globe, 2020)

4.3.2 Albert River Morphology near Burketown

The Albert River is a meandering incised channel within the floodplain that generally flows from the south-west to the north-east on the southern side of Burketown towards its outlet to the Gulf of Carpentaria. The river passes Burketown Airport and the suburb of South Burketown on the southern side. An anabranch of the Albert River has formed and is immediately adjacent to the eastern limit of Burketown. The river is then crossed by the Albert River bridge at Nardoo-Burketown Road and continues generally to the east and north-east away from Burketown where it is later met by Millar Creek. The Albert River continues to its outlet at the Gulf of Carpentaria.

Figures showing the general elevation ranges of the floodplain topography around Burketown are presented in Appendix D.

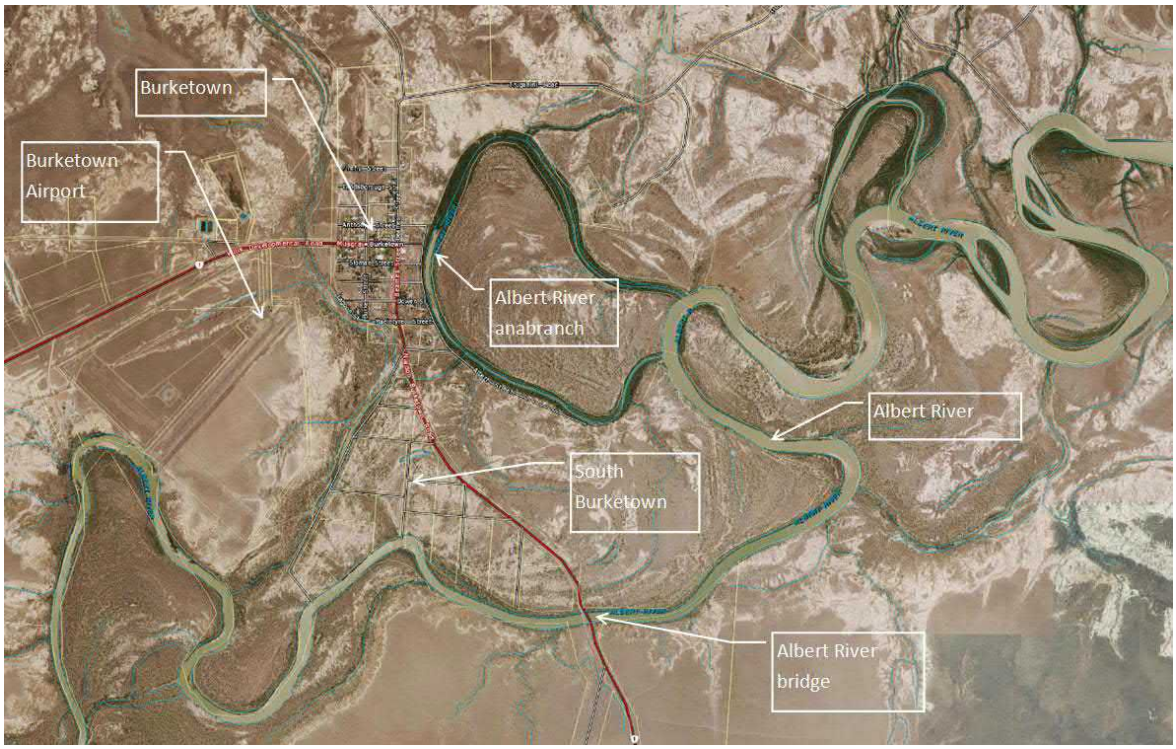


Figure 4.2 Albert River and Burketown (Image sourced from QLD Globe, 2020)

4.3.3 Design Flood Estimates, Flood Simulations and Defined Flood Event

Three methods were applied to determine the 1 % AEP peak discharge at the Burketown Airport Gauge:

- Flood Frequency Analysis (FFA) using DNRM gauges determined the 1 % AEP peak discharge at Burketown are 3750 m^3/s (linear) and 4560 m^3/s (logarithmic)
- Broad scale hydraulic modelling method determined the 1 % AEP peak discharge at Burketown is 3100 m^3/s
- FFA undertaken using data from the Burketown Airport gauge determined the 1 % AEP peak discharge at Burketown is 4243 m^3/s.

Iterative hydraulic modelling determined that the 2011 flood had a peak discharge of 3329 m^3/s to match the simulated flood level with the recorded Burketown Airport gauge flood level. The FFA results suggest the 2011 event was between the 2 % and 5 % AEP.

The FFA showed there is variation in the 1 % AEP peak flow estimates with inherent uncertainty, therefore flood simulations for events greater than the 2011 flood were not undertaken. Justification for this is outlined below:

- Minimal uncertainty exists in the flood level for the 2011 event as it is a gauged recording. This is in contrast to the design flood estimates that have been made. It is considered that adoption of a DFE with minimal uncertainty exposes Council to less risk.
- The peak flow estimated for the 2011 flood event falls within the range of flow values estimated for the 1 % AEP design flood for Burketown, although at the lower end of the estimates.
- Adoption of the highest recorded flood level as the DFE is considered to be consistent with the provisions in the State Planning Policy (SPP) guidance material for flood risk ([2]DILGP, 2016). The SPP allows for Councils to adopt their choice of event as the DFE.

Council has subsequently adopted the 2011 flood as the DFE in the *Burke Shire Council Planning Scheme (2020).*

The 2011 flood peak discharge of 3329 m^3/s was then simulated with the current configuration of the Albert River bridges and incorporated earthworks within the model domain undertaken after 2011. This model configuration is considered to be representative of the 2011 flood for current conditions and has been adopted for flood risk assessment purposes in this study.

A full description of the flood frequency analysis and regional flood modelling is provided in Appendix B.

4.3.4 Flood Behaviour

Flood behaviour is often based on flood hazard and the characteristics of flow within the floodplain. The flood hazard rating classification utilised in the hydraulic modelling is consistent with that developed by the Queensland Reconstruction Authority (QRA) (QRA, 2012).

The basis of this classification is the relationship between flood depth and flood velocity at each given location. The depth is multiplied by the velocity of the flow to understand how hazardous the flow at the location is to life and property. For example, flow with a depth of 0.4 m and velocity of 2 m/s is considered outside the typical vehicle stability tolerance for a large four-wheel-drive. Figure 4.3 summarises this classification system.

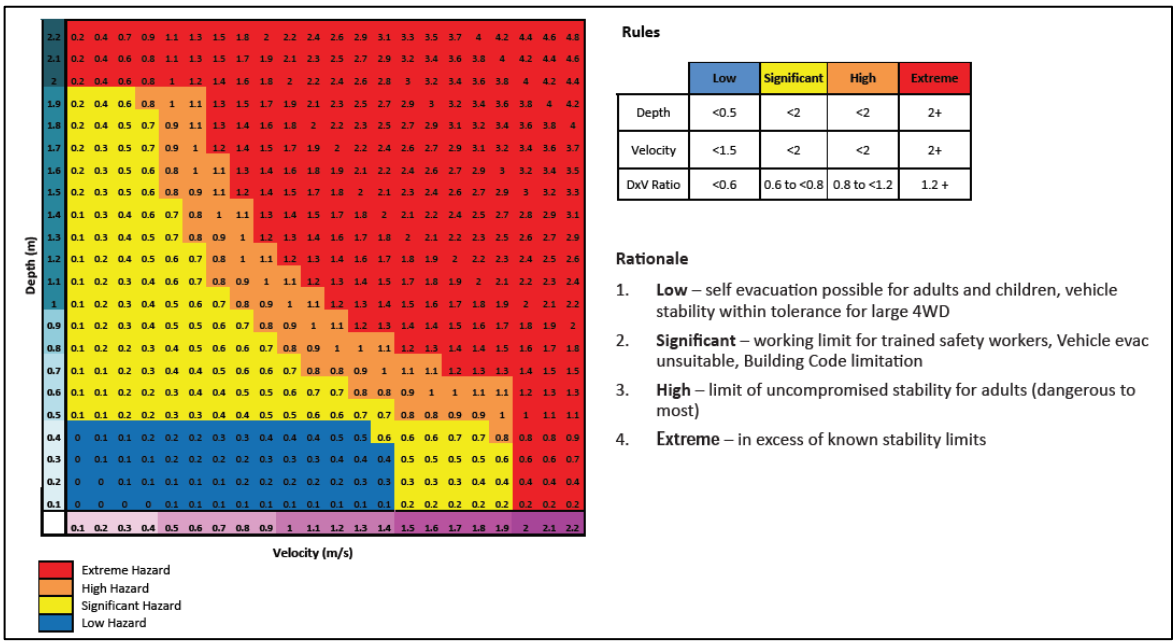


Figure 4.3 QRA Flood Hazard Classification

4.3.5 Flood Characteristics

Regional flood modelling of the 2011 event of the Albert River floodplain demonstrates that flood water approaching Burketown is very widespread. The Albert River would generally have a low conveyance capacity compared to the entire floodplain and flood maps show large inundation extents outside the bounds of the river. The flood height is the highest at the south-west of Burketown and lowest at the north-east of Burketown.

There are some flood-free areas, primarily in the town centre, in the north of town and east of the Water Treatment Plant.

To describe the flood characteristics of the 2011 regional flood event simulation, flood maps have been produced (presented in Appendix E) for several parameters, including, flood height (inundation extent), flood depth, flood velocity and flood hazard.

4.3.6 Flood Extent Verification

Figure R5 (Appendix D) shows that all of South Burketown is predicted to be inundated and most of the airport area (except the runway, apron (light aircraft parking area) and passenger waiting area is predicted to be inundated.

Anecdotal information (comments from Cr Tonya Murray and Cr Paul Poole) received at the stakeholder meeting was that the runway was not inundated in any recent major floods and the flood extents depicted in Figure R1 and Figure R5 are a reasonable representation of the 2011 event.

4.3.7 Critical or Vulnerable Infrastructure and Facilities within Burketown

There are numerous critical or vulnerable infrastructure and facilities within Burketown that would be affected during major flood events. These are listed in Table 4.1 with their purpose during a flood emergency. Descriptions of the potential flood impacts on these facilities during regional and local flood events are provided in Sections 4.3.7 and 4.4.3, respectively.

Table 4.1 Critical or Vulnerable Infrastructure and Facilities

Critical or Vulnerable Infrastructure or Facility	Address	Purpose of Infrastructure or Facility during flood emergency
Airport	Access from Wills Developmental Road (National Highway 1/State Route 84)	Transfer of general or medical supplies or emergency services personnel. Transfer of injured persons to other health centres.
Albert River Bridges	National Highway 1 (Nardoo Burketown Road)	Access to or from town
Caravan Park	Sloman Street	Itinerant residents with caravans and motorhomes may need to relocate to higher ground within Burketown or out of Burketown to towns not likely to be affected in the event of a pending major flood
Carpentaria Land Council Aboriginal Corporation	Musgrave Street	Community facility
Communications Tower	Truganini Road	Telecommunications (Mobile and Landline only)
Community Hall	Sloman Street	Community facility. Evacuation Centre.
Council offices	Musgrave Street between Burke Street and Beames Street	Co-ordination of Emergency Response.
Council Works Depot	Eastern side of Beames Street between Musgrave Street and Sloman Street	Plant, equipment and work crews during emergency activation, response and recovery
Diesel Plant / Ergon Power Station	Corner of Anthony Street and Burke Street	Power supply

Critical or Vulnerable Infrastructure or Facility	Address	Purpose of Infrastructure or Facility during flood emergency
Fire, SES and Volunteer Marine Rescue	Eastern side of Beames Street opposite Firefly Street	Sheds for operations and training and to house 4WD vehicle (1), flood boat (1) and trailer (1).
Kindergarten	Corner of Landsborough Street and Beames Street	Community facility
Petrol Station and Grocery Store	Corner of Beames Street and Gregory Street	Provision of general supplies and fuel
Police Station	Gregory Street	Co-ordination of Emergency Response
Post Office and Convenience Store	Corner of Beames Street and Sloman Street	Provision of general supplies
Primary School	Corner of Beames Street and Marshall Lane	Community facility
Primary Health Care Clinic	Truganini Road (north of town)	Provision of health care services
Wastewater Treatment Plant	Access from Wills Developmental Road (National Highway 1/State Route 84)	May require shutdown if inundated. Sewage may back up into houses due to flooded underground sewerage system.
Water Treatment Plant	Access from Wills Developmental Road (National Highway 1/State Route 84)	Supply of potable water

4.3.8 Flood Impacts on Critical or Vulnerable Infrastructure and Facilities

The following utilities and facilities were reported to be impacted during the most recent major flood in 2011 according to ABC North West Queensland in 2011:

- Telecommunications were down due to vermin damaging the network and some residents reported not being able to use the phone for more than a week
- The sewerage system was inundated in low-lying areas and some houses experienced sewage backing up, which required portable toilets to be set up in the dry areas of town
- Burketown Airport runway was partly inundated preventing larger aircraft from landing, only light aircraft could land meaning provision of supplies to town was restricted. Further advice from Council regarding the 2011 flood was that 300 m of landing area at the river end and approximately 50% of the apron was inundated.

The LDMP states an area of concern is the location of the water treatment plant and that the power supply to it is via poles and lines from the diesel plant (corner of Burke St and Anthony St). The poles and lines are within the road reserve of Wills Developmental Road and traverse the major overland flow path between the town centre and the Airport Access Road. The 2011 flood depth and velocity maps (Appendix E) show the flood depth is up to 2 m and the flood velocity is up to 1.5 m/s in this overland flow path where the power poles are located. Impact of flood debris and scour around the poles may reduce their stability causing them to fall, hence cutting power to the water treatment plant. Protection of the poles against debris and scour is recommended and is described in Section 5.3.

Floods maps (Appendix E) for an event equivalent to the 2011 flood under current conditions show that most of the critical or vulnerable infrastructure and facilities are not inundated. It is noted that flood depths would be higher for events of magnitude greater than the 2011 flood and the infrastructure and facilities may be impacted. Critical or vulnerable infrastructure or facilities that are not inundated are not shown.

Table 4.2 Flood Impacts on Critical or Vulnerable Infrastructure or Facilities during 2011 Regional Flood Event

Critical or Vulnerable Infrastructure or Facility	Depth of Inundation for 2011 regional flood event (m)	Inundation comment	Access comment during 2011 regional flood event
Airport	Varies.	Southern end of runway inundated, and part of apron inundated. Flood borders the runway perimeter.	Airport not accessible by road due to inundation.
Albert River Bridges	N/A	Approaches inundated	Not accessible
Powerline/poles between Diesel Plant and WTP	Up to 3-4 m	Flood velocities approximately 0.5 – 1 m/s but may be higher locally.	N/A
Primary Health Care Clinic	N/A	Lot partially inundated at south east corner	Accessible from town centre
Wastewater Treatment Plant	Not inundated	Flood water causes backing up of system for low lying areas	Not accessible from town centre due to inundation over Wills Developmental Road
Water Treatment Plant	Not inundated	N/A	Not accessible from town centre due to inundation over Wills Developmental Road

4.3.9 Key Road Crossings within Burketown

Vehicle access within and beyond the town area could be cut during regional or local flooding until flood waters recede and unsealed roads dry out, are inspected and repaired for traffic to safely pass.

During flood events when road crossings are overtopping, flow conditions can be highly variable in that:

- The depth of overtopping flow can vary along the crossing
- The flood hazard (depth times velocity product) can vary along the crossing
- Depth and flood hazard can vary with time
- Road pavement may have been washed away and not visible beneath flood water making vehicle passage dangerous
- Floating or submerged flood debris can impact moving vehicles or pedestrians
- The additional risk of transient salt-water crocodiles during flood conditions can pose hazard to pedestrians moving through flood water.

Key road crossings within Burketown are as follows:

Wills Developmental Road (National Highway 1/State Route 84) west of Musgrave Street.

This is a sealed road and is the sole access route between town and Burketown Airport, the Wastewater Treatment Plant and the Water Treatment Plant. The gully cross-drainage culverts comprise reinforced concrete box culverts in the following configuration:

- 15/1200 mm (wide) x 900 mm (high) on the left bank,
- 7/2500 mm (wide) x 1400 mm (high) centrally in the channel, and
- 15/1200 mm (wide) x 900 mm (high) on the right bank.

Airport Access Road between Wills Developmental Road and Burketown Airport.

This is a sealed road and is the sole access route between Wills Developmental Road and Burketown Airport. The road is crossed by two gullies, the northern gully conveys flows beneath the road in cross-drainage reinforced concrete box culverts with configuration 6/1200 mm (wide) x 900 mm (high); the southern gully conveys flows over the road via a causeway.

Nardoo Burketown Road (National Highway 1) between Bowen Street and Albert River bridge.

This is a sealed road and links Burketown and Normanton. The road is crossed by multiple gullies between town and the Albert River bridge. Overland flow is conveyed beneath the road via small cross-drainage culverts and over the road via causeways.

4.3.10 Flood Characteristics at Key Crossings

Descriptions of the flood characteristics during the simulated 2011 regional flood event at the key road crossings are provided below.

Wills Developmental Road (National Highway 1/State Route 84) west of Musgrave Street

Inundation above the road surface is generally 0.8 m deep and flood hazard is in the 'high' range (QRA flood hazard criteria) at the gully crossing just west of town. The length of inundated road is approximately 500 m.

Airport Access Road between Wills Developmental Road and Burketown Airport

Inundation above the road surface is generally 0.7 m deep along its length and 0.9 m deep at the causeway (lowest road surface). The length of inundated road is approximately 430 m.

Nardoo Burketown Road (National Highway 1) between Bowen Street and Albert River bridge

The maximum inundation above the road surface is approximately 2.8 m and flood hazard is in the 'extreme' range (QRA flood hazard criteria) at the gully crossings on this road south of town.

4.3.11 Property Flooding

Determination of above-floor flooding for houses and businesses was not in the scope of this study. The LDMP states that buildings in Burketown are constructed above the minor and moderate flood levels but not above the major flood level.

The maps (Appendix E) show properties that may be affected by ground level flooding during a flood approximately equivalent to the 2011 flood event.

4.4 Local Flood Risk Assessment

4.4.1 Local Catchment Context

The topography of the local catchment flood model domain is characterised by several overland flow paths and flat/low grade areas. The local flood model domain does not include

the Albert River and its potential backwater influence on local drainage. The major overland flow path through the model domain starts south of Burketown where flow break outs from the left bank of the Albert River occur during river flooding. This flow path conveys flow to the north between the airport and South Burketown and the town centre, across Wills Developmental Road and past the cemetery. Other overland flow paths join this major overland path mostly from the west near the airport. The remainder of the model domain is typified by low gradient areas and minor depressions some of which may be undrained. Vegetation cover is sparse and minimal over exposed ground.

The topography is shown on figures in Appendix D and overland flow paths are shown on local flood maps in Appendix F.

4.4.2 Flood Characteristics

Local flood modelling has been undertaken for the 10 % AEP and 1 % AEP events using a rain-on-grid hydraulic simulation (refer to Appendix B for more information) to illustrate the flood inundation extents (using a depth map) and flood hazard maps. Mapping shows most of the inundation is in overland flow paths but parts of the town centre including roads and some lots could experience inundation. Some of these affected areas may be undrained or slow to drain due to low surface grades. Areas with higher flood hazard are within overland flow paths and can occur at road/overland flow path crossings.

4.4.3 Flood Impacts on Critical or Vulnerable Infrastructure and Facilities

Floods maps (Appendix F) for the 10 % and 1 % AEP local flood events under current conditions show that most of the critical or vulnerable infrastructure and facilities are not inundated or are unlikely to experience significant inundation of the lot. Vehicle access from adjacent roads to within the lot are considered likely based on flood hazard characteristics.

Table 4.3 Flood Impacts on Critical or Vulnerable Infrastructure or Facilities during 10 % AEP and 1 % AEP Local Flood Events (Critical or Vulnerable Infrastructure or Facilities not inundated are not shown)

Critical or Vulnerable Infrastructure or Facility	Depth of Inundation for 10 % AEP local flood event (m)	Depth of Inundation for 1 % AEP local flood event (m)	Inundation comment	Vehicle access comment during 1 % AEP local flood event
Airport	Not inundated	Not inundated	N/A	Airport not accessible due to inundation of Airport Access Rd but would be of short duration.
Albert River Bridges	N/A	N/A	Albert River not included in local flood model.	Not accessible from town due to inundation of multiple causeways
Carpentaria Land Council Aboriginal Corporation	N/A	N/A	No significant inundation	N/A
Communications Tower	Varies	Varies	No significant inundation at Tower	Accessible from town centre
Council Offices	N/A	N/A	Not inundated	N/A
Council Works Depot	N/A	N/A	No significant inundation	N/A
Diesel Plant / Ergon Power Station	N/A	N/A	Not inundated	Accessible from town centre
Fire and SES	N/A	N/A	No significant inundation	Accessible from town centre

Critical or Vulnerable Infrastructure or Facility	Depth of Inundation for 10 % AEP local flood event (m)	Depth of Inundation for 1 % AEP local flood event (m)	Inundation comment	Vehicle access comment during 1 % AEP local flood event
Kindergarten	N/A	N/A	Not inundated	Accessible from town centre
Library	N/A	N/A	Not inundated (ground level raised since ground survey date)	Accessible from town centre
Petrol Station	0.1 – 0.2	0.1 – 0.2	Eastern and southern lot boundaries inundated	Accessible from town centre
Police Station	0.1 – 0.2	0.1 – 0.2	No significant inundation	Accessible from town centre
Post Office	0.1 – 0.2	0.1 – 0.2	Eastern lot boundary inundated	Accessible from town centre
Powerline/poles between Diesel Plant and WTP	> 0.5	> 0.5	Flow velocities at overland flow path may impact poles	Poles not accessible
Primary School	N/A	N/A	Not inundated	Accessible from town centre
Primary Health Care Clinic	0.1 – 0.2	0.1 – 0.2	No significant inundation	Accessible from town centre
Wastewater Treatment Plant	0.1 – 0.2	0.1 – 0.2	No significant inundation	Accessible from town centre
Water Treatment Plant	0.1 – 0.2	0.1 – 0.2	No significant inundation	Accessible from town centre

4.4.4 Flood Characteristics at Key Crossings

Descriptions of the flood characteristics during the simulated 10 % AEP and 1 % AEP local flood events at the key road crossings are provided below. The table is a guide only as to the overtopping flood depth and flood hazard and not intended to provide advice as to the level of safety during actual flood events, which is the responsibility of the SES and Queensland Police.

Table 4.4 Flood Characteristics at Key Crossings during Simulated Local Flood Events

Flood Characteristic	Wills Developmental Road (National Highway 1/State Route 84) west of Musgrave Street	Airport Access Road (between Wills Developmental Road and Airport)	Nardoo Burketown Road (between Bowen Street and Albert River bridge)
10% AEP flood depth over road (m)	Road surface not inundated	0.15 m	Inundated at approximately three locations. [1]Highest depth = 0.29 m
10% AEP flood hazard over road (m^2/s) and QRA Flood Hazard Classification	Road surface not inundated	0.14 m^2/s Low	[1]Highest hazard = 0.28 m^2/s Low
1 % AEP flood depth over road (m)	0.30 m	0.20 m	Inundated at approximately three locations. [1]Highest depth = 0.52 m
1 % AEP flood hazard over road (m^2/s) and QRA Flood Hazard Classification	0.07 m^2/s Low	0.22 m^2/s Low	[1]Highest hazard = 0.58 m^2/s Low

[1]Gully crossing approximately 600 m south of Bowen Street.

4.4.5 Property Flooding

Determination of above-floor flooding for houses and businesses was not in the scope of this study. The maps (Appendix F) show properties that may be affected by overland flow during the 10 % AEP and 1 % AEP local flood events.

5. FLOOD RISK MANAGEMENT MEASURES

5.1 Current Emergency Response Measures

This section assesses the current emergency response measures for flood risk management for Burketown. Any improvements to the measures are identified and described in Section 5.2.

5.1.1 Flood Watches and Flood Warnings

This section provides a summary of the Bureau of Meteorology's Flood Watch and Flood Warning system for the Nicholson River Flood Watch Area ([5]Bureau of Meteorology, 2017), within which the Albert River and Burketown reside. Further details are provided in the brochure produced by the BOM ([3]Bureau of Meteorology, 2019). This section outlines more specific flood warning information to that mentioned in the LDMP (Section 5.1 Warning notification and dissemination).

Flood Watches may be issued by the BOM when the combination of forecast rainfall and catchment conditions indicates flooding is likely. They are typically issued 1 to 4 days before an anticipated flood event depending on the confidence in rainfall forecasts. It is noted that Flood Watches are qualitative early advice using forecast rainfall and can apply to major river systems within the Nicholson River Flood Watch Area.

Flood Warnings for the Nicholson River Flood Watch Area are issued once daily based on 9am observations and when one or more of the following criteria are met:

1. The river level in at least one forecast location has exceeded, or is expected to exceed, the minor flood level

2. The flood class levels (defined as the target lead time and trigger height) at forecast locations are met

3. The flood class levels defined at information locations are exceeded.

Quantitative predictions are based on all available information at the time of warning issue and include expected flood class (minor, moderate or major) with more specific information on the height and time of water levels at the Burketown Airport gauge on the Albert River.

The BOM has classified minor, moderate and major flood levels for Burketown per the table below.

Table 5.1 Flood Level Classifications for the Burketown Airport gauge on Albert River

Flood level classification	Gauge flood level
First report height	4.5 m
Minor flood level	5 m
Moderate flood level	5.5 m
Major flood level	6 m

Flood Warnings can be issued in the River Height Bulletin for the Nicholson River Flood Watch Area (1 hourly and 3 hourly), which is updated and issued when:

- Automatic stations are typically within 1.0 metre of minor flood level and there are at least two sites reporting
- There is receipt of any river height reading at a manual station.

Flood Warnings issued by the BOM for the Nicholson River basin can be viewed at the following site:

http://www.bom.gov.au/qld/flood/gulf.shtml

5.1.2 Rainfall and River Height Stations

The Bureau of Meteorology (and other agencies) owns and maintains rainfall and river height stations that under certain flooding circumstances within the Flood Watch Area may provide information that can be used by the BOM to disseminate flood warnings for the Albert River and Burketown. These stations are listed in Table 5.2.

The Burketown Airport/Airstrip gauge on the Albert River is the only flood forecast location in the Flood Watch Area and is a quantitative station.

Burke Shire Council can view the information to understand the recent rainfall and river conditions at the stations listed in **bold** in Table 5.2 that may lead to potential flood warnings and flood conditions in the Albert River and Burketown. The data is available at the following site:

http://www.bom.gov.au/qld/flood/gulf.shtml

Table 5.2 BOM Rainfall and River Height Stations on the Gregory River and Albert River within the Nicholson River Flood Watch Area ([6]Bureau of Meteorology, 2019)

Station No.	Station Name	River	Gauge Type	[1]Target Warning Lead Time	Trigger height
029044	Burketown Post Office	N/A	Manual Rainfall Station	N/A	N/A
029077	Burketown Airport/Airstrip	N/A	Automatic Rainfall Station	N/A	N/A
029157	**Burketown Airport/Airstrip**	**Albert River**	**Manual River Height Station**	**2 days**	**> 5.5 m**
529040	[2]Burketown Tide	Albert River	Automatic River Height Station	N/A	N/A
529009	**[3]Gregory Downs TM**	**Gregory River**	**Automatic Rainfall and River Height Station**	**N/A**	**N/A**
029166	**[3]Riversleigh TM**	**Gregory River**	**Automatic Rainfall and River Height Station**	**N/A**	**N/A**
029100	Gregory Downs Outstation	N/A	Manual Rainfall Station	N/A	N/A
029081	Gregory Downs Station	N/A	Manual Rainfall Station	N/A	N/A

[1]The minimum lead time that will be provided before the height or the flood class level given is exceeded.

[2]Owned by Dept. Science and IT and Innovation.

[3]Owned by Dept. of Natural Resources & Mines.

It is noted that the Burketown Airport Gauge has a 'high' priority such that if there is a temporary or permanent loss of this station there will be a high impact on supply of flood warning information regarding Albert River flooding and expected impact on Burketown.

It is considered that use of the Burketown Airport Gauge to provide warning of impending minor, moderate or major flooding is insufficient as it is:

- Is too close to Burketown
- Is a manual station
- Has a 'high' priority in the flood warning network as there isn't an alternative gauge to provide flood warning information regarding Albert River flooding and expected impact on Burketown.

5.1.3 Evacuation

People in Burketown can experience extended periods of isolation during regional floods. Road access within town and outside of town may not be possible during local or regional flood events. Access routes may take days to weeks to reopen depending on the time it takes for unsealed roads to dry out and become trafficable, or for damaged roads to be inspected and repaired for safe passage.

Specific information about access for the purposes of evacuating areas that will be inundated or have become inundated is provided below. Regional and local flood hazard maps (Appendix E and F) illustrate locations within the town that may have access by vehicle or travel by foot cut by flooding.

Documentation

The Local Disaster Management Plan (Section 08. EVACUATION CENTRE MANAGEMENT and Section 10. LDMP SUB PLANS) states an Evacuation Sub Plan has been developed for the Shire. The evacuation plan details 'the trigger points and actions required for evacuation of part or all the populated areas in the Shire'. Council has advised the document does not exist.

The document is considered vital for flood risk planning and response in Burketown.

Evacuation Centre

During the 2011 flood, Council set up an evacuation centre at the shire hall (Council offices location between Sloman Street and Musgrave Street). Due to inundation affecting the sewerage system, portable public toilets were set up on dry roadways.

The 2011 flood height map shows this area is not inundated and flood-free access via Beames Street to the Primary Health Care Clinic and Fire and SES is available.

Road Access within Burketown

During local flood events evacuation from residential houses is not anticipated as flood depths are not expected to exceed floor levels.

Local flood hazard maps illustrate the locations of overland flow paths within the town that may cut road access by vehicle or travel by foot during short duration (typically a few hours) storm events. Generally, within the street network of Burketown town centre, flood hazard is under 0.45 m^2/s and in the 'low' QRA flood hazard classification meaning movement is within the tolerance of a large four-wheel-drive.

The 2011 flood hazard map, however, illustrate that the perimeter of the Burketown town centre has flood hazard in the 'significant' and 'high' range meaning movement by vehicle is unsuitable. Movement by large four-wheel-drive truck adapted for movement through flood water may be possible within the town centre in 'Low' flood hazard areas as shown on the regional flood maps (Appendix E). Alternative access within town is by boat.

Access between Burketown and Airport

Access from Burketown to the airport may be cut at the Airport Access Road causeway during local flood events. Flood maps for the 1 % AEP flood event provided in Appendix E show the flood hazard is approximately 0.3 m^2/s ('Low' QRA flood hazard classification).

During a regional flood like the 2011 regional flood event, access to the airport for evacuation from town would not be possible by vehicle due to the flood hazard. It is noted that the airport (runway and passenger waiting area) has higher elevation and may be flood-free while access between the airport and town is by boat only.

Access from and to Burketown

Burketown has road access to Mount Isa, Cloncurry and Normanton outside of wet season closures. Local or regional floods may cut access for short or long periods.

5.1.4 Flood Emergency Response

Documentation

The Local Disaster Management Plan (Section 05. RESPONSE STRATEGY **Operational Planning** and Section 10. LDMP SUB PLANS) states the 'Resupply Sub Plan' and 'SOP and Concept of Operations Plan' have been developed for the Shire, however Council has advised that the documents do not exist.

Improvements to this section of the LMDP are identified in Section 5.2.4 of this report.

Activation

The LDMP (Section 5.2 Activation of response arrangements) outlines generic triggers, actions and communications that can be applied to a pending event.

Improvements to this section of the LMDP are identified in Section 5.2.4 of this report.

General Council and Resident Response

Correspondence received at the stakeholder meeting (September 2019) and information in online news articles provide the following insight into the town's response to regional floods:

- The Council, Emergency Management Queensland and residents are extremely proactive (ABC North West QLD, 2011) and are familiar with the actions required to prepare for impending floods and respond to flood conditions as they have gone through the experience on numerous occasions in recent times

- The Council is aware that regional floods are unpredictable and due to the limited number of gauges to provide information about flood levels they regularly monitor how the water is moving

- The Council and locals are aware:
  - that floods take days to rise and affect the town that provides time to respond before the flood water peaks
  - of the low-lying areas that will be affected first and that these residents will require relocation
  - the town may become isolated and they will have to wait out floods if they choose to stay.

- The SES boat was used by the Police, for ferrying people to and from the airport and for movement of goods

- Food was flown into Burketown by light aircraft due to no access by road

- Once roads are trafficable after inundation, re-supply of goods can be brought from Mount Isa to Gregory by truck and then from Gregory to Burketown by light aircraft (Savannah Aviation has traditionally provided this service).

Burke Shire Council

Burke Shire Council is the primary authority for managing the planning for emergency response to impending floods and the response to flood conditions as they happen. Council has 30 active staff and 3 on-call staff during the wet-season.

Local Disaster Management Group (LDMG)

The LDMG is established under section 29 of the Disaster Management Act 2003 (the Act) and the Disaster Management Regulation 2014. The LDMG core group comprises Burke Shire staff and Councillors, Officer in Charge (Burketown Police) and the Emergency Management Coordinator (Queensland Fire and Emergency Service).

Emergency response responsibilities are defined by the core group and advisors listed in the Local Disaster Management Plan (LDMP) Burke Shire Council (2019). Specific responsibilities are determined by the Local Disaster Management Group and other emergency response agencies. The LDMG can request support from the District Group.

Queensland Police Service

The responsibilities of Queensland Police Service are outlined in the Local Disaster Management Plan. They are the Primary Authority for control and co-ordination of emergency response tasks.

There is one Police Officer permanently stationed at Burketown during the wet season.

State Emergency Service

The Burketown SES is approved to:

- Provide agency support including communications, welfare, emergency lighting, food handling, air observation, re-supply and evacuation
- Provide emergency lighting for the Royal Flying Doctor aircraft
- Provide flood boat operations
- Provide incident management
- Provide storm damage operations including working at heights, temporary roof repairs, chainsaw operations, debris cleanup and sandbagging
- Conduct search and rescue or similar operations
- Help injured persons or protect persons or property from danger or potential danger
- Conduct other activities to help communities prepare for, respond to and recover from an event or disaster.

Emergency Response Facilities and Equipment

The Burketown joint State Emergency Service (SES), Volunteer Marine Rescue (VMR) and Rural Fire Brigade has sheds located on the eastern side of Beames Street opposite Firefly Street.

The sheds house the operations/training centre and one (1) dual cab 4WD utility vehicle, one (1) flood boat and one (1) trailer for general rescue.

Council plant and equipment including operators are available on an as-needed basis.

5.2 Emergency Response Modification Measures

5.2.1 Flood Watches and Flood Warnings

The Flood Watch system utilised by the BOM for qualitative early advice of potential flooding that may affect the Albert River and Burketown is considered appropriate as the response time of the Albert River and floodplain occurs over days before flood levels rise to levels that impact Burketown, giving Burketown adequate time to respond to the advice.

The Flood Warning system utilised by the BOM for quantitative advice of flooding that is likely to affect the Albert River and Burketown is considered sufficient, however the instrumentation the Flood Warning system is dependent on is recommended be upgraded (refer Section 5.2.2).

5.2.2 Rainfall and River Height Stations

Burke Shire Council engaged Telstra to propose upgrades to the Bureau of Meteorology flood warning network across the Burke Shire. Engeny has reviewed this report and comments are provided below on the recommendations made by Telstra.

An additional automatic river height station upstream of Burketown to detect changing river heights to provide advanced warning of upstream flooding is recommended.

Site 12 km upstream of Burketown on Albert River

The existing Burketown Airport Gauge is a manual station with the gauge boards located on the outside of the river bend at the southern end of the runway at the airport boundary. They are being affected by erosion and are difficult to access.

The assessment by Telstra (2019) recommended relocating the Burketown Airport Gauge site 12 km upstream of Burketown on the Albert River. The proposed site is described as suitable based on accessibility, soil conditions and erodibility. This proposed site is likely to record changes in the height of the Albert River due to flood breakout from the Gregory River and Nicholson River at the confluence of the two rivers.

Engeny agrees with the recommendations made by Telstra for relocation and upgrade of the Burketown Airport Gauge. The bank stabilisation works, re-survey of gauge boards at the existing site and installation of a ground-based station with a camera are recommended to be undertaken as a priority, as the site is a high priority site in the BOM Flood Warning Network for Burketown. Keeping the existing site in operation permanently would be an advantage as it would act as a back-up to the new station.

The advantages of the relocation are that:

- The gauge would be automatic not requiring an operator to attend and record water levels
- The gauge would provide water levels during flood conditions
- The site is further upstream and would provide more warning time to burke shire council of approaching flood water.

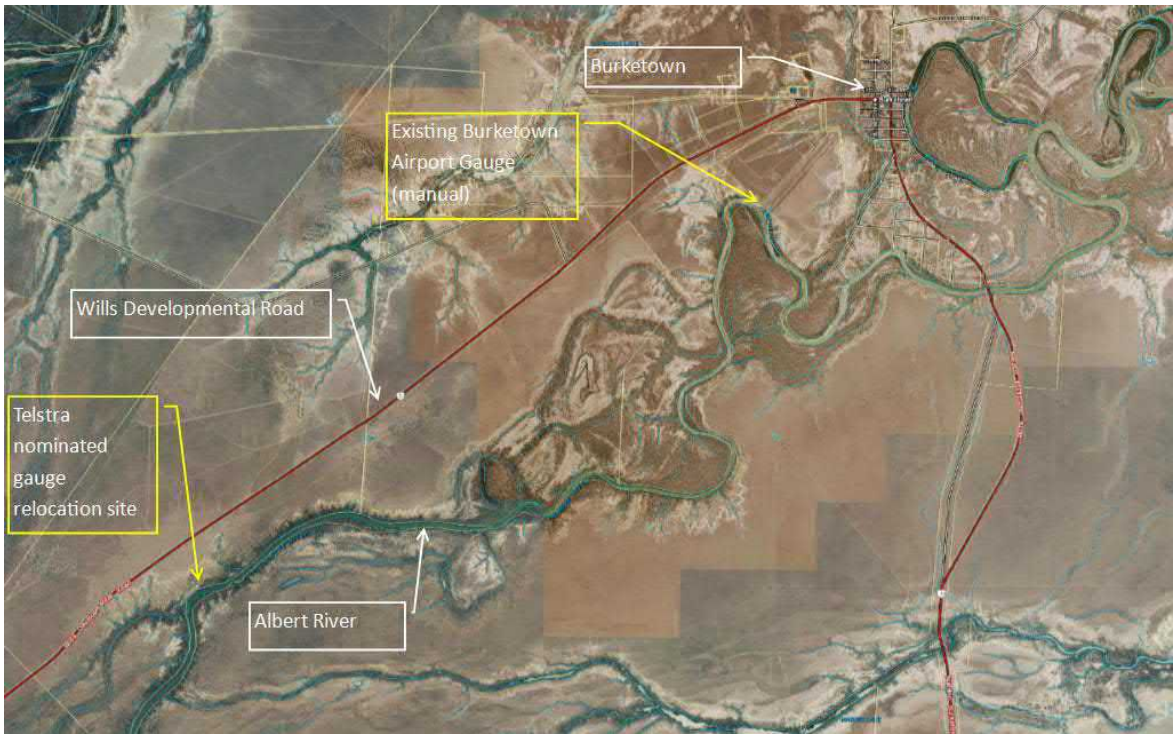


Figure 5.1 Telstra Nominated Re-Location Site for Automatic Rainfall and River Height Station on Albert River

Site 65 km Upstream of Burketown on Beames Brook

A high-level review by Engeny of the upstream waterways suggests a suitable location for an additional automatic rainfall and river height station may be just upstream of the confluence of Beames Brook and the Barkly River. The co-ordinates of this location are E313900, N7991160. The site is adjacent to an access track crossing of Beames Brook at a rural property (Lot 3345 PH 731) with access from nearby Wills Developmental Road (refer to Figure 5.2). The location is approximately 65 km stream length upstream of the Burketown Airport gauge.

This gauge would record changes in river height from upstream flood break out from the Gregory River into Beames Brook. The site, however, is upstream of the confluence of the Gregory River and Nicholson River and may not record changes in river height due to flood breakout of these two rivers at the confluence, unless it is from backwater. Downstream of this gauge location, the headwater of the Barky River commences (Beames Brook diverges into the start of the Barkly River). Beames Brook then joins One Mile Creek, which further downstream has a confluence with the Barkly River, forming the Albert River.

The location (or other potential locations) would have to be assessed in detail to provide additional flood warning information for Burketown.

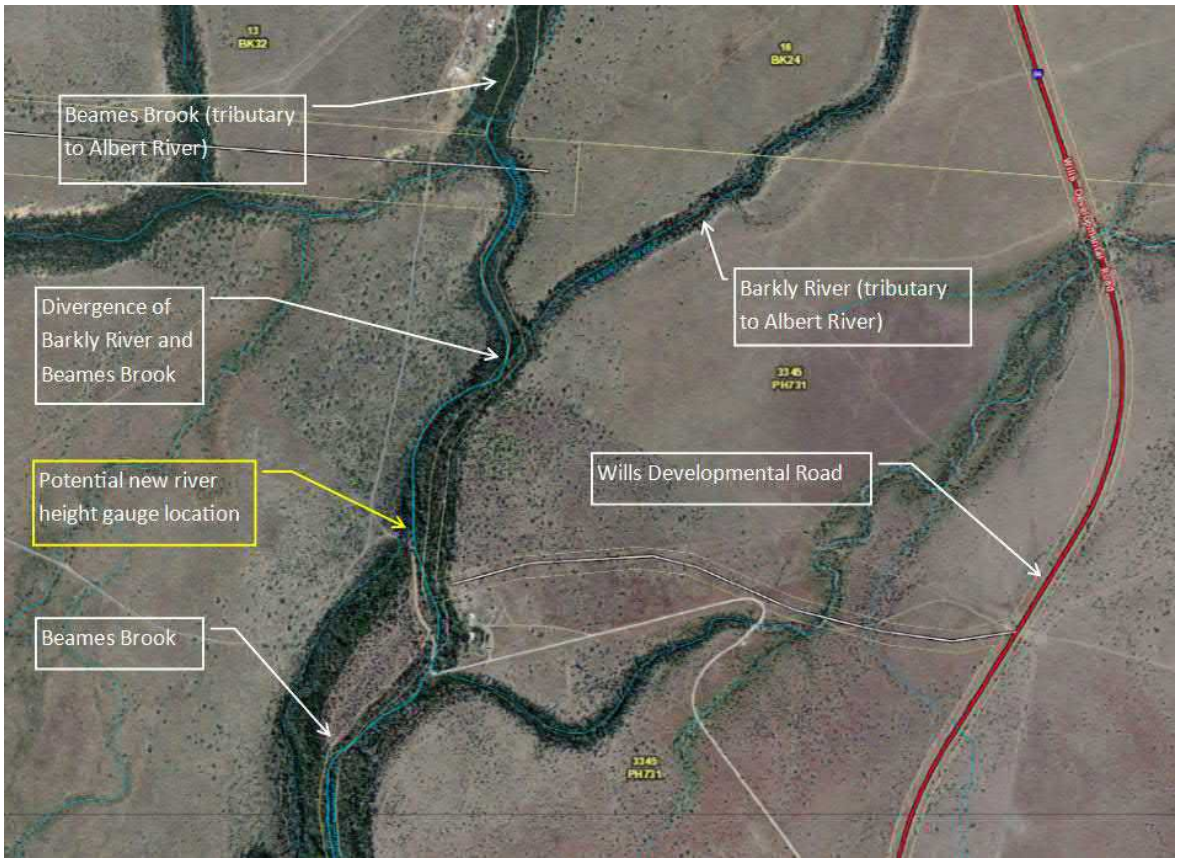


Figure 5.2 Potential Location for Additional Automatic Rainfall and River Height Station on Beames Brook

Site 87 km Upstream of Burketown on Running Creek

The assessment by Telstra (2019) recommended a new automatic rainfall and river height station upstream of the Wills Developmental Road crossing of Running Creek. Immediately downstream of the crossing is the confluence of Running Creek and Beames Brook. The gauge location would be approximately 87 km upstream of the existing Burketown Airport Gauge. This gauge would record changes in river height from upstream flood break out from the Gregory River into Beames Brook.

This potential location is considered appropriate for provision of additional flood warning information for Burketown.

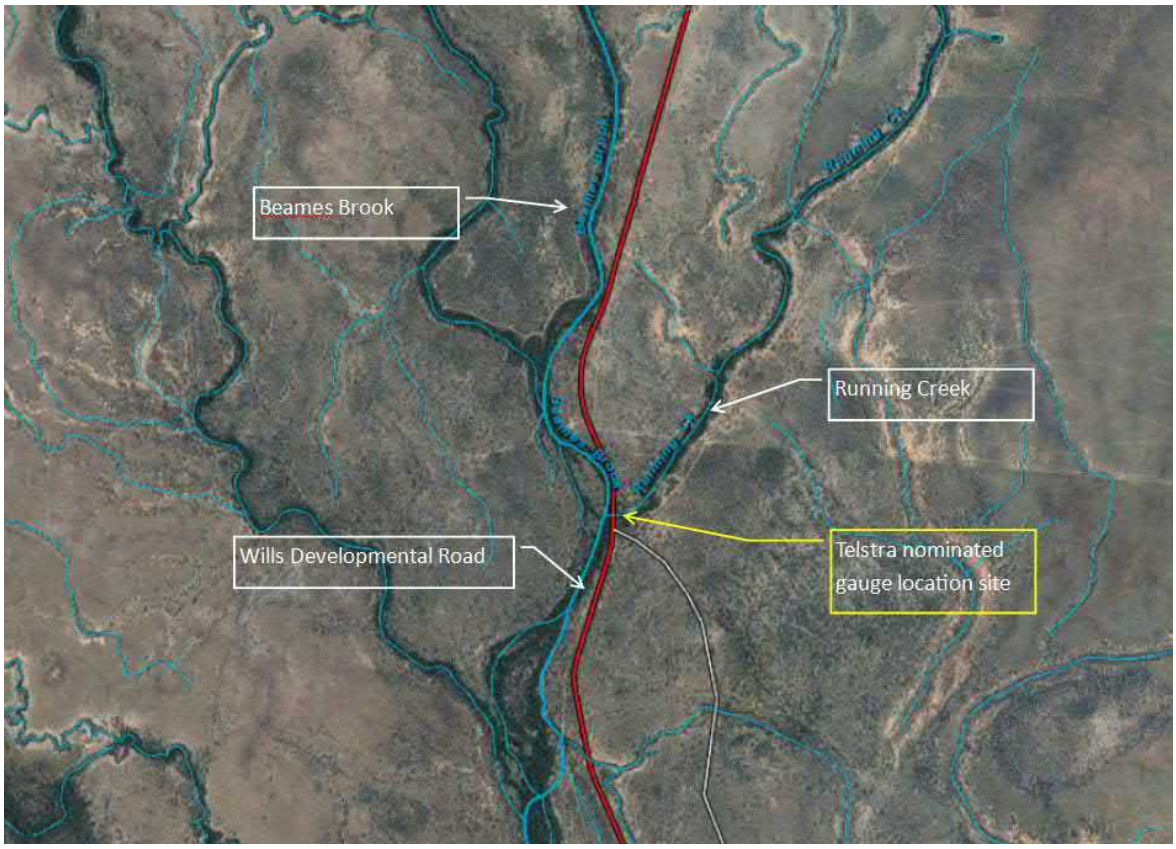


Figure 5.3 Telstra Nominated Location Site for Automatic Rainfall and River Height Station at Running Creek

Site Upstream of Burketown on Gregory River

The assessment by Telstra (2019) recommended a new automatic rainfall and river height station downstream of the Doomadgee Road/National Highway 1 crossing of the Gregory River. A short distance downstream of the crossing is the confluence of the Gregory River and the Nicholson River.

To the east of the crossing beyond the right bank of the confluence of the two rivers is One Mile Creek, a tributary to the Albert River. This location is approximately 32 km upstream of the existing Burketown Airport Gauge. This gauge would record changes in river height in the Gregory River from direct catchment flooding and backwater from flooding of the Nicholson River. This gauge location under certain flood conditions and flood levels provide additional information as to potential flooding that may occur in the Albert River due to flood water breakout from the Gregory River and Nicholson River floodplains.

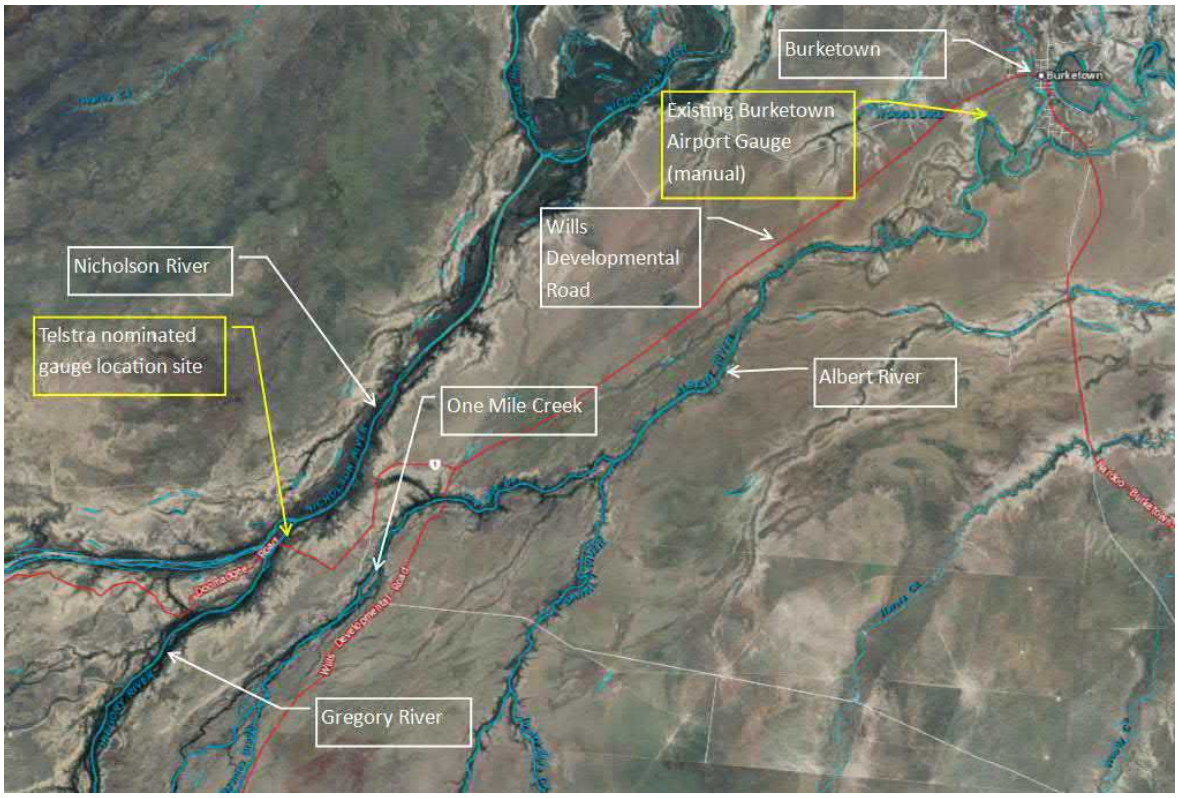


Figure 5.4 Telstra Nominated Location Site for Automatic Rainfall and River Height Station at Gregory River Creek

5.2.3 Evacuation

Documentation

Council has advised that the 'Evacuation Sub Plan' referred to in Section 10 of the LDMP does not exist, therefore it is recommended Council commences preparation of the document.

Until the document is completed and adopted by Council, Section 10 LDMG SUB PLANS should be removed from the LDMP.

Evacuation Centre

The Council office location between Sloman Street and Musgrave Street, which has been used previously for this purpose is considered appropriate for an evacuation centre.

Road Access within Burketown

No mitigation measures have been identified to improve road access within the Burketown town centre during regional flood events as evacuations should have been completed by the time the town centre is inundated.

Access Between Burketown and Airport

As local flood events are likely to be of short duration, it is recommended that attempting access to the airport be after the Airport Access Road causeway is no longer being overtopped by flood water.

To provide flood-free access to the airport during local flood events, the Airport Access Road at the causeway would have to be raised and culverts installed to provide cross-drainage capacity beneath the road. It is noted that the duration of inundation at the causeway would be short and is unlikely to cause inconvenience.

Councillors advised in the stakeholder meeting that providing flood-free road access during regional flood events from town to the airport is cost-prohibitive and not of concern at this stage. The current method of access between town and the airport by boat is considered appropriate. Maintaining availability of at least two boats within the town centre (including the Fire and SES facility or secondment of private boats) suitable for traversing shallow water is recommended during wet seasons.

Access To and From Burketown

No modifications to improve road access from and to Burketown is proposed as the focus of this study is on Burketown.

5.2.4 Response

Documentation

It is recommended that Council commences preparation of the 'Resupply Sub Plan' and 'SOP and Concept of Operations Plan' documents referred to in Section 10 of the LDMP. Until the documents are completed and adopted by Council, Section 10 LDMG SUB PLANS should be removed from the LDMP.

Activation

Triggers and actions for specific rainfall depths and flood levels that are applicable to potential regional flood scenarios have been identified to supplement the generic triggers and actions in Section '5.2 Activation of response arrangements' in the LDMP. These are presented in Table 5.3.

Table 5.3 Recommended Triggers, Actions and Communications for Regional Flood Events

Emergency Level	Trigger	Action	Communications
Alert	• The BOM has identified that in general, 100 mm or heavier falls in 24 hours over a wide area has occurred, which will most likely cause major flooding, particularly in the middle and lower reaches of the Nicholson and Gregory Rivers around Burketown ([3]Bureau of Meteorology, 2019). • Bureau of Meteorology issues a Flood Watch for the Nicholson River Flood Watch Area with qualitative advice that Albert River flooding may occur and affect Burketown. • Bureau of Meteorology issues a Flood Warning for the Nicholson River Flood Watch Area with quantitative advice that the first report height (4.5 m) has been exceeded at the Burketown Airport Gauge.	• Monitor daily updates (9am) issued by the BOM on the Flood Warning website http://www.bom.gov.au/qld/flood/gulf.shtml • Monitor previous 24 hour rainfall and flood levels at rainfall and river height gauging stations upstream • Share the Flood Watch or Flood Warning information with Council Operations and Outdoor staff, LDMG, QFES, SES and Police • Share information with community on social media platform (Facebook), Council's Notices Distribution (e-mail) and local radio • Undertake Actions for Alert Level per LDMP document	• Local Disaster Co-ordinator (LDC), Chair of LDMG and LDMG to be made aware of situation and contactable
Lean Forward	• Alert level is satisfied, and significant rainfall is occurring in the catchment	• Undertake Actions for Lean Forward level per LDMP document • Chair and LDC monitors BOM advice and is in contact with BOM	• Local Disaster Co-ordinator (LDC), Chair of LDMG and LDMG to be contactable

Emergency Level	Trigger	Action	Communications
	• Bureau of Meteorology issues a Flood Warning for the Nicholson River Flood Watch Area with quantitative advice that the minor flood level (5 m) will be exceeded at the Burketown Airport Gauge and Burketown is expected to be affected.	• LDC and LDMG members to fly to Burketown if possible • QFES and LDC review potential flood impacts and flood maps • Share information with community on social media platform (Facebook), Council's Notices Distribution (e-mail) and local radio • Share the Flood Watch or Flood Warning information with Council Operations and Outdoor staff, LDMG, QFES, SES and Police • Hold community meeting at Council Hall • Provide advice to community on flood safety; procedures for potential evacuation; impacts to roads, critical infrastructure and services	
Stand Up	• Lean Forward level is satisfied, and significant rainfall is occurring in the catchment • Bureau of Meteorology issues a Flood Warning for the Nicholson River Flood Watch Area with quantitative advice that the moderate flood level (5.5 m) or major flood level (6.0 m) will be exceeded at the Burketown Airport Gauge. • Bureau of Meteorology continues to update Flood Warnings for the Nicholson River Flood Watch Area	• Undertake Actions for Stand Up level per LDMP document • Prepare Evacuation Centre • Share information with community on social media platform (Facebook), Council's Notices Distribution (e-mail) and local radio • Share Flood Warning information that there is approximately two (2) days lead time before the moderate flood level (5.5 m) will be reached	• LDCC contact through established land lines and generic email addresses • Chair, LDC and LDMG members present at LDCC, on established land lines and / or mobiles, monitoring emails

Emergency Level	Trigger	Action	Communications
Stand Down	• Bureau of Meteorology issues the final Flood Warning for the Nicholson River Flood Watch Area • The BOM Flood Warning states the flood level at the Burketown Airport Gauge is below the minor flood level (5 m) • Flood recovery taking place	• Undertake Actions for Stand Down level per LDMP document • Share Flood Warning information with community on social media platform, local radio, Council website	• LDMG members involved in recovery operations resume standard business and after hours contact arrangements

5.3 Protection of Critical Infrastructure

The recommended protection of the power poles for the transmission line at the overland flow path against flood debris and scour during local or regional floods is:

- Rock armouring around the base of the poles that are within the 2011 flood extent (between Airport Access Road and the western end of Musgrave Street). Rock size with d_{50} of 0.15 m to 0.20 m may be suitable for flood depth of 2 m and maximum velocity of 1.5 m/s (TMR, 2019). Depth of rock would typically be 0.30 m to 0.40 m.

- Installing bollards with concrete footings at least 1 m deep on the upstream (southern) side of the power poles to deflect flood debris. Bollard height could be typically 1 m to 2 m.

5.4 Regional Flood Behaviour Modification Measures

Flood behaviour modification works such as major drains or levees may in some circumstances reduce flood risk on a regional scale. The potential identification, investigation and simulation in hydraulic models of such works was discussed with Council.

Council advised that this has not been a topic of discussion within Council in the past and there is currently no desire for these types of works. The complexity, timeframe for delivery and expense of such works is high and the cost-benefit ratio is unlikely to justify them. The impacts of levees are uncertain in a complex floodplain and may cause undesirable outcomes such as; trapped low points behind the levee; concentration of flow resulting in higher flood velocity, flood levels and increased scour; relocation of underground services; alteration of road profiles; and need for property resumptions.

6. DEVELOPMENT ASSESSMENT AND PLANNING FOR BURKETOWN

6.1 Introduction

A key objective for this study was to assess the flood characteristics and understand whether Council's land-use planning intentions are appropriate, given the level of risk posed by flooding.

6.2 Guidelines and Policies

Development controls specified or required by Council for areas in the flood hazard zone subject to development should be in alignment with recommendations in the guidelines and policies below. The following documents have been utilised to determine appropriate controls and parameters for risk-based development within Burketown.

- State Planning Policy – Natural hazards, risks and resilience ([1]DILGP, 2016).
- Guideline for the construction of buildings in flood hazard areas (Business Queensland, 2013).
- MP 3.5 – Construction of buildings in flood hazard areas (Department of Housing and Public Works, 2012).
- Construction of Buildings in Flood Hazard Areas (Australian Building Codes Board, 2012).
- Queensland Urban Drainage Manual (Institute of Public Works Engineering Australia, 2017).

6.3 Flood Risk and Land Use Compatibility

The core matters for consideration in flood risk management and land use planning are listed below. This report responds to the core matters outlined in the sections below.

- The characteristics of the flood hazard
- The population and land uses exposed to the flood hazard
- The anticipated growth and development of the community
- The suitability of existing studies to inform the flood risks.

Other core mechanisms considered appropriate for managing flood risk in Burketown are:

- Emergency planning and management - Council's emergency planning and management measures are considered effective for flood events up to the defined flood event, however some recommendations have been made in section 5.2.

- Building control - An effective way of ensuring future development is compatible with flood risk are land use and development controls that are set by Council and based on best available flood characteristics. The Burke Shire Council Planning Scheme 2020 (active 6 February 2020) sets some development controls for future development in various land uses. Sections below describe other controls that can be considered by Council.

- Community awareness and education - Burketown has a low population but a strong community awareness, experience of and resilience to flooding. This forms a good basis for education programs that are likely to be effective in increasing the community's resilience. Sections below provide recommendations Council can consider to achieve this.

6.4 Development Areas

Council has identified areas for potential development including residential, rural residential and industrial zones. The locations of the areas are presented in Figure 6.1. The zones are shown on Map: BTN BZ2 in the Burketown Planning Scheme 2020.

South Burketown and West Burketown are the primary areas of interest for Burke Shire Council. South Burketown is a proposed rural residential subdivision and West Burketown is a proposed industrial subdivision.

Council's proposed subdivision plan for South Burketown identifies potential locations for building envelopes in large rural residential zoned lots. Flood modelling and mapping shows the entire area is subject to inundation in the 2011 flood event. Defined Flood Levels have been specified for most of the lots per the Planning Scheme ([2]Burke Shire Council, 2020).

Table 6.1 Development Area and Land Use Zone

Area label	Area name	Zone	Precinct	Land use	Population exposed to flooding
1	Mineral Baths	Township	-	-	No permanent residents, itinerant population only.
2	South Burketown	Rural residential	-	Rural residential	[2]Average of 2.5 per dwelling
3, 4, 5, 6, 12	West Burketown[1]	-	Industrial	Industrial	No permanent residents
7	Waste transfer site[1]	-	Industrial	Industrial	No permanent residents
8	Lots between Sloman St and Musgrave St adjacent to Albert River	Recreation and open space	-	Open space	No permanent residents, itinerant population only.
9, 10	Airport Light Industrial[1]	-	Industrial	Industrial	No permanent residents
11	Residential lots between Marshall Street and Landsborough Street	Township	Residential	Residential	[2]Average of 2.5 per dwelling
-	Lots 313 and 314 corner of Sloman and Beames St	Township	Commercial	Commercial	No permanent residents

[1]Zone not identified on Map: BTN BZ2 in the Burketown Planning Scheme 2020.

[2]idcommunity (2020)

The proposed subdivision layout prepared by Council (Appendix G) for the South Burketown rural residential area will decrease the number of lots so the intensification of use in the area will not be increased. The subdivision layout shows nine lots with one potential building envelope per lot nominated. The total expected population of South Burketown rural residential area once fully developed would be approximately 22-23 persons based on average household size of 2.5 (idcommunity, 2020) and that each building envelope contains one standard Class 1a dwelling. If Council chooses to allow more dwellings per building envelope the total population would be higher.

The anticipated growth and development of the West Burketown industrial area is not expected to be significant. The subdivision layout for West Burketown industrial area prepared by Council (Appendix G) shows nineteen smaller lots and four larger lots. Council anticipates the land use may be for laydown areas for civil contracting businesses or similar.

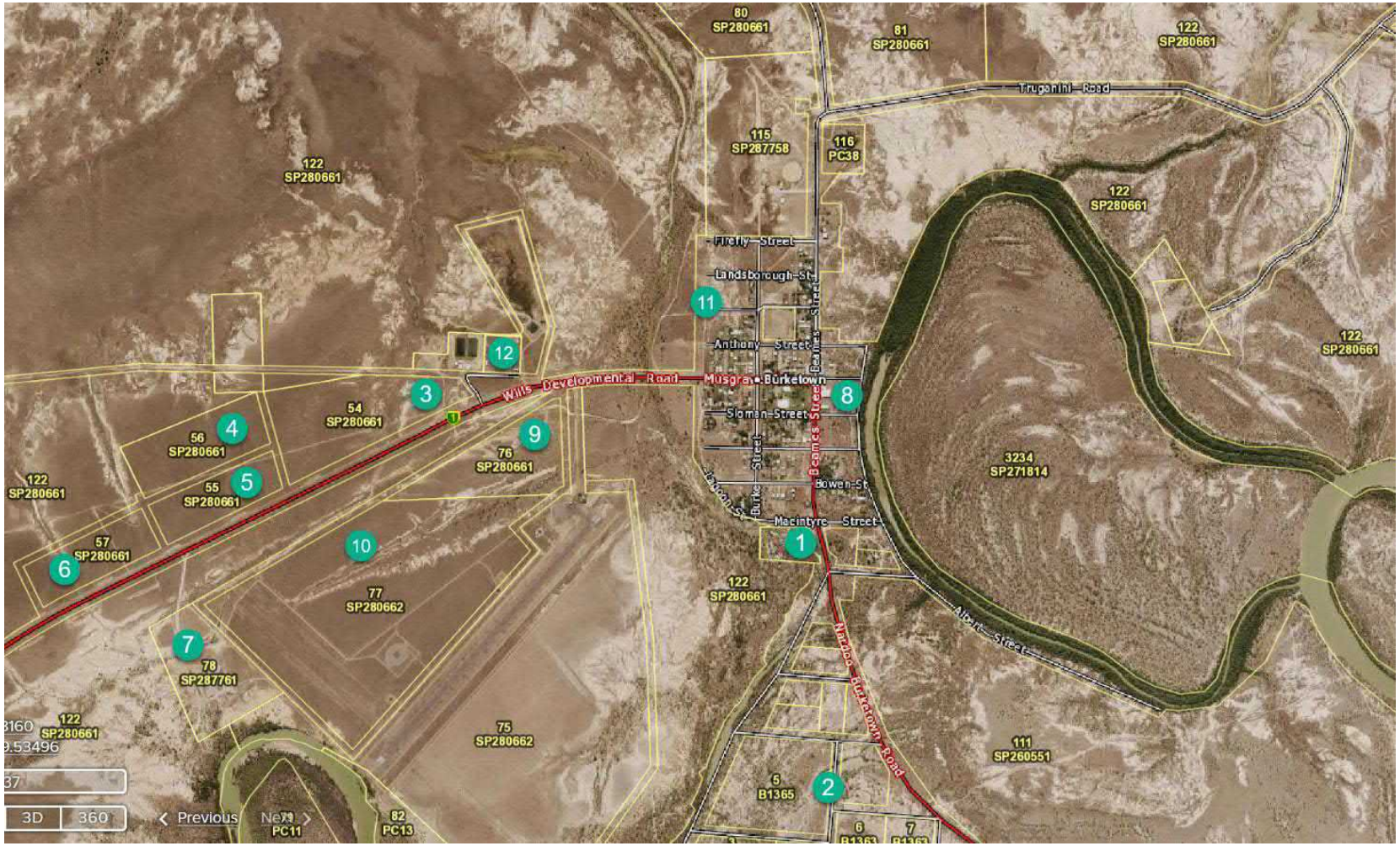


Figure 6.1 Development Areas

6.5 Flood Assessment of Development Areas

Council has requested Engeny undertake a flood assessment of these areas. This flood risk management study has involved undertaking flood modelling to an appropriate detail using best available data, analysis and simulation software to define the flood characteristics. The outputs presented in this report and Appendices are suitable to inform the risks to development areas associated with flooding. The flood assessments for the development areas are presented in Section 6.5.3.

6.5.1 Codes Applied to Assessment

The flood assessment for South Burketown and West Burketown has considered the Queensland Development Code and State Planning Policy overlay for storm tide inundation areas as described below.

Queensland Development Code

The Queensland Development Code (QDC) MP 3.5 – Construction of buildings in flood hazard areas has been applied to the flood assessment to determine the suitability of lots and proposed building envelope locations in South Burketown for the Defined Flood Event (DFE).

QDC MP 3.5 states that the Code applies in a practical way for construction of new residential buildings that are in a flood hazard area with a defined flood level that has been designated by a local council under a planning scheme. These conditions are satisfied for South Burketown. The limitation for the deemed-to-satisfy provisions only apply to residential buildings in flood hazard areas with a maximum flow velocity of water not greater than 1.5 metres per second. The Code applies to Class 1 buildings that are inundated up to one metre.

QDC MP 3.5 does not apply to parts of flood hazard areas that are subject to storm surge or coastal wave action.

Coastal Hazard and Storm Surge

The State Planning Policy Interactive Mapping System (DSDIP, 2020) shows the medium and high storm tide inundation areas at South Burketown (refer Figure 6.2) and West Burketown (Figure 6.3). The locations of the proposed building envelope locations in South Burketown (Figure H-1) and the proposed lots in West Burketown Table 6.6 in are not within the high storm tide inundation areas. Other locations within the development areas may be affected by storm tide inundation and may be subject to requirements in State Code 8: Coastal development and tidal works ([3]DES, 2019).

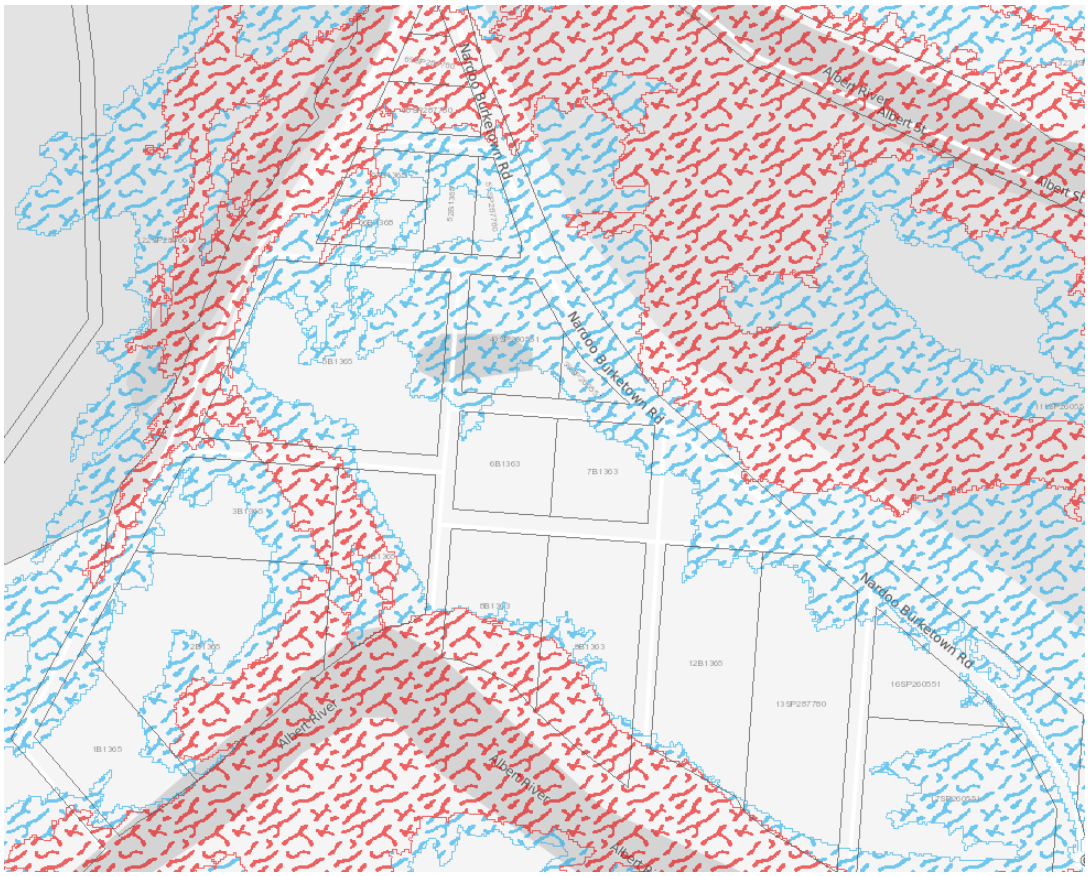


Figure 6.2 Medium and High Storm Tide Inundation Areas at South Burketown (DSDIP, 2020)

Figure 6.3 Medium and High Storm Tide Inundation Areas at West Burketown (DSDIP, 2020)

6.5.2 Assessment Constraints

The assessment has been undertaken per the following constraints:

- Assessment is based on current flood modelling using the latest available information including topographical information and hydrological analysis
- The assessment is subject to change brought about by new studies, industry guidelines and standards or updated information from any source
- Flood events larger than the Defined Flood Event have not been assessed due to lack of long-term data and uncertainty of events of this magnitude
- Planning responses, controls or parameters for the Defined Flood Event will not mitigate residual risks associated with less probable events
- Areas within the domain of the flood study may be subject to more frequent inundation than the Defined Flood Event, and have not been considered in the assessment
- Should Council choose to permit development in flood hazard areas, they accept the flood risks documented in this report
- The impacts of Climate Change have not been analysed or assessed.

6.5.3 Flood Assessments

A flood assessment for each of the identified development areas has been undertaken for the regional flood (DFE) scenario. The assessment describes the characteristics of flooding including extent, depth, velocity, hazard and access for:

- Development areas (listed in Table 6.1) including West Burketown are presented in Table 6.2
- South Burketown building envelope locations shown on subdivision plan in Appendix G presented in Table 6.3.

Table 6.2 Regional Flood Assessment (2011 flood) of Development Areas

Area label	Development area	Flood extent	Flood depths	Flood velocity	Flood hazard (QRA Flood Hazard Classification)	Access	Comments regarding suitability for development (subject to controls)
Area 1	Mineral Baths	Lot totally inundated	1 - 2 m	0.5 – 1 m/s	0.6 – 0.8 m^2/s (Significant)	Location is close to and has road access town centre for self-evacuation purposes prior to being inundated.	Suitable subject to controls and assessment of proposed development.
Area 2	South Burketown	Area totally inundated	0.15 – 4 m	Generally, 0.2 – 0.5 m/s or 0.5 – 1 m/s Up to 1.5 m/s	< 0.6 (Low) to > 1.2 m^2/s (Extreme)	Area has road access to town centre for self-evacuation purposes prior to being inundated. There is not a route from South Burketown to the town centre that is flood-free or does not have 'Low' flood hazard during the 2011 flood event (DFE).	Refer to Table 6.3.
Areas 3, 4, 5, 6	West Burketown	Area totally inundated	0.15 – 0.5 m	Generally, 0.2 – 0.5 m/s. Up to 1 m/s	Generally, < 0.6 m^2/s (Low)	Area has road access to town centre for self-evacuation purposes prior to being inundated.	Suitable subject to controls and assessment of proposed development.

Area label	Development area	Flood extent	Flood depths	Flood velocity	Flood hazard (QRA Flood Hazard Classification)	Access	Comments regarding suitability for development (subject to controls)
Area 7	Waste transfer site	Inundated apart from dump platform (fill area)	0.5 – 3 m	Generally 0.2 – 0.5 m/s.	0.6 – 0.8 m^2/s (Significant) and > 1.2 m^2/s (Extreme)	Area has road access to town centre for self-evacuation purposes prior to being inundated.	Suitable subject to controls and assessment of proposed development. Some flood impacts from proposed development may be acceptable subject to hydraulic simulations and approval.
Area 8	Lots between Sloman St and Musgrave St adjacent to Albert River	Majority of area inundated	0 – 2 m	0.5 – 1 m/s	< 0.6 m^2/s (Low), 0.6 – 0.8 m^2/s (Significant), 0.8 – 1.2 m^2/s (High)	Location is close to and has road access to town centre for self-evacuation purposes prior to being inundated.	Suitable subject to controls and assessment of proposed development.
Area 9, 10	Airport Light Industrial	Area totally inundated	0.15 – 2 m	0.2 – 0.5 m/s and 0.5 – 1 m/s	< 0.6 m^2/s (Low), 0.6 – 0.8 m^2/s (Significant), 0.8 – 1.2 m^2/s (High)	Road reserve exists at boundary of these areas for road access to town centre for self-evacuation purposes prior to being inundated.	Development preferably in areas of 'Low' hazard. Suitable subject to controls and assessment of proposed development.

Area label	Development area	Flood extent	Flood depths	Flood velocity	Flood hazard (QRA Flood Hazard Classification)	Access	Comments regarding suitability for development (subject to controls)
Area 11	Residential lots between Marshall Street and Landsborough Street	Area partly inundated	0 – 0.15 m	< 0.1 m/s	< 0.6 m^2/s (Low)	Road reserve exists at boundary of these areas for road access to town centre for self-evacuation purposes prior to being inundated.	Inundated area is subject to flood backwater and storm tide inundation. Suitable subject to controls and assessment of proposed development.
Area 12	Lot 51 SP127908	Flood-free	N/A	N/A	N/A	Road reserve exists at boundary for road access to town centre prior to surrounding area being inundated.	Suitable.
-	Lots 313 and 314 corner of Sloman and Beames St	Lots totally inundated	0.5 – 2 m	0.1 – 0.2 m/s	0.6 – 0.8 m^2/s (Significant)	Road reserve exists at boundary of these areas for road access to town centre for self-evacuation purposes prior to being inundated.	Suitable subject to controls and assessment of proposed development.

Table 6.3 Regional Flood Assessment (2011 flood) of Proposed Building Envelope Locations in South Burketown Rural Residential Area

Lot and Plan	Access	Flood depth	Velocity	Flood hazard (QRA Flood Hazard Classification)	Building envelope location
Lot 1 B1363	Lot has access via Nardoo Burketown Rd to town centre for evacuation prior to inundation.	0 – 0.15 m	0.2 – 0.5 m/s	Low	Building envelope not in ideal location for flood characteristics. Refer section 6.7.2.
Lot 2 B1363	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.15 – 0.5 m	0.5 – 1 m/s	Low/Significant	Building envelope not in ideal location for flood characteristics. Refer section 6.7.2.
Lot 3 B1363	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.15 – 0.5 m	0.5 – 1 m/s	Significant	Building envelope not in ideal location for flood characteristics. Refer section 6.7.2.
Lot 4 B1363	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.5 – 1 m	0.5 – 1 m/s	Significant	Suitable subject to controls and assessment of proposed development.
Lot 5 B1365	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.15 – 0.5 m	0.5 – 1 m/s	Significant	Suitable subject to controls and assessment of proposed development.
Lot 6 B1363	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.5 – 1 m	0.2 – 0.5 m/s	Significant	Building envelope not in ideal location for flood characteristics. Refer section 6.7.2.

Lot and Plan	Access	Flood depth	Velocity	Flood hazard (QRA Flood Hazard Classification)	Building envelope location
Lot 7 B1363	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	1 – 2 m	0.5 – 1 m/s	Significant	Building envelope not in ideal location for flood characteristics. Refer section 6.7.2.
Lot 12 B1365	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.5 – 1 m	0.5 – 1 m/s	Significant	Building envelope not in ideal location for flood characteristics. Refer section 6.7.2.
Lot 13 SP287780	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.5 – 1 m	0.2 – 0.5 m/s	Significant	Suitable subject to controls and assessment of proposed development.
Lot 16 SP260551	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	0.5 – 1 m	0.5 – 1 m/s	Significant	Envelope location not specified. Suitable subject to controls and assessment of proposed development.
Lot 17 SP260551	Lot has proposed unsealed road access to Nardoo Burketown Rd and town centre for evacuation prior to inundation.	1 – 2 m	0.2 – 0.5 m/s	Significant	Envelope location not specified.

6.6 Burketown Flood Risk Management

6.6.1 Flood Warning

The BOM Flood Warning System for potential flood events that will impact Burketown provides at least two days warning lead time before the moderate level flood level at the Burketown Airport Gauge is exceeded. Improvements to the Flood Warning System have been made in section 5.2, which will provide more information regarding upstream rainfall and river conditions and greater redundancy to Burketown.

The warning time of pending moderate floods (and greater) that is available to Burketown is of high value when it comes to emergency response, notifying the community, and preparing for and undertaking evacuations. This is possible because Burketown has a small population that is concentrated in a small area close to the town centre.

It is considered that the available warning time for moderate floods is adequate for notification of the community and for evacuation to designated areas within Burketown to occur.

6.6.2 Community Resilience

Burke Shire Council and the local and regional community are well aware the region is flood prone. They have experienced numerous moderate and major floods and are adept at responding to and recovering from the events.

The Council and community are aware of the low-lying areas that will be inundated first in pending moderate or major floods and that there is adequate warning time of pending floods that are likely to affect Burketown. The community appears to be aware that there is inconvenience and financial losses associated with flood events and are aware that these consequences are likely to occur again in the future.

Council has advised that when evacuations have been undertaken in previous major floods, they have proceeded safely in a straightforward manner without incident.

The high resilience of Council and the community to flooding puts them in good stead to manage appropriately planned and zoned new development areas, provided adequate controls are in place.

Means to increase the community's resilience to flooding are presented in the next section.

6.6.3 Flood Risk Management Measures

Council has advised that major structural measures for flood risk mitigation in Burketown are unfeasible and cost-prohibitive for the Shire. This leaves non-structural or procedural measures as the preferred and suitable flood risk management measures.

The following procedural management measures for Council to consider implementation of to reduce flood risk to tolerable or acceptable levels for future development are as follows:

- Council should develop and implement a Flood Warning Plan as part of the Local Disaster Management Plan incorporating information from this study to detail:
  - Methods of notifying residents (telephone, text-message, doorknocking etc.) when the Bureau of Meteorology issues Flood Watches and Flood Warnings and the information to include in the notices
  - When the effective warning time (approximately two days) that the moderate flood level at the airport gauge will be reached to enable self-evacuation
  - Triggers and Actions for different emergency alert levels (refer Section 5.2.4).
- Council should develop and implement an Evacuation Plan as part of the Local Disaster Management Plan incorporating information from this study to detail:
  - The location/s of evacuation centres or safe locations within Burketown for residents in low-lying areas to relocate to
  - Areas that will be inundated and the order they will be inundated to allow adequate warning time, self-evacuation and potential emergency evacuation by emergency services
  - The relief of evacuees.
- Council should raise additional flood awareness of the community by developing and implementing a Flood Education Programme for the community including aspects such as:
  - The flood mapping prepared for this study and presented in Appendices E and F should be made available to the community and prospective developers (viewed in person at Council offices) so they are fully aware of the flood risks in an area of interest.
  - Outlining aspects of flooding (low-lying areas that are likely to be inundated first, characteristics and dangers, extent of historical inundation, location of safe areas within the town centre, impacts of flooding on services and roads)
  - Flood warning time prior to reaching the moderate flood level to existing community and to new residents and land buyers
  - Dissemination of the Flood Education Programme annually and prior to the wet season
  - Procedures for potential evacuation of residents.
- It is recommended that a local flood assessment be undertaken by a suitably qualified and experienced person for proposed development of lots within the model domain

(18 % AEP, 10 %, 5 %, 2 % and 1 % AEP) shown in figures in Appendix F to demonstrate no worsening and/or no actionable nuisance is predicted to occur as a result of works.

6.7 Parameters for Risk-based Planning of Development Areas

6.7.1 Development Areas other than South Burketown and West Burketown

Based on the flood assessment of potential development areas, parameters for risk-based development to reduce flood risk are provided in the following table.

Table 6.4 Parameters for Risk-Based Development of Development Areas

Area label	Development area	Parameters for risk-based development
Area 1	Mineral Baths	Signage to be placed that area is subject to inundation during regional flooding. Potential structures for future Mineral Baths to be designed and built to structurally withstand potential flood forces and demonstrate no worsening and/or no actionable nuisance.
Area 7	Waste transfer site	Compensatory earthworks may be suitable subject to demonstration of no worsening and/or no actionable nuisance.
Area 8	Lots between Sloman St and Musgrave St adjacent to Albert River	Area is zoned Open space and recreation. Signage to notify that area is subject to inundation during regional flooding. Potential structures for Open space and recreation to be designed and built to structurally withstand potential flood forces and demonstrate no worsening and/or no actionable nuisance.
Area 9, 10	Airport Light Industrial	Compensatory earthworks may be suitable subject to demonstration of no worsening and/or no actionable nuisance.

Area label	Development area	Parameters for risk-based development
Area 11	Residential lots at Marshall Street	Minor earthworks filling on low lying lots to provide free-draining platform for local flood events. Development subject to local flood model hydraulic simulations to demonstrate no worsening and/or no actionable nuisance. Habitable floor levels to be above DFL plus freeboard per Planning Scheme. Development should not be permitted in the coastal hazard or storm tide area.
-	Lots 313 and 314 corner of Sloman and Beames St	Area is zoned Commercial. Required fill pad to achieve the floor level above DFL plus freeboard likely to be too high and inappropriate for commercial development. Floor levels above DFL plus freeboard per Planning Scheme could be achieved by specifying future building structures on stumps.

6.7.2 South Burketown (Area 2)

General Considerations

Potential parameters to be considered by Council to control development in South Burketown rural residential area are provided as follows:

- New residential buildings should have habitable floor levels set above the DFL plus 500 mm freeboard. All estimated 1 % AEP and certain potentially rarer event peak flood events would fall within this freeboard, with an additional allowance for other uncertainties. This freeboard requirement should be specified on the Burketown South *Proposed Subdivision of Lands Dwg No. 17055/ROL/04* and in the Planning Scheme.
  - This freeboard provides reduced risk to occupants who remain in their homes in the event of pending major flooding that may isolate them for extended periods. If it is well understood based on flood forecasting details that the occupants are safe within a dwelling, it also reduces the demand for evacuation and any burden that could be placed on Council and/or emergency services.
  - The raised dwelling should be self-supporting during isolation such that adequate food, potable water and power is available to occupants.
- The number of habitable dwellings per lot should be limited by Council such that the risk to safety is acceptable to Council.
- Development in areas with ‘Extreme’ hazard must be avoided

- Proposed development should be designed and certified for the soundness of structures to withstand local hydraulic conditions including flood velocities for the area shown on flood maps (Appendix F), plus buoyancy and debris forces, including:
  - Requirements in Section 2 of Construction of Buildings in Flood Hazard Areas (Australian Building Codes Board, 2012) should be demonstrated in development applications for proposed development in the South Burketown rural residential area
  - Performance Requirements and Acceptable Solutions in Part 3 of MP 3.5 – Construction of buildings in flood hazard areas (Business Queensland, 2013) should be included in the Burketown Planning Scheme and applicable to proposed development in the South Burketown rural residential area
  - Fencing beneath raised dwellings should be restricted or prevented such that conveyance of flood water is unimpeded and does not affect the structural soundness of the dwelling
  - New dwellings should be constructed with appropriate water-resistant materials to withstand flood damage
  - If it cannot be demonstrated in a development application that new dwellings are designed and certified to withstand the flood forces of local hydraulic conditions, then the application should be refused.

- Proposed development for the South Burketown rural residential area should be conditioned with the following controls:
  - Occupants of dwellings are to self-evacuate upon being notified of pending inundation of the area or they may be isolated for long periods during floods
  - Assistance from emergency services or other service providers may not be available to individual properties and cannot be relied upon
  - The development application should demonstrate that the proposed development will not increase the potential for danger to personal safety or property.

- Certificate of Title for each lot to include encumbrance stating land is:
  - flood-prone
  - subject to development conditions and are to be listed on the Title.

Building Envelope Locations

Based on flood characteristics shown in the flood mapping, recommendations are provided for potential relocation of building envelopes in Table 6.5. The suggested locations the building envelopes are relocated to remain outside the high storm tide inundation areas. The suggested building envelope locations are shown in Figure 6.4 and Appendix H.

Table 6.5 Potential Building Envelope Amendments for South Burketown Rural Residential Area

Lot and Plan	Potential building envelope location amendments
Lot 1 B1363	Envelope to be relocated to the east to 'Low' hazard area.
Lot 2 B1363	Envelope to be relocated to the west to area of lower depth, velocity and hazard.
Lot 3 B1363	Envelope to be relocated to the north east to 'Low' hazard, low depth and low velocity area shown on flood maps in Appendix E.
Lot 4 B1363	No amendments recommended.
Lot 5 B1365	No amendments recommended.
Lot 6 B1363	Envelope to be relocated to the north east to area of lower depth, velocity and hazard.
Lot 7 B1363	Envelope to be relocated to the north (north of Closed Road) to area of lower depth, velocity and hazard.
Lot 12 B1365	Envelope to be relocated to the north to area of lower depth and velocity.
Lot 13 SP287780	No amendments recommended.
Lot 16 SP260551	Envelope should be located on highest ground surface on lot.
Lot 17 SP260551	Lot not recommended for development due to depths greater than 1 m.

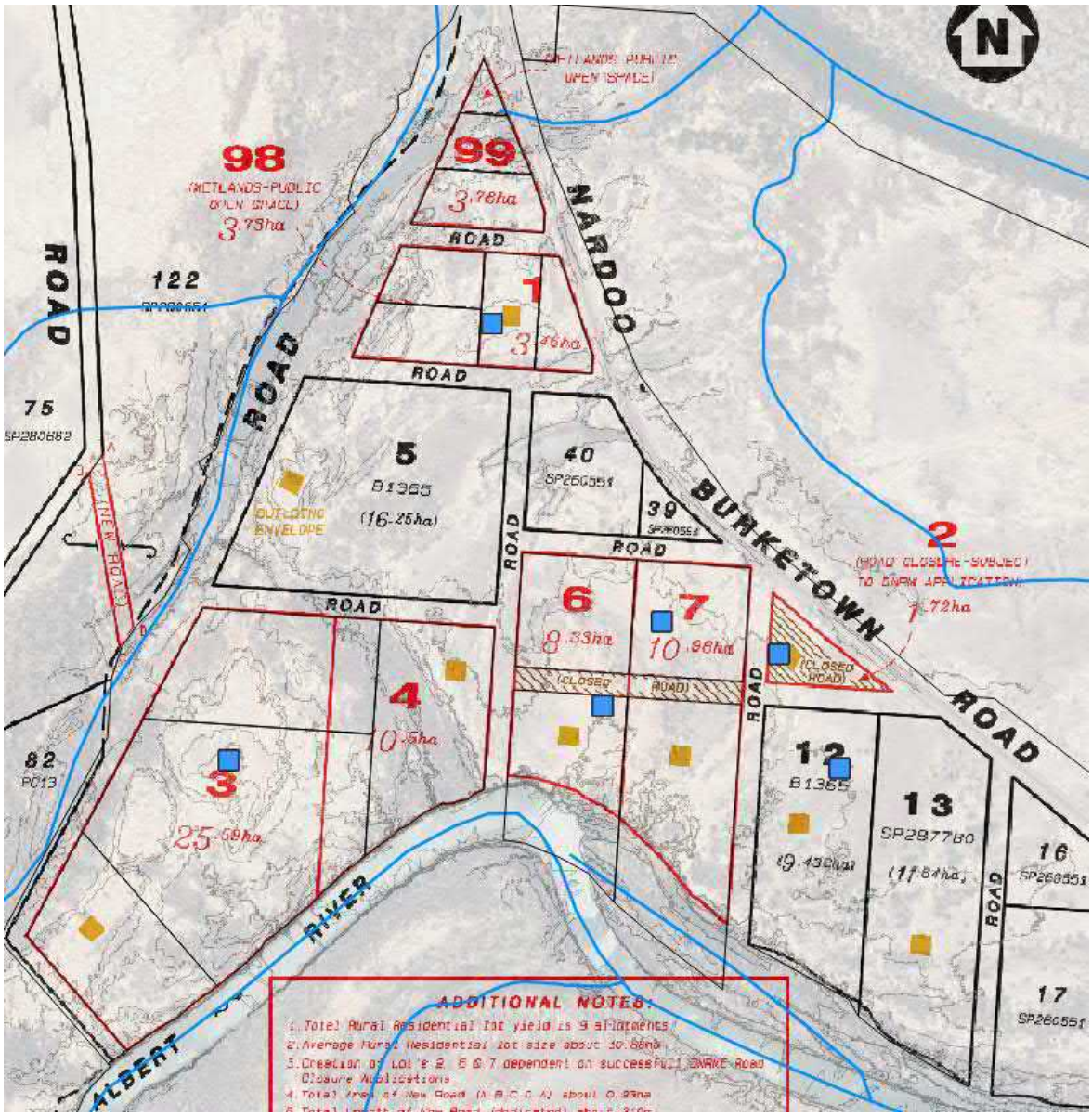


Figure 6.4 South Burketown - Potential Building Envelope Location Amendments shown by Blue Squares (locations by Council depicted by yellow squares)

Filling in Rural Residential Zone

The nine proposed rural residential lots (lots 1 to 7, 12 and 13) shown on the subdivision plan in Appendix G cover an area of approximately 98 ha. The building envelope area of each lot is 1000 m^2, totalling 0.9 ha and accounts for less than 1 % of the total lot area. The Planning Scheme restricts filling in the rural zone to a maximum of 150 mm (without triggering the Operational Works Code). If filling of building envelopes (per locations presented in section 6.7.2) is proposed as part of development applications to a maximum of 150 mm, and due to the small total building envelope area relative to the total lot area, it is not considered that tangible flood impacts will occur during local flood events or the regional 2011 (DFE) flood event.

6.7.3 West Burketown (Areas 3, 4, 5, 6, 12)

General Considerations

Potential parameters to be considered by Council to control development in West Burketown industrial are provided as follows:

- New building structures should be demountable type only (Class 10 buildings – non-habitable building or structure (QBCC, 2020)). It is noted that MP 3.5 guideline does not apply to Class 10 buildings (non-habitable buildings or structures) including demountable buildings.
- New building structures should have floor levels set above the DFL plus 500 mm freeboard.
- Fencing beneath raised building structures should be restricted or prevented such that conveyance of flood water is unimpeded
- The number of buildings per lot should be limited to limit the risk to safety to an acceptable level as determined by Council
- Workers are to self-evacuate upon being notified of pending inundation of the area
- Stored materials should not be buoyant and limited to types that will remain in place (by tethering to concrete footings for example) during flow velocities up to 0.5 m/s
- Filling of large areas is not recommended due to expected widespread impacts to floodplain levels.

Building Structure, Stored Materials and Stockpile Locations

Based on flood characteristics shown in the flood mapping, potential building structures, stored materials and stockpile locations for each lot in West Burketown are provided in Table 6.6 and general locations (dashed blue areas) are shown in Figure 6.5 and Appendix H. Areas not recommended are shown by dashed red areas or by default are all other locations not covered by dashed blue areas. Note that dashed areas are approximate only and not scalable. Proposed lot numbers are found on the Industrial Precinct plan in Appendix G. The area labels are shown on Figure 6.1.

Table 6.6 Parameters for Risk-Based Development of West Burketown

Area label	Proposed lot #	Parameters for risk-based development (refer to Figure H-2 for locations)
Area 3	24	Building structures, stored materials and stockpiles should be restricted to the eastern half of the lot where flow velocity is less than 0.2 m/s (dashed blue area). Building structures, stored materials and stockpiles where flow velocity is greater than 0.5 m/s (western half of lot) should not be permitted (dashed red area).
Area 3	25	Building structures, stored materials and stockpiles should be restricted to the north-western part of the lot where flow velocity is generally less than 0.2 m/s (dashed blue area). Building structures or storage of materials in locations where flow velocity is greater than 0.5 m/s (eastern half of lot) should not be permitted (dashed red area).
Area 3	26	Building structures, stored materials and stockpiles should be restricted to the northern central part of the lot where flow velocity is less than 0.2 m/s (dashed blue area). Building structures or storage of materials in locations where flow velocity is greater than 0.5 m/s (southern half of lot) should not be permitted.
Area 3	27-32	Stored materials are to be aligned parallel to the rear property boundary along direction of flow (dashed blue areas). Building structures, stored materials and stockpiles should be restricted to the northern most quarter of each lot (dashed blue areas). Driveway access to each lot should be from the northern boundary to prevent need for driveway crossover over potential inter-allotment open channel at southern boundary (refer section 6.8.1).
Area 3	33	Building structures, stored materials and stockpiles should be restricted to the far eastern end of the lot where flow velocity is less than 0.2 m/s (dashed blue area). Driveway access to each lot to be at northern boundary to prevent need for driveway crossover over potential inter-allotment open channel at southern boundary (refer section 6.8.1).
Area 4	56	Building structures, stored materials and stockpiles should be restricted to the north-western part of the lot where flow velocity is less than 0.2 m/s (dashed blue area).
Area 5	34-37	Building structures, stored materials and stockpiles should be restricted to the northern most quarter of each lot (dashed blue area).

Area label	Proposed lot #	Parameters for risk-based development (refer to Figure H-2 for locations)
Area 5	38-41	Stockpiling should not be permitted due to potential for concentration of runoff to lots to the north.
Area 5	42-45	Stockpiling should be restricted to the northern most quarter of each lot (dashed blue areas).
Area 6	Existing Lot 57 SP280661	Stockpiling should be restricted to the parts of lot where flow velocity is less than 0.5 m/s. Building structures, stored materials and stockpiles where flow velocity is greater than 0.5 m/s should not be permitted.
Area 12	Existing Lot 51 SP127908	Flood-free areas may be subject to inundation in flood events greater than the magnitude of the 2011 flood event (DFE).

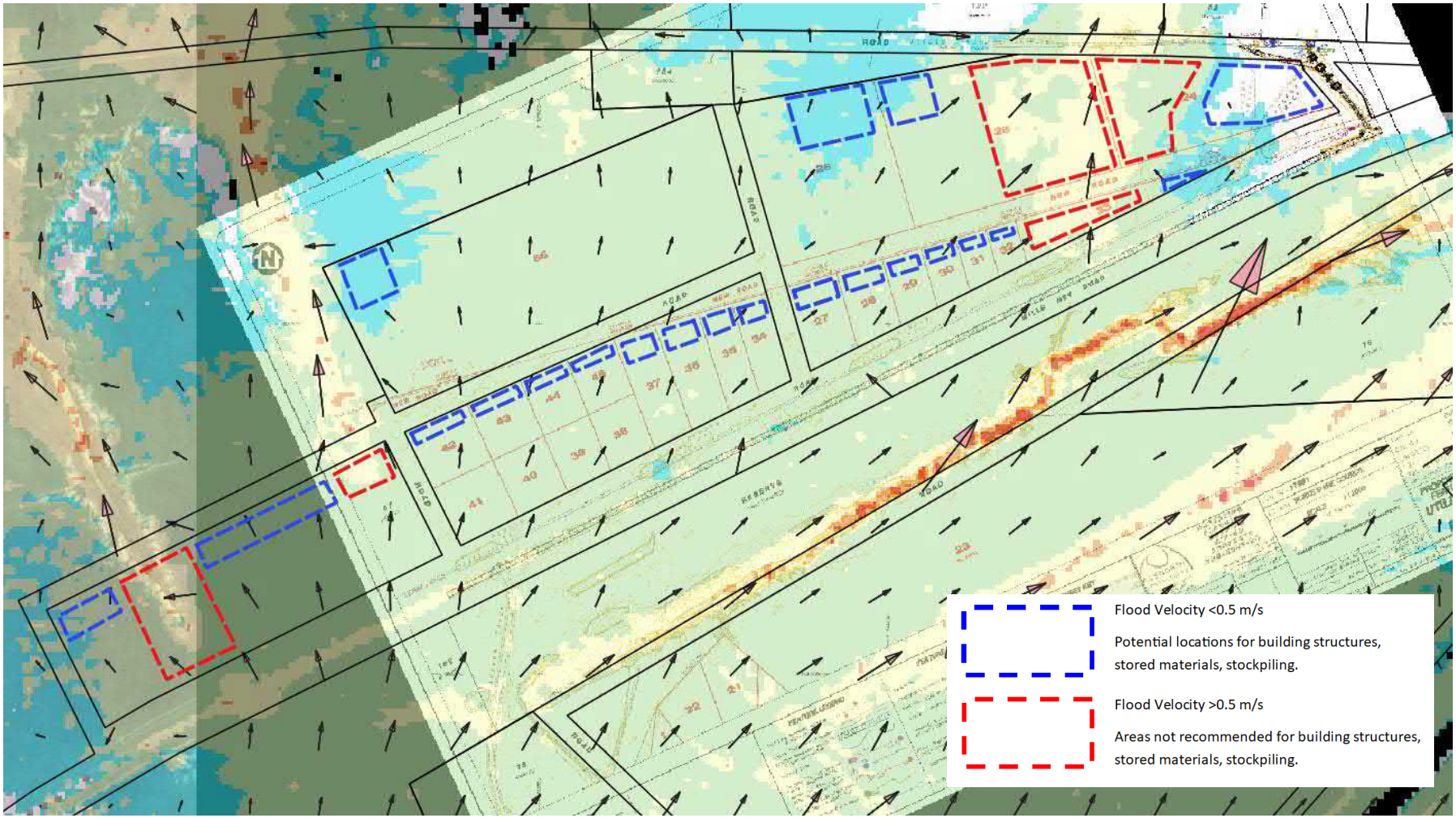


Figure 6.5 **West Burketown - Potential Building Structures, Stored Materials and Stockpile Locations (shown by dashed blue areas).**

Hydraulic Simulation of Stockpiles

The Burke Shire Planning Scheme does not allow filling in the Industrial Precinct with a height greater than 200 mm. Hydraulic modelling to determine the impacts of filling large areas in the Industrial Precinct was not undertaken. Flood depths in the regional 2011 flood (DFE event) over the proposed industrial lots (Appendix G) in West Burketown are generally in the range of 0.15 – 0.5 m. It is expected that filling of large areas to 200 mm height on the proposed lots would likely cause widespread impacts to floodplain levels to the north and south of the lots. Filling of large areas is therefore not recommended.

A preliminary regional flood analysis for the DFE was undertaken however, to determine if flood impacts could occur due to stockpiles being placed on numerous industrial lots in West Burketown. The development scenario included stockpiles located in the northern half of each of proposed lots 27 to 33 with a height of 200 mm above existing ground surface and footprint dimensions of 20 m by 20 m. Results were assessed and it was concluded that stockpiles in this configuration are unlikely to cause widespread impacts to the floodplain. Stockpiles are preferred on the proposed lots 24 to 26 (in locations described in Table 6.6) due to the expected minimal flood impacts to surrounding areas. It is recommended that only one (1) 20 m by 20 m by 200 mm (high) stockpiles be allowed per lot and up to two (2) 20 m by 20 m x 200 mm (high) stockpiles for lots 24 to 26 and lot 56.

6.8 Stormwater Management Concepts

As described in previous sections, the subject proposed lots in the West Burketown industrial precinct and South Burketown rural residential area are totally inundated in the regional 2011 flood (DFE) with flood depths in West Burketown generally 0.15 – 0.5 m and flood depths in South Burketown up to 4 m. Flood behaviour modification works for mitigation of regional flood impacts in Burketown have been ruled out per discussion in section 5.4.

Conceptual stormwater drainage works to address Acceptable Outcome (AO31) of the Planning Scheme, if applicable, for local flood events in West Burketown and South Burketown are discussed in this section. There are limitations to the concepts that can be recommended due to terrain, large areas of the two regions and cost constraints to Council.

Potential works to improve stormwater drainage in local flood events for the town centre have been identified in Section 6.8.3.

6.8.1 West Burketown

Based on discussions with Council representatives, the initial development area of interest in West Burketown include ten proposed lots (lot numbers 24 to 33) for industrial zoning and are shown on the subdivision plan in Appendix G.

An overland flow path covers proposed lots 24 to 25 and proposed lot 33 that conveys runoff in local flood events in a northerly direction from Wills Developmental Road in the south.

Proposed lots 24 to 33 pond runoff in local flood events to different depths due to low grade and depressions in the terrain.

An inter-allotment open drainage channel can be provided spanning proposed lots 28 to 33 to reduce ponding and aid conveyance of runoff through these lots to the overland flow path at the 'New Road' road reserve at the northern boundary of proposed lot 33.

The inter-allotment channel drainage channel should have the following nominal characteristics; trapezoidal section, top width approximately 20-25 m, 1V:4H batters and maximum depth 0.3 m. The top width has been based on the width of an existing surface drainage feature. The southern boundary of the channel is offset from the lot boundary by a nominal 10 m. Longitudinal grade of the channel invert should be based on detailed survey. The channel invert should tie in neatly to existing ground levels at upstream and downstream ends. The inter-allotment channel should be contained within a drainage easement in Council's favour. The alignment of the inter-allotment channel is consistent with the direction of flow in the regional flood event and is not expected to inhibit flow conveyance in regional flood events. The longitudinal profile of the 'New Road' between proposed lots 33 and 25 (at the overland flow path) such that conveyance of flow across the road reserve is not constrained should be investigated based on site inspection and detailed survey. A schematic showing the alignment of the drainage channel is presented in Figure 6.6.

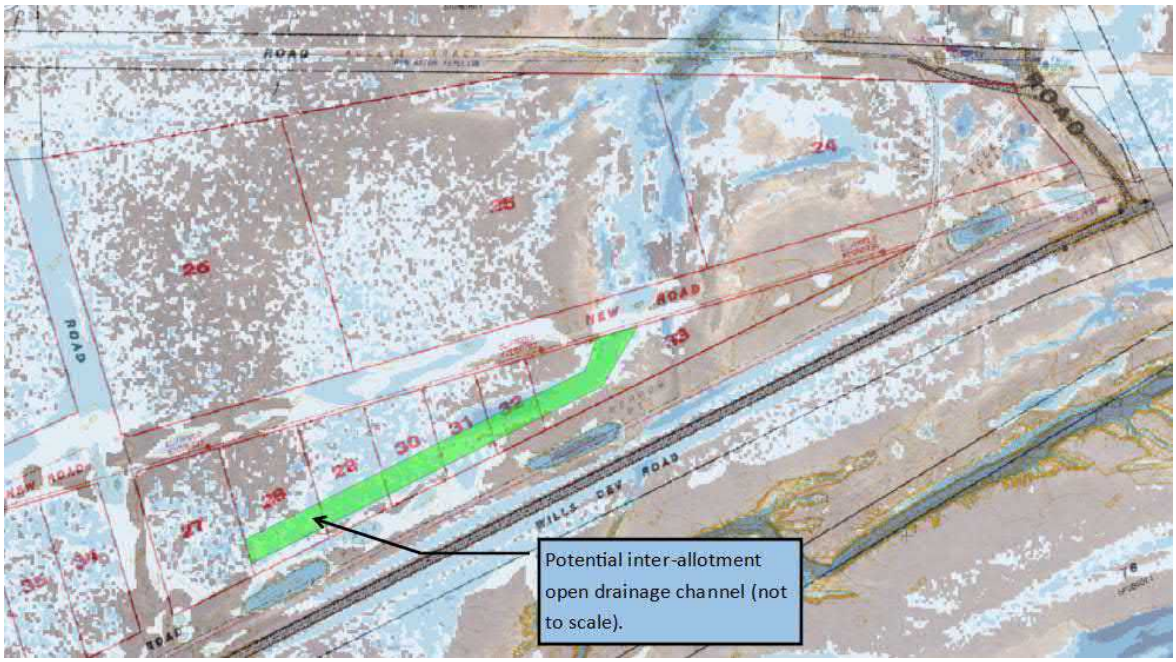


Figure 6.6 Potential Inter-Allotment Open Drainage Channel Spanning Proposed lots 28-33 in West Burketown (1% AEP local flood event depth extents shown)

Modifications to the overland flow path to improve conveyance within proposed lots 24 and 25 are not advised due to the large area of the overland flow path and to not concentrate flow.

Raising the elevation of any local roads above existing levels in West Burketown to create a crown for cross drainage is not advised due to potential flood impacts that may result due to constraint of overland flow.

Based on flood characteristics from local and regional modelling, no other conceptual recommendations for stormwater management are considered appropriate for West Burketown.

6.8.2 South Burketown

Based on review of flood characteristics for local flood events and proposed low lot density, it is not considered that stormwater drainage works such as detention, open channels or levees are relevant or applicable to South Burketown.

6.8.3 Local Flood Measures

The local flood depth maps were inspected, and the following areas were identified where earthworks or drainage works could potentially be undertaken to reduce the flood risk to existing properties/lots. Some of the lots may not currently have dwellings on them, and the potential works may provide the opportunity for the lots to be developed with lower flood risk. Only lots within the town centre were assessed.

Table 6.7 Potential Property and Local Road/Drainage Modifications

Area in Town Centre	Potential works
Lots south of Bowen Street and west of Burke Street	Fill the northern row of lots facing Bowen Street so ground surface falls towards Bowen Street. Bowen Street road profile to be modified to convey runoff to the west to overland flow gully.
Lots between Bowen Street and Gregory Street (west of Burke Street)	Fill the northern row of lots facing Gregory Street so ground surface falls towards Gregory Street. Gregory Street drainage channel (may require modification) within road reserve to convey runoff to the west to overland flow gully. Fill the southern row of lots facing Bowen Street so ground surface falls towards Bowen Street. Bowen Street drainage channel within road reserve to be modified to convey runoff to the west to overland flow gully.
Lots between Gregory Street and Sloman Street (west of Burke Street)	Construct inter-allotment drainage (piped or open drain) along rear of lots to convey runoff to the west to overland flow gully.
Lot between Anthony Street and Marshall Lane (east of Burke Street)	Fill lot so ground surface falls towards surrounding streets. Drainage channels within road reserve at frontages to be modified to convey runoff (runoff to flow west along Anthony Street to intersection with Burke Street; runoff to flow north along Burke Street to intersection with Marshall Lane; runoff to flow west along Marshall Lane to intersection with Burke Street). Burke Street drainage (eastern

Area in Town Centre	Potential works
	side) within road reserve to be modified to convey runoff to the north to intersection with Firefly Street. Firefly Street drainage to be modified to convey runoff to west to overland flow path at Firefly Street.
Lots between Marshall Lane and Landsborough Street (east of Burke Street)	Fill lots so ground surface falls towards Landsborough Street and Burke Street. Landsborough Street drainage to be modified to convey runoff to west to intersection with Burke Street. Refer to row 'L4' above regarding modification of Burke Street drainage.
Lots between Landsborough Street and Firefly Street (west of Burke Street)	Fill lots so ground surface falls towards surrounding streets. Drainage channels within road reserve at frontages to be modified to convey runoff (runoff to flow west along Landsborough Street to overland flow gully; runoff to flow north along Burke Street to intersection with Firefly Street; runoff to flow west along Firefly Street to overland flow path at Firefly Street).

7. CONCLUSION

This study was prepared using information gathered from site inspection, client consultation, review of existing documentation and publicly available information, and regional and local scale flood modelling. The study has identified the flood risks to existing critical and vulnerable infrastructure, and existing and proposed development areas.

Regional hydraulic modelling for the 2011 flood event identified the peak flood velocity may impact the power poles for the transmission line between the diesel plant and water treatment plant. This is in addition to the impacts already known to the sewerage system in low-lying areas and airport. Local hydraulic modelling for the 1% Annual Recurrence Interval (AEP) event shows most of the critical or vulnerable infrastructure and facilities are not inundated or are unlikely to experience significant inundation.

The existing flood risk management measures and historical information were assessed, and it was found that the Burketown community and Burke Shire Council are well prepared to respond to major regional flood events due to high resilience to flooding, adequate warning time to moderate floods provided by the flood warning network, and good understanding of the low-lying areas and which areas will be impacted first allowing for relocation of residents.

Regional major flooding equivalent to the 2011 event has widespread inundation impacts to Burketown and Council advised that structural mitigation measures for major regional flooding are undesired and not financially feasible. The impacts of levees for example are uncertain in a complex floodplain and may cause undesirable outcomes.

The flood assessment for the proposed development areas found that:

- Rural residential development in South Burketown is acceptable but some proposed building envelope locations require slight relocation to areas of lower flood velocity and/or depth to satisfy Queensland Development Code MP 3.5, and must also satisfy other conditions such as being resistant to flood forces (hydrodynamic action) and erosion/scour.
- Development in West Burketown industrial precinct is acceptable but must satisfy conditions regarding building Class, stored materials and filling.

Conceptual stormwater drainage works for West Burketown and the town centre have been identified and proposed. Works in South Burketown were not considered relevant due to low lot density and flood characteristics.

Recommended measures for flood risk management have been proposed for consideration by Council and are presented in section 8.

It is noted that flood behaviour predicted by the TUFLOW hydraulic model is inherently reliant on the underlying baseline data. As such, the flood information provided in this report and in any digital data provided are inherently reliant upon the accuracy of the data used for the study.

8. RECOMMENDATIONS

During the consultation process, Council advised that due to the capital expense of providing flood-free roads, such as access between town and the airport, and because the Council and residents have successfully handled numerous major floods in the past, that no major capital works are desired at this stage.

Recommended measures for flood risk management are presented in Table 8.1 below.

Table 8.1 Recommended Measures for Flood Risk Management

Measure	Description
Emergency Response Planning	Council prepares the following Sub Plans for flood response planning and adopts them for use within the Shire: • Evacuation Sub Plan • Resupply Sub Plan • SOP and Concept of Operations Plan Until the Sub Plans are completed and adopted by Council, Section 10 LDMG SUB PLANS should be removed from the LDMP. Refer Section 6.6.3 for advice regarding evacuation plans.
Emergency Response Planning	Develop and implement a Flood Warning Plan per Section 6.6.3 as part of the LDMP.
Emergency Response Planning	Consider implementing the recommended Triggers, Actions and Communications for Regional Flood Events into the LDMP update per Table 5.3.
Emergency Response Planning	The bank stabilisation works and re-survey of gauge boards and installation of a ground-based station with a camera at the existing Burketown Airport Gauge site are recommended to be undertaken as a priority, as the site is a high priority site in the BOM Flood Warning Network for Burketown. The upgraded existing gauge site is recommended to be kept in operation permanently as it would act as a back-up to the new station.
Emergency Response Planning	Council to consult with Telstra and BOM and obtain funding if required to prioritise the installation of the new automatic rainfall and river height station at Albert River (12 km upstream of Burketown) at the location proposed in the Telstra (2019) report.
Emergency Response Planning	Council to consult with Telstra and BOM and obtain funding if required to install new automatic rainfall and river height station on Running

Measure	Description
	Creek (87 km upstream of Burketown) at the location proposed in the Telstra (2019) report.
Community Flood Awareness and Preparedness	Council should determine which elements of this Flood Risk Management Study to share (and the format of how they are shared) with the community to increase awareness and resilience to flood risks (refer Section 6.6.3)
Protection of Critical Infrastructure	Consider installing protection measures for the power line between Airport Access Road and the western end of Musgrave Street identified in Section 5.3.
Risk based planning for development areas	Consider implementing stormwater management concepts identified in Section 6.7 to support proposed development.
Stormwater Management	Consider implementing parameters for risk-based development per Section 6.8.

In addition to the recommended measures, it is advised that flood modelling be updated and revised as additional data becomes available to improve the confidence of flood discharge estimates.

9. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g. This report does not provide legal advice.

10. REFERENCES

ABC News (2011). Rising floodwaters force outback evacuations. ABC News online article, 15 March 2011. https://www.abc.net.au/news/2011-03-15/rising-floodwaters-force-outback-evacuations/2658370.

ABC North West Queensland (2011). Warnings current for the Gulf and northwest. Burke Shire update. EMQ update. ABC News online article, 18 March 2011. https://www.abc.net.au/local/stories/2011/03/01/3151661.htm

Australian Building Codes Board (2012). Construction of Buildings in Flood Hazard Areas. Version 2012.2. Standard. https://www.business.qld.gov.au/industries/building-property-development/building-construction/laws-codes-standards/queensland-development-code. Australian Building Codes Board.

[1]Bureau of Meteorology (2020). Leichhardt, Nicholson, Gregory & Settlement Rivers map. http://www.bom.gov.au/qld/flood/brochures/leichhardt/map.shtml. Bureau of Meteorology. Australian Government.

[2]Bureau of Meteorology (2020). Climate statistics for Australian locations. Summary statistics BURKETOWN AIRPORT. http://www.bom.gov.au/climate/averages/tables/cw_029077.shtml. Bureau of Meteorology. Australian Government.

[3]Bureau of Meteorology (2019). Flood Warning System for The Nicholson River. http://www.bom.gov.au/qld/flood/brochures/nicholson/nicholson.shtml. Bureau of Meteorology. Australian Government.

[4]Bureau of Meteorology (2019). Flood Warning River Height Stations Flood Classifications. http://www.bom.gov.au/qld/flood/networks/section4.shtml. Bureau of Meteorology. Australian Government.

[5]Bureau of Meteorology (2019). Flood Watch Areas. Queensland. http://www.bom.gov.au/water/floods/floodWarningServices.shtml. Bureau of Meteorology. Australian Government.

[6]Bureau of Meteorology (2019). Coastal Rivers – North. Leichhardt, Nicholson, Settlement (QLD Part). Flood Warning Network as at 17/10/2019. http://www.bom.gov.au/qld/flood/brochures/river_maps.shtml. Bureau of Meteorology. Australian Government.

Burke Shire Council (2019). Burke Shire Local Disaster Management Plan 2018-19. Burke Shire Council.

[1]Burke Shire Council (2020). About Burke Shire. http://www.burke.qld.gov.au/about-burke-shire. Burke Shire Council.

[2]Burke Shire Council (2020). Burke Shire Council Planning Scheme 2020. http://www.burke.qld.gov.au/planning. Burke Shire Council.

Business Queensland (2013). MP 3.5 – Construction of buildings in flood hazard areas. https://www.business.qld.gov.au/industries/building-property-development/building-construction/laws-codes-standards/queensland-development-code.

Courier Mail (2011). It is a total disaster zone – almost. Courier Mail online article, 12 March 2011. Website no longer available.

Department of Housing and Public Works (2012). Guideline for the construction of buildings in flood hazard areas. https://www.business.qld.gov.au/industries/building-property-development/building-construction/laws-codes-standards/queensland-development-code. Department of Housing and Public Works. QLD Government.

Department of Planning, Industry and Environment (2005). Floodplain Development Manual. The management of flood liable land. https://www.environment.nsw.gov.au/research-and-publications/publications-search/floodplain-development-manual. Department of Planning, Industry and Environment. NSW Government.

[1]DES (2020). Coastal Hazard Areas Map. Storm Tide Inundation Areas. 6862-344. Version 4 – July 2015. https://apps.des.qld.gov.au/coastal-hazards/data/pdf/6862-344.pdf

[2]DES (2020). Coastal Hazard Areas Map. Storm Tide Inundation Areas. 6862-433. Version 4 – July 2015. https://apps.des.qld.gov.au/coastal-hazards/data/pdf/6862-433.pdf

[3]DES (2019). Guideline: State Development Assessment Provisions. State Code 8: Coastal development and tidal works. EPP/2018/4294. Version 2.00. https://environment.des.qld.gov.au/coastal/development/pdf/state-code8-coastal-development-tidal-works.pdf. Department of Environment and Science. QLD Government.

[1]DILGP (2016). State Planning Policy - State interest guideline. Natural hazards, risk and resilience. April 2016. https://www.dlgrma.qld.gov.au/resources/guideline/spp/spp-guideline-natural-hazards-risk-resilience.pdf Department of Infrastructure, Local Government and Planning.

[2]DILGP (2016). State Planning Policy - State interest guideline. Natural hazards, risk and resilience. April 2016. https://www.dlgrma.qld.gov.au/resources/guideline/spp/spp-technical-manual-natural-hazards-fit-for-purpose-approach.pdf Department of Infrastructure, Local Government and Planning. QLD Government.

DSDIP (2020). State Planning Policy Interactive Mapping System. https://spp.dsdip.esriaustraliaonline.com.au/geoviewer/map/planmaking Department of State Development, Manufacturing, Infrastructure, and Planning. QLD Government.

Engeny (2013). Burke Shire Council. Burketown Flood Mapping. October 2015. Engeny Water Management.

Engeny (2015). Queensland Reconstruction Authority. Phase 2 Flood Mapping – Bundle 11. Burketown Flood Modelling. October 2015. Engeny Water Management.

idcommunity (2020). Regional QLD Population and dwellings. https://profile.id.com.au/australia/population?WebID=200.

QBCC (2020. Classification summary of buildings and structures. https://www.qbcc.qld.gov.au/sites/default/files/BCA%20Classes%20of%20Building.pdf. Queensland Building and Construction Commission.

QLD Globe (2020). Queensland Globe. Department of Natural Resources, Mines and Energy. State of Queensland.

Queensland Reconstruction Authority (QRA) (2012). *Planning for Stronger, More Resilient Floodplains Part 2 Report.*

Telstra (2019). Telstra's Response to Burke Shire Council. Flood Monitoring Network. 23 October 2019.

TMR (2019). Table 5.5.4 (a) – Equations for sizing riprap at bridge piers. Equation 5.5.4 (e). *Bridge Scour Manual. Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour (2018).* January 2019. The State of Queensland (Department of Transport and Main Roads).

APPENDIX A

Glossary of Terms

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 (i.e., a one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national survey height datum as a reference level for defining reduced levels; 0.0 m AHD corresponds approximately to 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. If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence–probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures (i.e. their ability to reduce the AAD).
Average Recurrence Interval (ARI)	A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger than the selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also *annual exceedance probability*).
Catchment	The area of land draining to a particular site. It is related to a specific location, and includes the catchment of the main waterway as well as any tributary streams.
Community	Refers to the entirety of the population located physically in proximity to the study area.
Consequence	The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse (e.g. death or injury to people, damage to property and disruption of the community) or beneficial.
Critical Duration	The duration of a storm event that results in the worst flooding at a particular location of interest
Design Flood	The flood event selected for the treatment of existing risk through the implementation of structural mitigation works such as levees. It is the flood event for which the impacts on the community are designed to be limited by the mitigation work. For example, a levee may be designed to exclude a 2% AEP flood, which means that floods rarer than this may breech the structure and impact upon the protected area. In this case, the 2% AEP flood would not equate to the crest level of the levee, because this generally has a freeboard allowance, but it may be the level of the spillway to allow for controlled levee overtopping (see also *annual exceedance probability, floodplain, freeboard* and *probable maximum flood).*
Design Rainfall	The rainfall events that result in in design flood events (see *design flood).*

Development	Development may be defined in jurisdictional legislation or regulation. This may include erecting a building or carrying out of work, including the placement of fill; the use of land, or a building or work; or the subdivision of land. Infill development refers to the development of vacant blocks of land within an existing subdivision 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 is intensification of use with development of a completely different nature to that associated with the former land use or zoning (e.g. the urban subdivision of an area previously used for rural purposes). New developments generally involve rezoning, and associated consents and approvals. It may require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. Redevelopment refers to rebuilding in an existing developed 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**.**
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 improving 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.
Effective warning time	The effective warning time available to a flood-prone community is equal to the time between the delivery of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. The effective warning time is typically used for people to self-evacuate, to move farm equipment, move stock, raise furniture, 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.
Existing flood risk	The risk a community is exposed to as a result of its location on the floodplain.
Flash flooding	Flood that is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. It is generally not possible to issue detailed flood warnings for flash flooding. However, generalised warnings may be possible. It is often defined as flooding that peaks within six hours of the causative rain.
Flood	Flooding is a natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both (see also *catchment flooding* and *coastal flooding*).

Flood awareness	An appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.
Flood Damage	The tangible (direct and indirect) and intangible costs (financial, opportunity costs, clean-up) of flooding. Tangible costs are quantified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people that are attributed to a flooding episode.
Flood education	Education that raises awareness of the flood problem, to help individuals understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
Flood emergency management plan	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. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies.
Flood fringe areas	The part of the floodplain where development could be permitted, provided the development is compatible with flood hazard and appropriate building measures to provide an adequate level of flood protection to the development. This is the remaining area affected by flooding after flow conveyance paths and flood storage areas have been defined for a particular event (see also *flood storage areas*).
Flood hazard	Potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.
Floodplain	An area of land that is subject to inundation by floods up to and including the probable maximum flood event – that is, flood-prone land.
Flood prone land	Land susceptible to flooding by the probably maximum flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.
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 handbook, usually includes both written and diagrammatic information describing how particular areas of flood-prone land are to be used and managed to achieve defined objectives. It outlines the recommended ways to manage the flood risk associated with the use of the floodplain for various purposes. It represents the considered opinion of the local community and the floodplain management entity on how best to manage the floodplain, including consideration of flood risk in strategic land-use planning to facilitate development of the community. It fosters flood warning, response, evacuation, clean-up and recovery in the onset and aftermath of a flood, and suggests an organisational structure for the integrated management for existing, future and residual flood risks. Plans need to be reviewed regularly to assess progress and to consider the consequences of any changed circumstances that have arisen since the last review.
Flood planning area (FPA)	The area of land below the flood planning level, and is thus subject to flood-related development controls.
Flood planning levels (FPL)	The FPL is a combination of the defined flood levels (derived from significant historical flood events or floods of specific annual exceedance probabilities) and freeboards selected for floodplain management purposes, as determined in management studies and incorporated in management plans.
Flood prone land	Land susceptible to flooding by the probably maximum flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural damage and potentially, in some cases, reduce contents damage.
Flood readiness	An ability to react within the effective warning time (see also *flood awareness* and *flood education*).
Flood risk	The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types – existing, future and residual.
Flood storage areas	The parts of the floodplain that are important for temporary storage of floodwaters during a flood passage. 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 (see also *flow conveyance areas* and *flood fringe areas*).
Flood study	A comprehensive technical investigation of flood behaviour. It defines the nature of flood hazard across the floodplain by providing information on the extent, level and velocity of floodwaters, and on the distribution of flood flows. The flood study forms the basis for subsequent management studies and needs to take into account a

	full range of flood events up to and including the probable maximum flood.
Flood Frequency Analysis	Flood Frequency Analysis (FFA) refers to procedures that use recorded and related flood data to identify underlying probability model of flood peaks, at a particular location in the catchment, which can then be used to perform risk-based design and flood risk assessment, while providing input to regional flood estimation methods.
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 flow, or a significant increase in flood levels.
Flow	The rate of flow of water measured in volume per unit time – for example, cubic metres per second (m3/s). Flow 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).
Flow conveyance 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 flow, or a significant increase in flood levels.
Freeboard	It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc.
Frequency	The measure of likelihood expressed as the number of occurrences of a specified event in a given time. For example, the frequency of occurrence of a 20% annual exceedance probability or five-year average recurrence interval flood event is once every five years on average (see also *annual exceedance probability, annual recurrence interval, likelihood* and *probability*).
Gauge height	The height of a flood level at a particular gauge site related to a specified datum. The datum may or may not be the AHD (see also *Australian height datum*).
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, it refers to 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 handbook, the hazard is flooding, which has the potential to cause damage to the community.
Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level, extent and velocity.
Hydrograph	A graph that shows how the flow or stage (flood level) at any particular location varies with time during a flood.

Hydrology (Hydrological)	The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Hyetograph	A graphical representation of the distribution of rainfall over time.
Impervious	Surfaces are considered to be impervious if they are constructed from a material that water is unable to pass through
Local overland flooding	Inundation by local runoff on its way to a waterway, rather than overbank flow from a stream, river, estuary, lake or dam. Can be considered synonymous with stormwater flooding.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Minor, moderate and major flooding	These terms are often used in flood warnings to give a general indication of the types of problems expected with a flood: • Minor flooding causes inconvenience such as minor roads closures and the submergence of low-level bridges. The lower limit of this class of flooding on the reference gauge may be the initial flood level at which landholders and townspeople begin to be flooded. • Moderate flooding refers to the inundation of low-lying areas, which requires stock to be removed and/or some houses to be evacuated. Main traffic routes may be covered. • Major flooding refers to when appreciable urban areas and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
Modification measures	Measures that modify either the flood or the property or the response to flooding. There are three generally recognised ways of managing floodplains to minimise the risk to life and to reduce flood losses: • By modifying the response of the population at risk to better cope with a flood event (Response Modification); • by modifying the behaviour of the flood itself (Flood Modification); and • by modifying or removing existing properties and/or by imposing controls on property and infrastructure development (Property Modification).
Peak flow	The maximum flow occurring during a flood event past a given point in the river system (see also *flow* and *hydrograph*).
Probability	A statistical measure of the expected chance of flooding. It is the likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity indicating an outcome that is certain. Probabilities are commonly expressed in terms of percentage. For example, the probability of 'throwing a six' on a single roll of a die is one in six, or 0.167 or 16.7% (see also *annual exceedance probability*)..

Probable maximum flood	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from PMP 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	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 (WMO 1986). It is the primary input to probable maximum flood estimation.
Residual flood risk	The risk a community is exposed to that is not being remedied through established risk mitigation measures. In simple terms, for a community, it is the total risk to that community, less any measure in place to reduce that risk.
Risk	The effect of uncertainty on objectives' (ISO31000:2009). NOTE 4 of the definition in ISO31000:2009 also states that 'risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence'. Risk is based upon the consideration of the consequences of the full range of flood behaviour on communities and their social settings, and the natural and built environment (see also *likelihood* and *consequence*).
Riverine flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Runoff	The amount of rainfall that drains into the surface drainage network to become stream flow; also known as rainfall excess.
Social Capital	The networks of relationships among people who live and work In a particular community, enabling that community to function effectively.
Stage	Equivalent to water level. Both stage and water level are measured with reference to a specified datum (e.g. the Australian height 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.
Temporal Pattern	A temporal pattern refers to the series of time vs rainfall depth intervals that combine to make a rainfall event.
Vulnerability	The degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards. Vulnerability is assessed in terms of ability of the

	community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability (see also *flood awareness*).
Warning lead time	Time between the issuing of a message containing a flood prediction and the time when the predicted flood height is reached (or when the stream peaks below that height)
Water surface profile	A graph showing the flood stage along a watercourse at a particular time.

APPENDIX B

Regional and Local Flood Analysis

BURKE SHIRE COUNCIL

Burketown Flood Risk Management Study

Regional and Local Flood Analysis

March 2020

M7106_002-REP-002-REV0

www.engeny.com.au
P: 07 3221 7174
Level 7, 500 Queen St Brisbane QLD 4000 | PO Box 10183 Brisbane QLD 4000

DISCLAIMER

This report has been prepared on behalf of and for the exclusive use of BURKE SHIRE COUNCIL and is subject to and issued in accordance with BURKE SHIRE COUNCIL instruction to Engeny Water Management (Engeny). The content of this report was based on previous information and studies supplied by BURKE SHIRE COUNCIL

Engeny accepts no liability or responsibility whatsoever for it in respect of any use of or reliance upon this report by any third party. Copying this report without the permission of BURKE SHIRE COUNCIL or Engeny is not permitted.

M7106_002 BURKETOWN FLOOD STUDY						
\\EGIBRAPP02\management$\Projects\M7000_Miscellaneous Deliv\Docs\Report\M7106_002-REP-002-0-Burketown-FS.docx		Clients\M7106_002		Burketown		FRMS\07
REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**PROJECT MANAGER**	**APPROVER (PD)**	**DATE**
Rev 0	Client Issue Final	Kelsey Mundt/Karl Umlauff	Karl Umlauff/Mark Page	Karl Umlauff	Mark Page	20 March 2020
Signatures						

CONTENTS

Appendices

List of Tables

List of Figures

1. INTRODUCTION

Engeny Water Management (Engeny) was engaged to deliver the Burketown Flood Risk Management Study (Burketown FRMS) on behalf of Burke Shire Council (BSC or Council).

A regional flood study was undertaken for Burketown in a previous engagement of Engeny by Council. This report documents the regional flood study and the development of a local flood study for Burketown. Results and mapping from the regional and local studies were used to inform the Burketown Flood Risk Management Study (Burketown FRMS) and are presented in Appendices to the FRMS.

2. PREVIOUS STUDIES

The following studies focussed on Burketown have been undertaken by Engeny. The objectives of each study are provided below.

- *Queensland Reconstruction Authority. Phase 2 Flood Mapping – Bundle 11. Burketown Flood Modelling.* Engeny Water Management dated April 2013.

The scope of the study was to develop a regional scale hydraulic model using inflow hydrographs provided by Queensland Reconstruction Authority to determine flood levels, velocities and hazard (and produce flood maps) in the vicinity of Burketown. The purpose of the study was to identify high level flood risks.

- *Burke Shire Council. Burketown Flood Mapping* by Engeny Water Management dated October 2015.

The scope of the study was to estimate the 1% AEP peak discharge flood flow at Burketown using flood frequency analysis of DNRM gauges, flood frequency analysis of the Burketown Airport gauge and broad scale rain-on-grid hydraulic modelling. The purpose of the study was to set flood planning levels for the Burketown area. The outcome of the study was that the 2011 flood event be adopted as the Defined Flood Event (DFE) for Burketown with additional freeboard set by Council in accordance desired risk profiles. Flood maps were produced for Burketown based on the design flow estimates. The regional TUFLOW flood model developed using the flood frequency analysis of the Burketown Airport gauge was adopted for further development for the purposes of the flood risk management study.

3. REGIONAL FLOOD MODEL

3.1 Overview

The TUFLOW 1D-2D hydraulic modelling package was utilised to undertake modelling of the regional (Albert River) flood behaviour in the Burketown township. The regional flood behaviour was based upon the 2011 historical flood event. The following sections outline the design event flood estimation, and the hydraulic model build, simulations, and results.

3.2 Discharge Frequency Estimation

A variety of techniques have been considered in order to estimate design flood estimates at Burketown. These methods included:

- DNRM Flood Frequency Analysis
- Broad Scale Hydraulic Modelling
- Burketown Airport Gauge Analysis.

The following sections outline the methodology and outcome from these various design event flood estimation techniques.

3.2.1 DNRM Flood Frequency Analysis

Purpose

A Flood Frequency Analyses (FFA) of DNRM gauges in the upper catchment was undertaken as a method to provide an estimation of the 1% AEP peak flow at Burketown, and to place the 2011 flood event in context. DNRM operate a number of streamflow gauges within the Nicholson and Leichhardt River basins. Given the longer durations of record, it is considered that more confidence can be applied to peak flow estimates derived from these gauge records. A FFA has been undertaken at selected gauge locations with the results used to derive a catchment area versus flow relationship which can then be applied to the catchment area upstream of Burketown to estimate peak design flows.

Gauges

Four gauges within the Flinders and Leichhardt Basin were selected for FFA. These gauges were selected based on proximity to Burketown, length of record and having catchment sizes of a similar order of magnitude to the flood gauge at the Burketown Airport. Details of the selected gauges are given in Table 3.1.

Table 3.1 Details of DNRM Streamflow Gauges Used in FFA

Station Name	Station Number	Catchment Area (km²)	Years of Record
Dugald River at Railway Crossing	915206A	660	48
Gunpowder Creek at Gunpowder	913006A	2,427	44
Leichhardt River at Doughboy Creek	913014A	3,524	39
Leichhardt River at Miranda Creek	913004A	5,961	31

Analysis

An annual peak flow series was extracted for each gauge location (as summarised above). These annual series were then fitted to a Log Pearson Type III distribution.

The 1% AEP peak flow results from the four FFA results were then plotted against catchment area to derive an overall relationship between 1% AEP peak flow and catchment area.

The results of the FFA for each gauge location are given in Appendix A. Figure 3.1 shows a plot of 1% AEP peak flow from the FFA predictions versus catchment area for the four gauges analysed. As demonstrated in Figure 3.1, two trendlines have been fitted to the data; a linear trendline using three of the four gauges assessed, and a logarithmic trendline utilising all four gauges assessed. An estimate of the 1% AEP peak flows at the Burketown Airport gauge has been made based on each of the trendlines shown in Figure 3.1. The results of this analysis are given in Table 3.2.

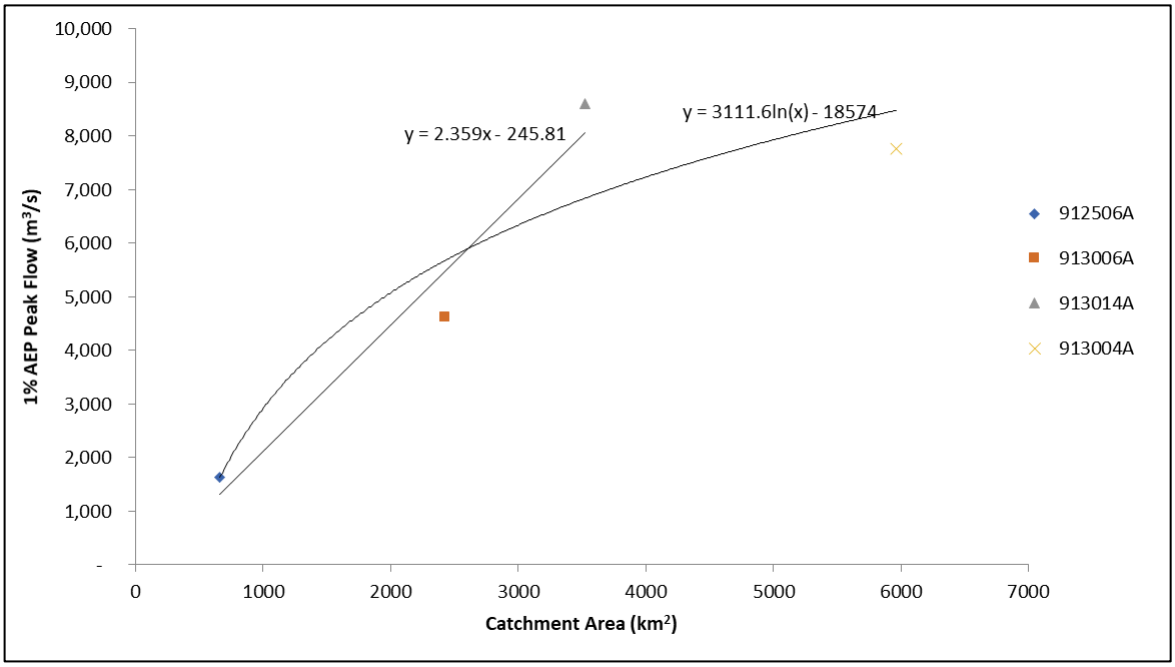


Figure 3.1 1% AEP Flood Estimates at DNRM Gauges

Table 3.2 Results of Trendline Fitting of DNRM Gauge Flows

Gauges Used	Trendline Type	1% AEP Peak Flow Estimate
915206A, 913006A, 913014A, 913004A	Logarithmic	4,560
915206A, 913006A, 913014A	Linear	3,750

Uncertainty

There are two key parameters that affect the accuracy of the FFA and the accuracy of the 1% AEP estimation. These are the length of record available at the gauges, and the calculated catchment area to Burketown used in conjunction with the trendline to estimate the 1% AEP peak flow.

The catchment area has been delineated utilising the available SRTM topographic data in conjunction with the broad scale hydraulic modelling (discussed in the following sections). However, due to the braided nature of the river systems upstream of Burketown, there may be some margin of error in the calculation of the catchment size.

The accuracy of the 1% AEP peak flow estimate utilising the FFA, and the magnitude of the probability limits are dependent on the length of record available at the gauges. The calculated peak flow magnitude for more frequent events are expected to be more accurate than those for the 1% AEP event.

3.2.2 Broad Scale Hydraulic Modelling

Purpose

A broad scale TUFLOW Rain-On-Grid (ROG) model was simulated to provide an alternative method to estimating the 1% AEP peak flow at Burketown.

Modelling

1% AEP flows at the Burketown Airport were estimated through application of rain-on-grid modelling over a broad scale hydraulic model representing the entire Nicholson and Leichhardt River basins. This modelling approach applies design rainfall values sourced from the Bureau of Meteorology (BoM) over the entire catchment area with the hydraulic model then routing rainfall runoff. Peak design flows were then extracted from the model at the Burketown Airport gauge location.

A 2D TUFLOW model was developed covering the extent of the Nicholson and Leichhardt Basins. The model was developed using the following sources of data:

- SRTM topographic data was used for the base model geometry. A grid resolution of 80 m was adopted for the model.
- The model extent covered the entire Nicholson and Leichardt River catchments (refer to Figure 3.2).
- A consistent Manning's 'n' value of 0.05 was applied across the entire model domain. This is considered representative of an average catchment value based on low resolution aerial photography available through Google Earth.

Figure 3.2 Hydraulic Model Extent

The 'direct rainfall' approach has been adopted for application of rainfall to the model. This approach applies net rainfall directly to the 2D cells within the developed TUFLOW model. Rainfall runoff and routing are modelled explicitly within the hydraulic model rather than relying on a separate hydrologic model.

1% AEP design rainfall depths were sourced from the IFD tool available from the BoM website. A consistent (non-spatially varying) rainfall depth was applied across the entire model extent. The location at which the rainfall was extracted was 18.625S, 139.100E. Design rainfall data was extracted for a number of other locations across the model extent, with variation typically being within ±10% of the adopted values. The 24, 48 and 72 hour durations were considered due to the significant size of the area considered. As such, the adopted values were considered appropriate for the high-level application.

An aerial reduction factor of 0.9 was applied to the design rainfall depths. The adopted 1% AEP rainfall depths are shown in Table 3.3.

Table 3.3 Adopted 1% AEP design rainfall depths

1% AEP Duration	1% AEP Rainfall Depth
24h	224.6
48h	273.9
72h	294.2

Results

A map of the results of the broad scale hydraulic modelling is presented in Appendix C. Table 3.4 summarises the 1% AEP peak flows at Burketown for the three durations considered (24hr, 48hr and 72hr). The maximum 1% AEP peak flow estimate occurs in the 48hr duration event. The peak flow derived from this method is generally consistent with the estimates derived from the other approaches adopted in this investigation.

Table 3.4 1% AEP Peak Flow Estimates from Broad Scale Hydraulic Modelling

Duration	1% AEP Peak Flow at Burketown (m^3/s)
24hr	2,920
48hr	3,100
72hr	2,990

3.2.3 Burketown Airport Gauge Analysis

Purpose

A Flood Frequency Analysis (FFA) was undertaken at the Burketown Airport gauge. Given the short duration of record at this location (15 years), it is considered that significant uncertainty exists with design flow estimates produced using this record. The FFA was undertaken to check for consistency between the other methodologies adopted to produce design flow estimates.

Rating Curve Development

To be able to undertake a FFA at the Burketown Airport gauge, a rating curve was required to be developed at the gauge.

The TUFLOW hydraulic model developed as part of the Queensland Reconstruction Authority *Phase 2 Flood Mapping – Bundle 11* project (Engeny, 2013) was used to develop the rating curve at the Burketown Airport gauge. A synthetic hydrograph was applied to the model. The flood levels corresponding to particular flows were extracted from the model at the gauge location. The resultant rating curve is shown in Figure 3.3.

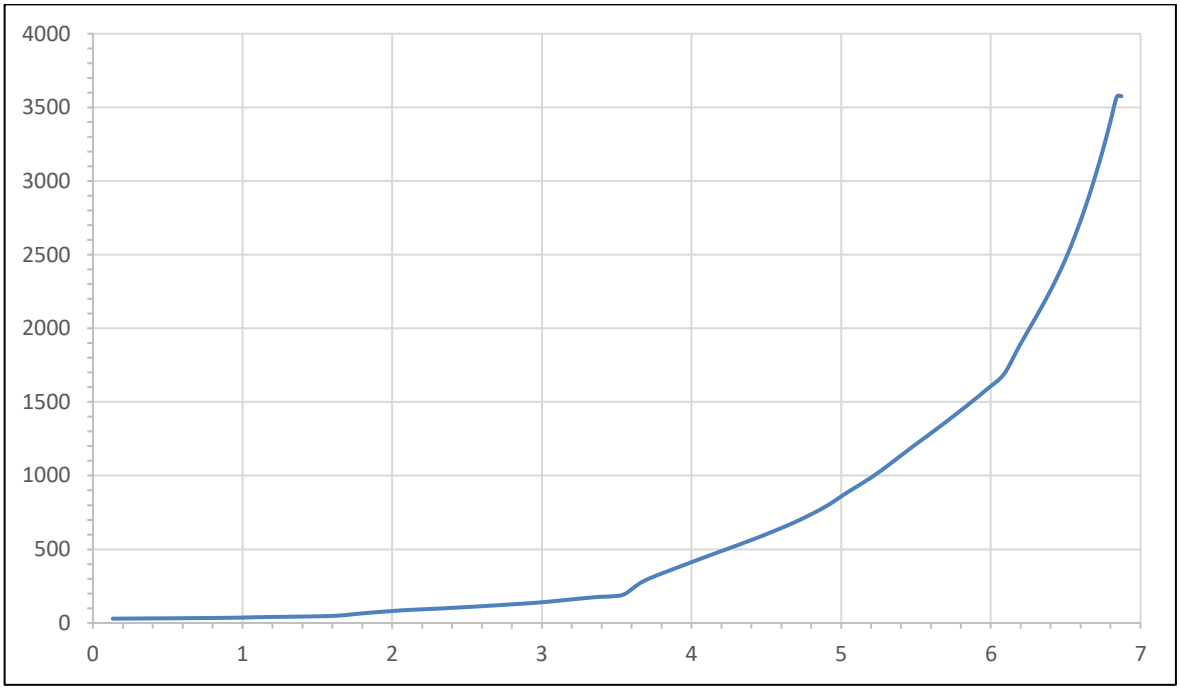


Figure 3.3 Rating Curve for Burketown Airport Flood Gauge

Flood Frequency Analysis

A Peak Over Threshold (POT) analysis was used as the basis for the FFA at the Burketown Airport Gauge. This approach was adopted over an annual maximum sequence to achieve the maximum number of flows assessed. The entire peak flow sequence supplied by BoM was adopted for the analysis. The number of flows recorded in the sequence was 16. For infrequent events such as the 1% AEP flood event, the results of the POT analysis should be consistent with the results from an FFA based on the annual maximum sequence.

The POT series was fitted to a Log Pearson Type III distribution. As outlined above, caution should be taken in the interpretation of the results of this analysis. The very short length of record would indicate significant uncertainty in the analysis results.

Results

The results of the FFA at Burketown Airport are given in Figure 3.4 and Table 3.5. The peak flow estimate for the 1% AEP design flood event is 4243 m^3/s. This is generally consistent with the estimates made using the other approaches adopted in this investigation, although as can be seen from Table 3.5, confidence limits for this estimate are very broad (indicating poor confidence).

Table 3.5 Results of FFA at Burketown Airport Gauge

AEP Flood Event	Peak Flow Estimate (m3/s)	95% Confidence Limits	
		Lower Bound (m^3/s)	Upper Bound (m^3/s)
10%	3,239	2,207	5,689
2%	4,038	2,677	7,613
1%	4,243	2,794	8,134

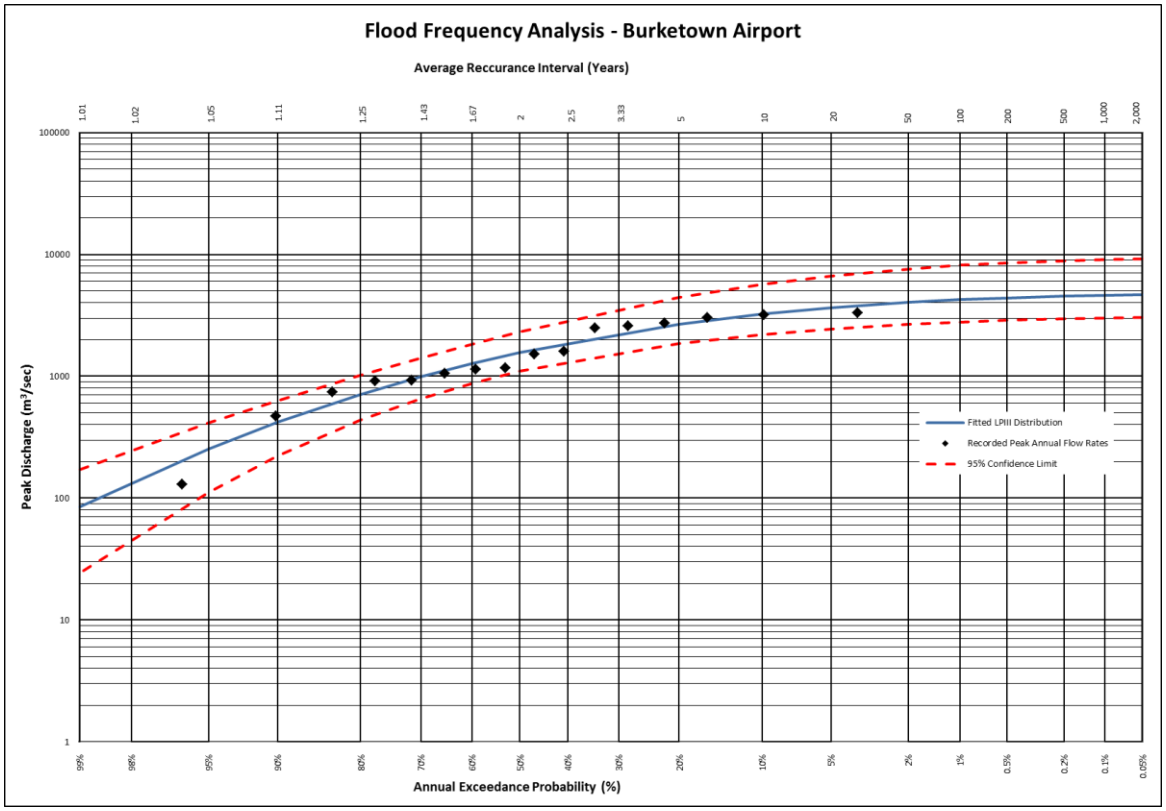


Figure 3.4 Results of FFA at Burketown Airport Gauge

3.3 Summary and Recommendation for Peak Catchment Discharge

Three different approaches to estimation of the 1% AEP peak flow at Burketown have been undertaken. A summary of the findings of each approach is presented in Table 3.6.

Table 3.6 Summary of 1% AEP Peak Flow Estimates

1% AEP Flow Estimation Approach	1% AEP Peak Flow Estimate (m^3/s)
DNRM Streamflow Gauge FFA	3,750 – 4,560
Broad Scale Hydraulic Modelling	3,100
Burketown Airport Gauge FFA	4,243

Based on the results in Table 3.6 it can be seen that whilst the 1% AEP peak flow estimates are broadly consistent with one another, significant variation exists (approximately 25%) between approaches. Additionally, as noted previously, significant uncertainty exists in the predicted flood flows.

Given the variation in 1% AEP peak flow estimates and the inherent uncertainty, it is recommended that the 2011 flood event be adopted as the Defined Flood Event (DFE) for Burketown, with an associated freeboard applied to this level to set habitable floor levels. While this freeboard should be set by Council in accordance with the desired risk profile, consideration could be given of a value of 500 mm – 600 mm. This is a figure commonly adopted by other Queensland councils and is generally consistent with guidance in the document *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017). This being the case, it is acknowledged that this level may prove impractical for development in some areas, and consideration could be given to reducing this level for some types of development (such as industrial or commercial uses).

All estimated 1% AEP peak flood flows would fall within this freeboard, with an additional allowance for other uncertainties. Table 3.7 summarises the predicted flood level at the Burketown Airport gauge for the upper and lower estimates for the 1% AEP peak flood flow. Predicted levels are based on the rating curve presented in Section 3.2.3.

Table 3.7 Predicted levels at Burketown Airport for Various Flows

Flow	Predicted Level at Burketown Airport Gauge (m AHD)
3,329 m^3/s (2011 Event)	6.78*
3,750 m^3/s (1% AEP Lower Estimate)	6.9
4,560 m^3/s (1% AEP Upper Estimate)	7.1

** Actual recorded value.*

The DFE recommendation has been made on the following basis:

- Minimal uncertainty exists in the flood level for the 2011 event as it is a gauged recording. This is in contrast to the design flood estimates that have been made. It is considered that adoption of a DFE with minimal uncertainty exposes Council to less risk.

- The peak flow estimated for the 2011 flood event falls within the range of flow values estimated for the 1% AEP design flood for Burketown, although at the lower end of the estimates.

- Adoption of the highest recorded flood level as the DFE is considered to be consistent with the provisions in the State Planning Policy (SPP) guidance material for flood risk (DILGP, 2016). The SPP allows for Councils to adopt their choice of event as the DFE.

3.4 TUFLOW Model Development and Results

The development of the regional TUFLOW 2D hydraulic model for the Burketown Township is summarised in the following sections. The layout of the regional TUFLOW model is shown in Appendix C.

3.4.1 Model Extent and Resolution

The TUFLOW model utilises the provided 1 metre LiDAR topographical data. The model cell size resolution selected was 10 m. The model extends from approximately 3 km upstream of the airport to approximately 4 km upstream of the boat ramp, located downstream of Burketown. Limitations associated with the model extent and boundaries are due to the extent of the provided topographic data.

3.4.2 Hydraulic Structures

The two bridge structures (traffic and pedestrian bridges) at the Albert River were incorporated into the model as layered flow constrictions (2d_lfcsh). The parameters for these two structures were based off photos and measurements taken during the site inspection as follows:

- Albert River traffic bridge
  - Deck thickness approximately 0.8 m
  - Spans; 9 x 15 m
  - Piers; 5 inline and 0.6 mm diameter
  - Guard rail; 1.5 m between posts, 0.4 m gap beneath guard rail, 0.3 m guard rail.

- Albert River pedestrian bridge
  - Deck thickness 0.7 m including 0.2 m high kerb
  - Spans; 9 x 8m
  - Hand rails 1.1 m high
  - Piers 1.0 m wide.

3.4.3 Hydraulic Roughness

A GIS based roughness map covering the study area was created to define the hydraulic roughness parameters. Each grid cell is assigned a Manning's 'n' roughness value based

upon the created delineation map. The GIS layer of existing land use was generated using the aerial photography.

Table 3.8 outlines the Manning's roughness parameters assigned to each land use within the study area.

Table 3.8 Adopted Roughness Parameters

Material Classification	Manning's 'n' Roughness Coefficient
Low Density Residential	0.200
High Density Bushland	0.090
Medium Density Bushland	0.060
Low Density Bushland	0.045
Open water, rivers in-channel with riparian veg	0.03

3.4.4 Model Boundary Conditions

The 2011 flood event synthetic hydrograph was applied as a flow vs. time inflow to the 2D surface using a "SA" region for the upstream boundary condition.

The downstream boundary conditions were applied where water was expected to exit the model. A normal depth, height versus flow relations downstream boundary was selected for these locations. Where floodplain storage was unable to be represented within the model due to limitations in the extent of the supplied topographic data, a vertical "glass wall" was applied. This is considered to be a conservative approach and acceptable for the purposes of this study.

3.4.5 Validation and Calibration

During the site inspection and discussion with Councillors, Council staff and some residents who were present during the 2011 event, only one flood height from the 2011 event was found. This was in the front yard of Lot 518 B1361 on Bowen Street. The measured flood depth was 0.50 m, while the flood model shows 0.70 m at this location. This single location is insufficient for calibration and the flood height at the Burketown Airport gauge was used as the sole calibration location to generate flood inundation maps for the Burketown area.

3.5 Regional Model Results

Flood level, depth, velocity and hazard maps have been prepared for the 2011 historical flood event and are provided in Appendix E of the main report.

4. LOCAL FLOOD MODEL

4.1 Overview

The TUFLOW 1D-2D hydraulic modelling package was utilised to undertake modelling of the local flood behaviour in the Burketown township. The Rain-On-Grid methodology approach was applied, where rainfall is applied to the entirety of the model extent. The following sections outline the model build, simulations, and results.

4.2 TUFLOW Model Development and Results

The key parameters adopted in the TUFLOW model to accurately represent local flood behaviour in the Burketown township are outlined in the following sections. The layout of the local TUFLOW model is provided in Appendix C.

4.2.1 Model Topography

The following sources of topography data were used in the TUFLOW model:

- 2010 1m LiDAR elevation data was used as the base topographical data.
- Detailed survey was “stamped” over the LiDAR where available. The detailed survey datasets available were:
  - Digital surface database containing all survey undertaken by AusNorth Consultants as of 2019.
  - Survey of “erosion gully” located between the airport and Wills Development Road.
  - Survey of the Firefly Street precinct and surrounds.
  - Survey of Moungibi Oval and Cemetery Raw Water Plant corridor
  - Moungibi Oval design surface tin.

4.2.2 Model Extent and Resolution

The model domain extends across the main township of Burketown, bounded by the local catchment boundaries to the north and west, and by the Albert River to the south and east.

A grid cell size of 3 m was selected for the TUFLOW model. The TUFLOW HPC software adopts an adaptive timestep process which adjusts model timesteps during simulation.

4.2.3 Hydraulic Structures

Culverts (circular and box culverts) have been modelled based on the structure survey data supplied by BSC. Culverts have been represented using embedded dynamically linked 1D elements. The internal culvert equations within TUFLOW automatically estimate energy losses based on the inputted structure geometry. The culvert configurations are presented in Appendix B.

4.2.4 Hydraulic Roughness

The hydraulic roughness (Manning's 'n') applied in the TUFLOW model was based on the varying land uses observed in the aerial photography of Burketown. Manning's 'n' values adopted for the defined land use types were based on industry standard values. Initial losses (IL) and continuing losses (CL) were applied to the hydraulic roughness. The IL and CL values applied to the direct rainfall model vary per land use type as a reflection of the percentage impervious for the land use. The base IL applied was 25 mm and the base CL was 5 mm/hr, based upon validation to the Rational Method and the values recommended in ARR2019 (Ball et. al., 2019) for Burketown. The adopted Manning's 'n' values in the model are summarised in Table 4.1.

Table 4.1 Adopted Manning's 'n' Values

Land Use	Manning's 'n' Value
Bare/Low Grass	0.04
Road	0.025
Open Water	0.015
Grass	0.05
Large Lot Residential	0.08
Medium Density Residential	0.15
Light Vegetation	0.055

4.2.5 Model Boundary Conditions

A constant-slope downstream boundary has been applied to the model to allow flow to leave the model uninhibited. Inflows for the model was rainfall hyetographs applied directly to the model domain.

4.2.6 Design Storms and Durations

The Intensity-Frequency-Duration (IFD) curve applied to the TUFLOW model was that which was downloaded from the Bureau of Meteorology (BoM) ARR2019 portal for the local catchment centroid (http://www.bom.gov.au/water/designRainfalls/revised-ifd/). The local TUFLOW hydraulic model was simulated for the 1:10 AEP and 1:100 AEP flood events, for durations ranging from 30 minutes to 6 hours. The simple approach to temporal pattern application as outlined in ARR2019 was adopted, with the Average Variability Method (AVM) temporal pattern applied to the design IFD.

4.3 Local Model Results

Flood depth and hazard mapping for the various minor overland flow paths in Burketown have been prepared for the 1:10 AEP and 1:100 AEP flood events and are provided in Appendix F of the main report.

5. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g. This report does not provide legal advice.

6. REFERENCES

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia), 2019.

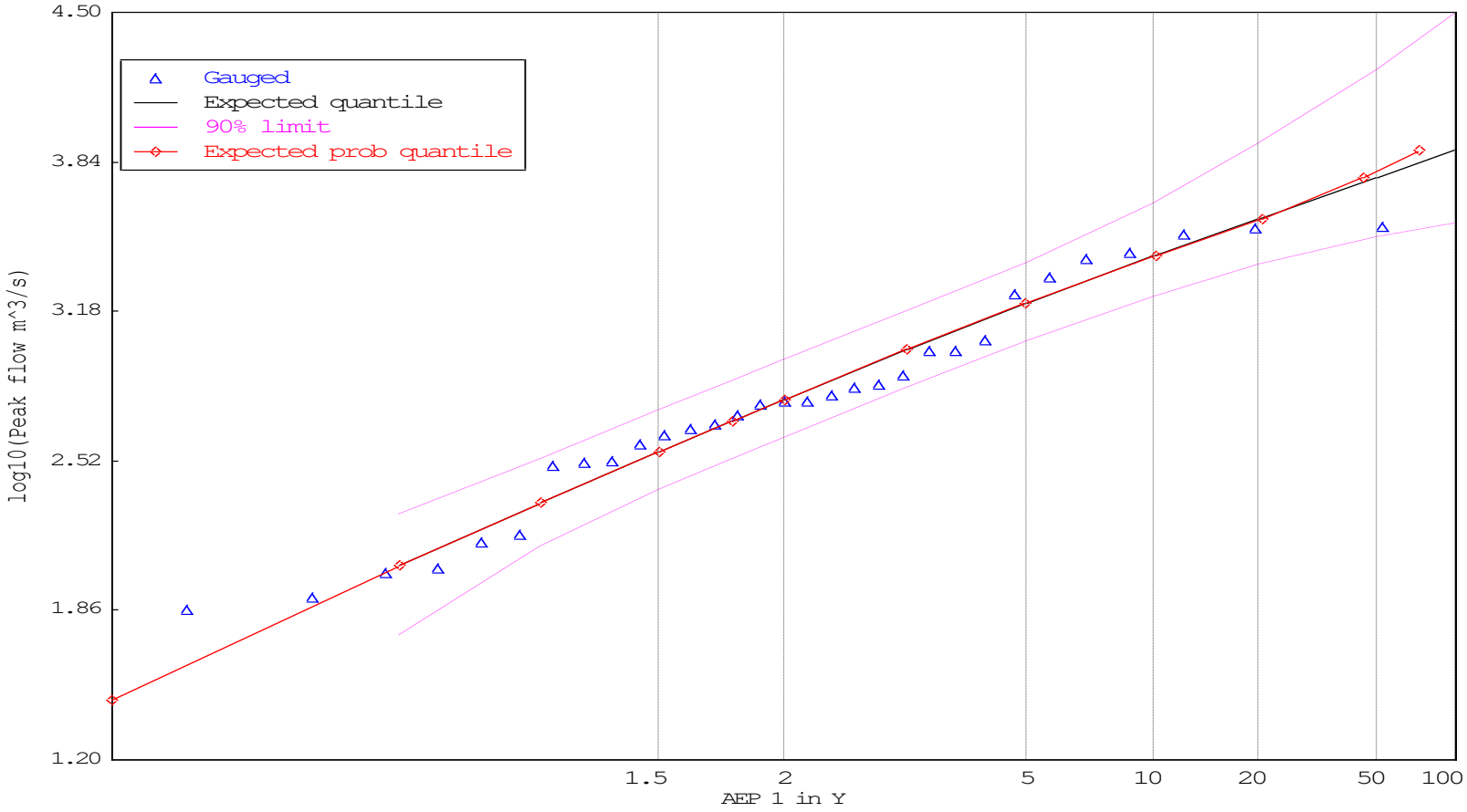
Bureau of Meteorology (2016). Design Rainfall Data System (2016). http://www.bom.gov.au/water/designRainfalls/revised-ifd/ Australian Government.

Engeny (2013). Burke Shire Council. Burketown Flood Mapping. October 2015. Engeny Water Management.

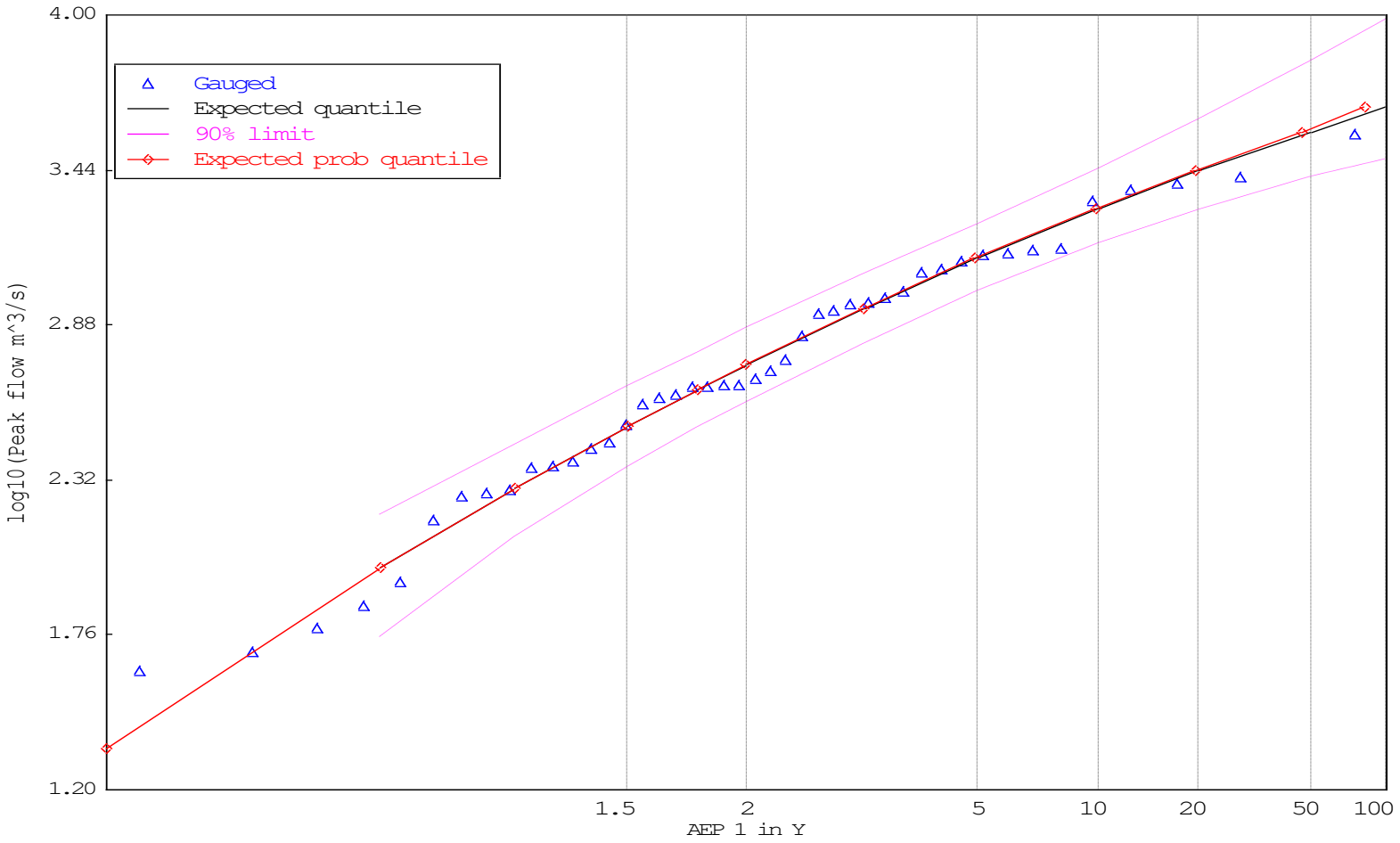
APPENDIX A

Flood Frequency Analysis Results

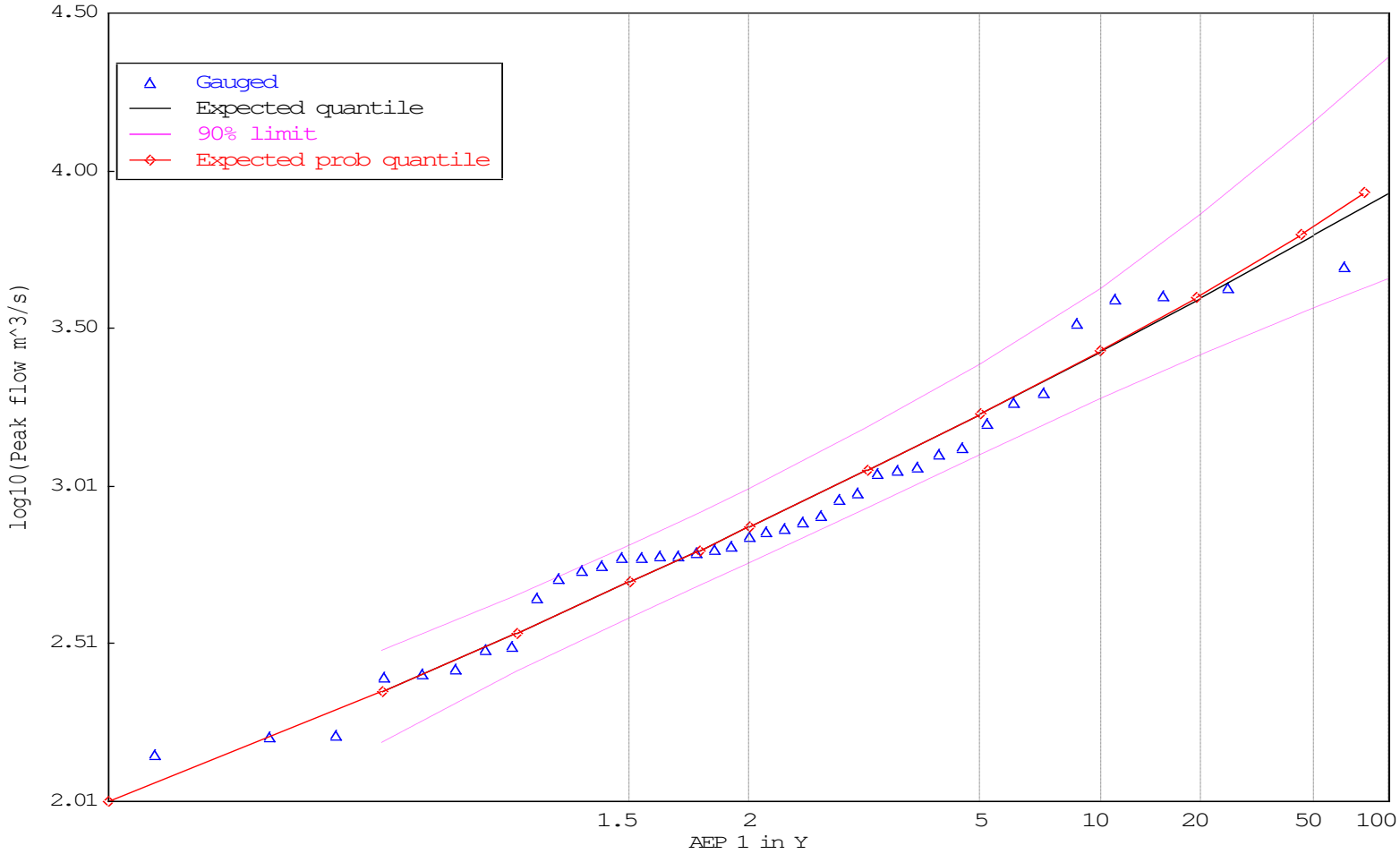
FFA Results for gauge 913004A – Leichardt River at Miranda Creek



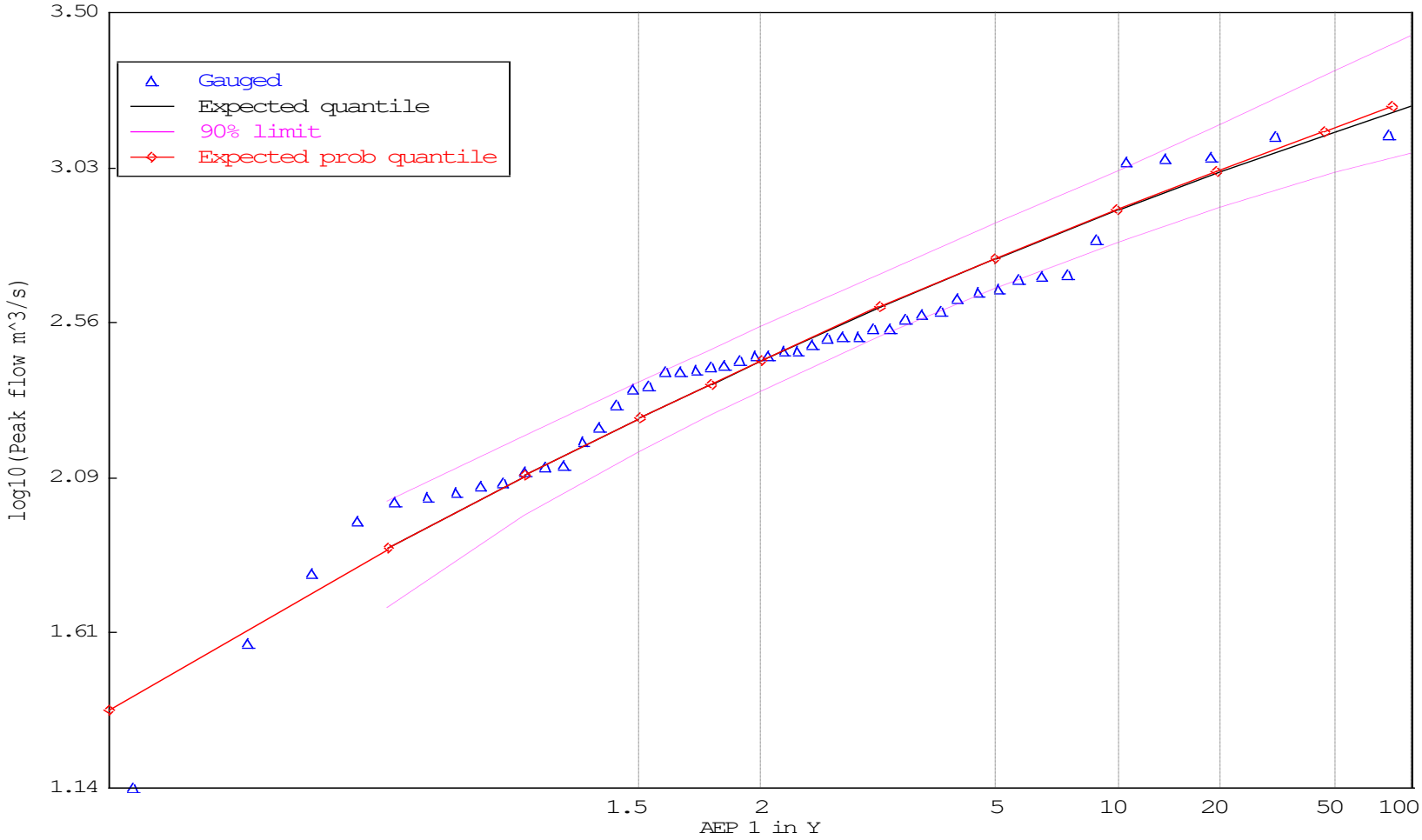
FFA Results for gauge 913006A – Gunpowder Creek at Gunpowder



FFA Results for gauge 913014A – Leichardt River at Doughboy Creek

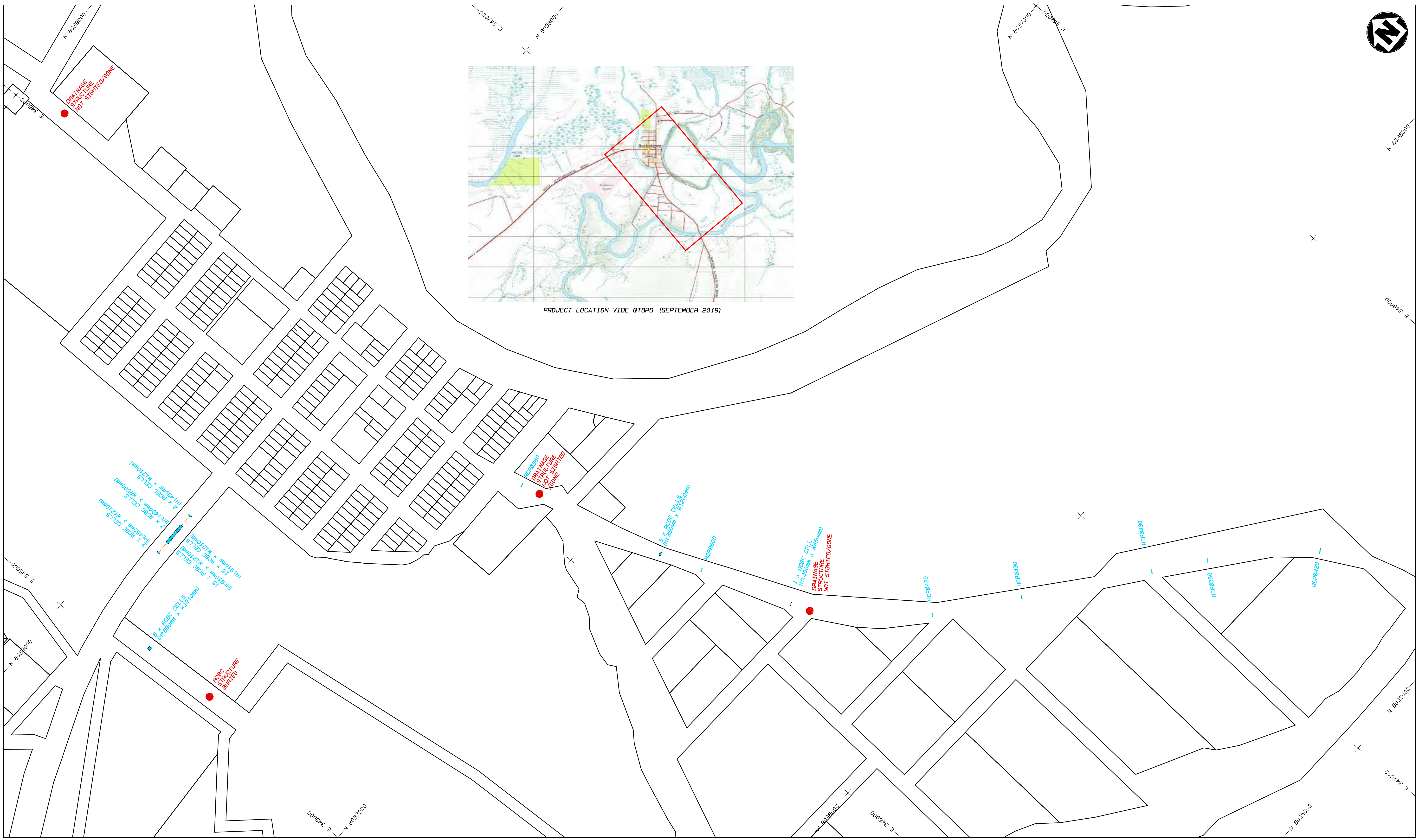


FFA Results for gauge 915206A – Dugald River at Railway Crossing



APPENDIX B

Cross Drainage Culvert Configurations



PROJECT LOCATION VIDE QTOPO (SEPTEMBER 2019)

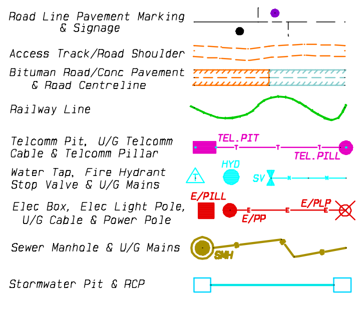
ADDITIONAL NOTES

1. Boundaries depicted hereon are derived from the Digital Cadastral Database (DCDB) and minimal connections to selected survey marks in the local area. Therefore the true location of all boundaries are subject to field survey.
2. The existence and location of all underground and overhead services must be verified with the relevant authorities prior to any excavation, demolition or construction works.
3. This plan and the associated survey data has been prepared for the purposes of identifying site opportunities and development constraints for a future development project and should not be used for any other purposes.

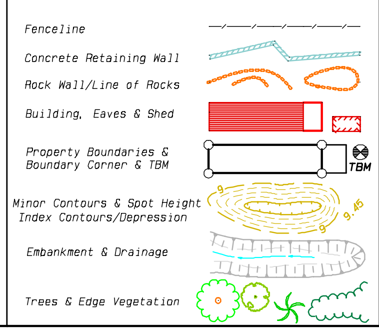
. . . . Date

. . . .
Brian Lane LS

FEATURE LEGEND



FEATURE LEGEND



MAP SHEET KEY

AUSNORTH CONSULTANTS
SURVEYING PLANNING MAPPING MINING PROPERTY ENGINEERING
B: (07) 4037 0144
M: 0427 570 100
F: (07) 4037 0166
PO Box 38
MACHANS BEACH QLD 4878
E: B.Lane@ausnorth.com.au

Rev	Description	Approved	Date

Job No. **19036**

Client **BURKE SHIRE COUNCIL**

SCALE 1 : 5000
(A1 Format)

0 100 200 300 400m

Meridian	MGA94 (Zone 54) VIDE RTK GPS	Datum	AHD VIDE PSM127703
Contour Int	N/A	Cad Ref	BTOWN ASSET LOC 2009
Surveyed	BJL 16/09/2019	Drafting	BJL 21/09/2019

Parish	BURKE
County	PORCHESTER
Locality	BURKETOWN
LGA	BURKE S.C.
Map Reference	
Original Desc.	

MAJOR STORMWATER ASSET LOCATION SURVEY FLOOD RISK MANAGEMENT STUDY
BURKETOWN

Dwg. No. **19036/ASC/01** Rev.

APPENDIX C

Figures

Burketown

Doomadgee

Carpentaria

Lawn Hill

Gregory Downs

Augustus Downs

N

Legend

- Town Location

Flood Depth (m)

- 0.0 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 5.0
- >5.0

Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 03 3221 7174
F: 03 3236 2399

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 12000 24000 m

Scale in metres (1:600000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Burketown Flood Risk Management Study

Broad Scale Hydraulic Modelling
1% AEP Flood Depth

Job Number: M7106_002
Revision: 0
Drawn: KM
Date: 9 /1 /2020

N

Legend

- Culverts
- Model Extent

Roughness / Land Use

- Road
- Open Water
- Grass
- Large Lot Residential
- Medium Density Residential
- Light Vegetation
- Topographical Change

Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 03 3221 7174
F: 03 3236 2399

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 600 1200 m

Scale in metres (1:20000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Burketown Flood Risk Management Study

Local TUFLOW Model Layout

Job Number: M7106_002
Revision: A
Drawn: KM
Date: 29 /11 /2019

N

Legend

- Downstream Boundary
- Bridge
- Inflow Location
- Model Extent

Roughness / Landuse

- Low Density Bushland
- Dense Bushland
- Low Density Residential
- Open Water

Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 03 3221 7174
F: 03 3236 2399

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 600 1200 m

Scale in metres (1:30000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Burketown Flood Risk Management Study

Regional TUFLOW Model Layout

Job Number: M7106_002
Revision: 0
Drawn: KM
Date: 9 /1 /2020

APPENDIX C

Coastal Rivers – North

Flood Warning Network

Coastal Rivers - North

LEICHHARDT, NICHOLSON, SETTLEMENT (QLD PART)

Flood Warning Network, as at 17/10/2019

Map produced by Flood Forecasting and Warning Services, Bureau of Meteorology, Brisbane

N

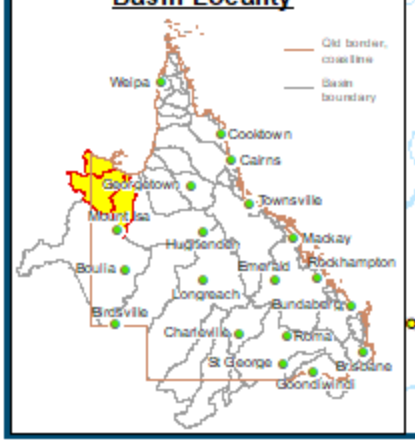
Gulf Of Carpentaria

Legend

- Automatic rainfall station (RN)
- Manual/Daily rainfall station (DN)
- Automatic river height station (RV)
- Manual river height station (RV)
- Forecast site (quantitative)
- Forecast site (qualitative)
- Population centre (large, medium, small)
- River, creek
- Major highway
- Main road
- Basin boundary
- Catchment boundary
- Dam, lake, water body
- Swamp

Note: Base spatial data shown in this map is obtained from Geoscience Australia and Queensland Department of Natural Resources, Mines and Energy.

Basin Locality



0 10 20 40 60 80
Kilometres

Map projection: Geographical Lat and Lon (GDA94).

(Ref: R:\pub\GIS\FW Network Map\FW Network Map(current)\Map mxd\LeichhardtNicholsonSettlement.mxd; R:\pub\GIS\FW Network Map\FW Network Map(current)\Map pdf\LeichhardtNicholsonSettlement.pdf)

Map 910, 912, 913

APPENDIX D

Figures

Legend

- Critical Infrastructure
- Roads
- Cadastre
- Town Centre

Communications Tower
Primary Health Care Clinic
Fire and SES
Kindergarten
Primary School
Wastewater Treatment Plan
Water Treatment Plant
Diesel Plant / Ergon Power Station
Carpentaria Land Council Aboriginal Corporation
Council Offices
Council Works Depot
Wills Developmental Road Multi Cell Culverts
Community Hall
Post Office and Convenience Store
Caravan Park
Police Station
Petrol Station and Grocery Store
Airport Access Road Causeway
Airport
Albert River Bridges

TRUGANINI ROAD
ROAD
BEAMES STREET
BOWEN STREET
MACINTYRE STREET
ALBERT STREET
NARDOO BURKETOWN ROAD

Level 7, 500 Queen Street, Brisbane
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
E: admin@engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 150 300 450 m

Scale in metres (1:12700 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Burketown Flood Risk Management Study

Figure 1 - Critical Infrastructure Locations

Job Number: M7106_002
Revision: 1
Drawn: SW
Checked: KU
Date: 3/4/2020

Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

0 300 600 m

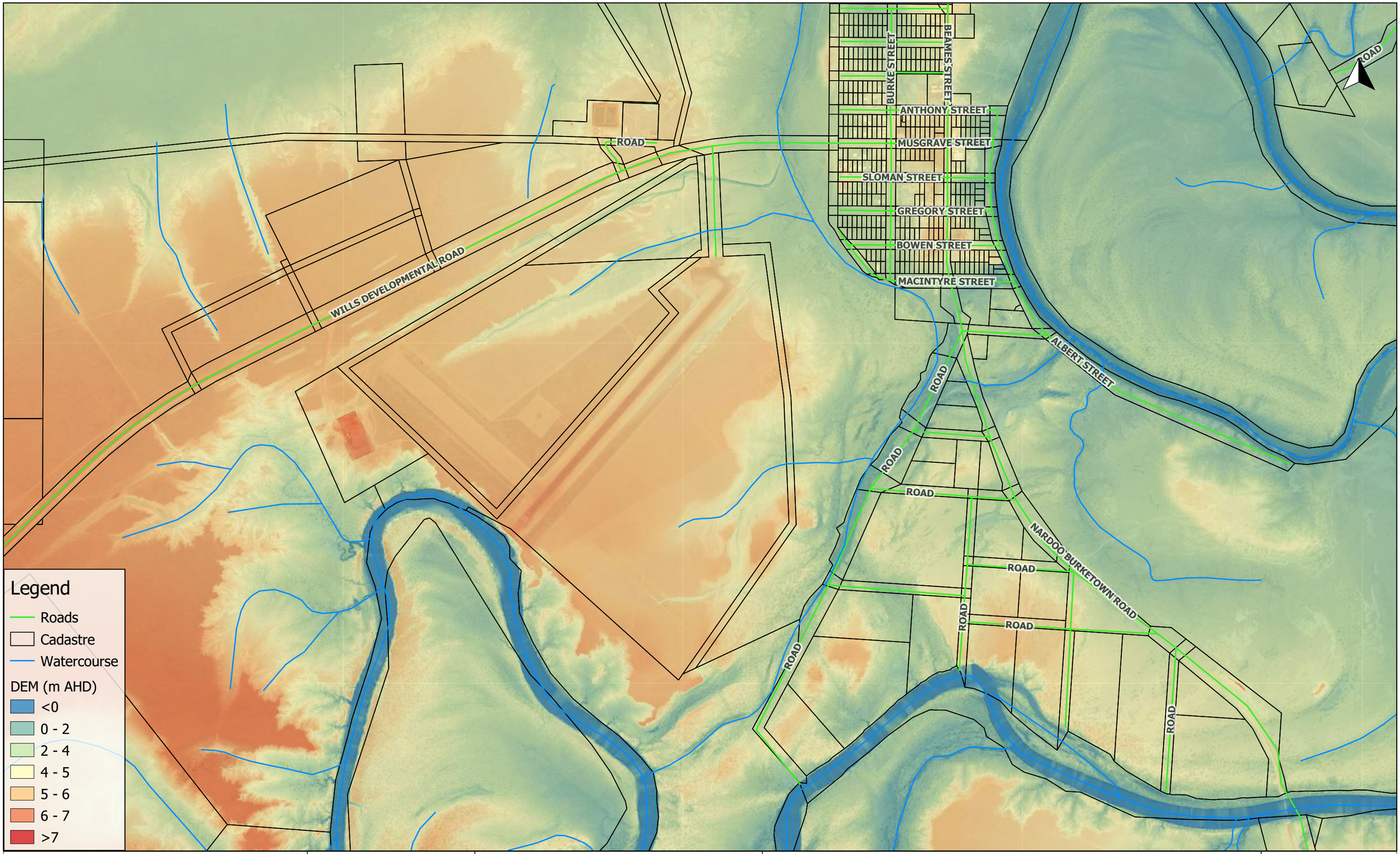
Scale in metres (1:14000@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

Burketown Flood Risk Management Study

Figure 2 - Burketown topography for north of Wills Development Road

Job Number: M7106_002
Revision: 0
Drawn: SW
Date: 10 /3 /2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

0 300 600 m

Scale in metres (1:14000@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 54

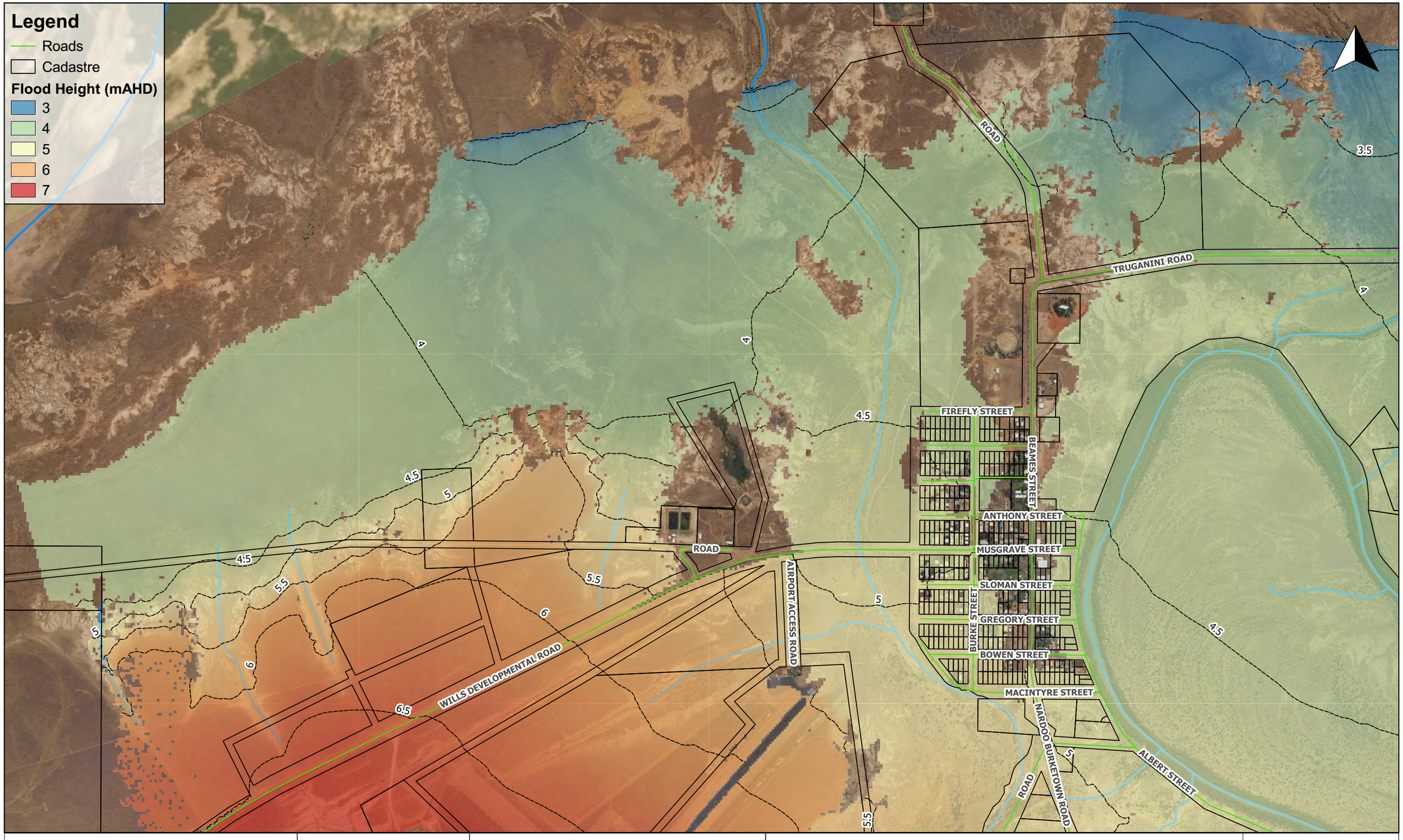
Burketown Flood Risk Management Study

Figure 3 - Burketown topography for south of Wills Development Road

Job Number: M7106_002
Revision: 0
Drawn: SW
Date: 10 /3 /2020

APPENDIX E

Regional Flood Mapping



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

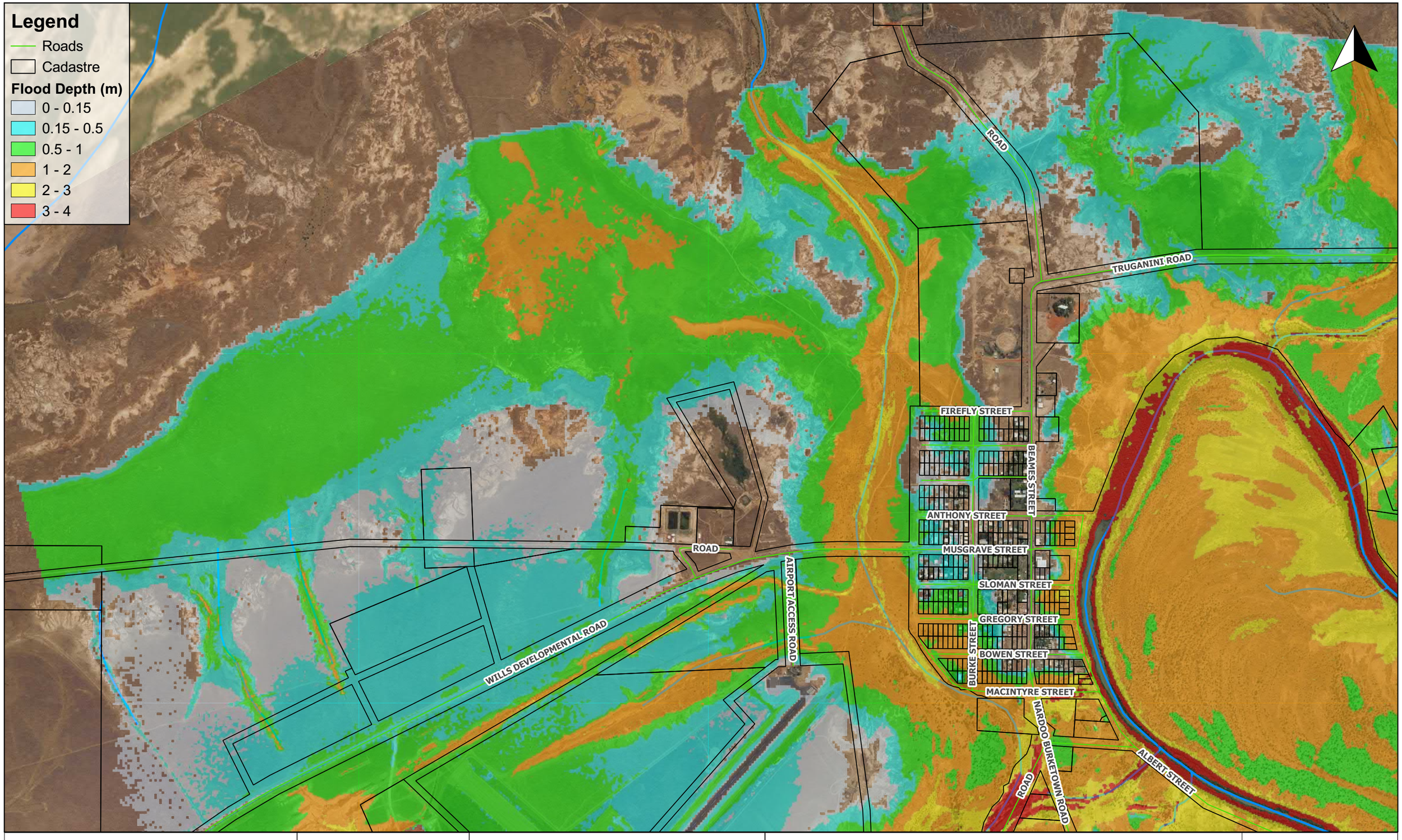
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R1 - Historical Event 2011 Flood Height Map (north of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R2 - Historical Event 2011 Flood Depth Map (north of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020

Legend

- Roads
- Cadastre

Flood Velocity (m/s)

- <= 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 1.5
- > 1.5

ROAD
TRUGANINI ROAD
FIREFLY STREET
BEAMES STREET
ANTHONY STREET
MUSGRAVE STREET
SLOMAN STREET
GREGORY STREET
BOWEN STREET
BURKE STREET
MACINTYRE STREET
NARDOO BURKETOWN ROAD
ALBERT STREET
ROAD
ROAD
AIRPORT ACCESS ROAD
WILLS DEVELOPMENTAL ROAD

Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R3 - Historical Event 2011 Flood Velocity Map (north of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020

Legend

- Roads
- Cadastre

Flood Hazard (m2/s)

- <0.6
- 0.6 to <0.8
- 0.8 to <1.2
- >= 1.2

ROAD
TRUGANINI ROAD
FIREFLY STREET
BEAMES STREET
ANTHONY STREET
MUSGRAVE STREET
SLOMAN STREET
GREGORY STREET
BOWEN STREET
BURKE STREET
MACINTYRE STREET
NARDOO BURKETOWN ROAD
ALBERT STREET
ROAD
AIRPORT ACCESS ROAD
WILLS DEVELOPMENTAL ROAD

Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

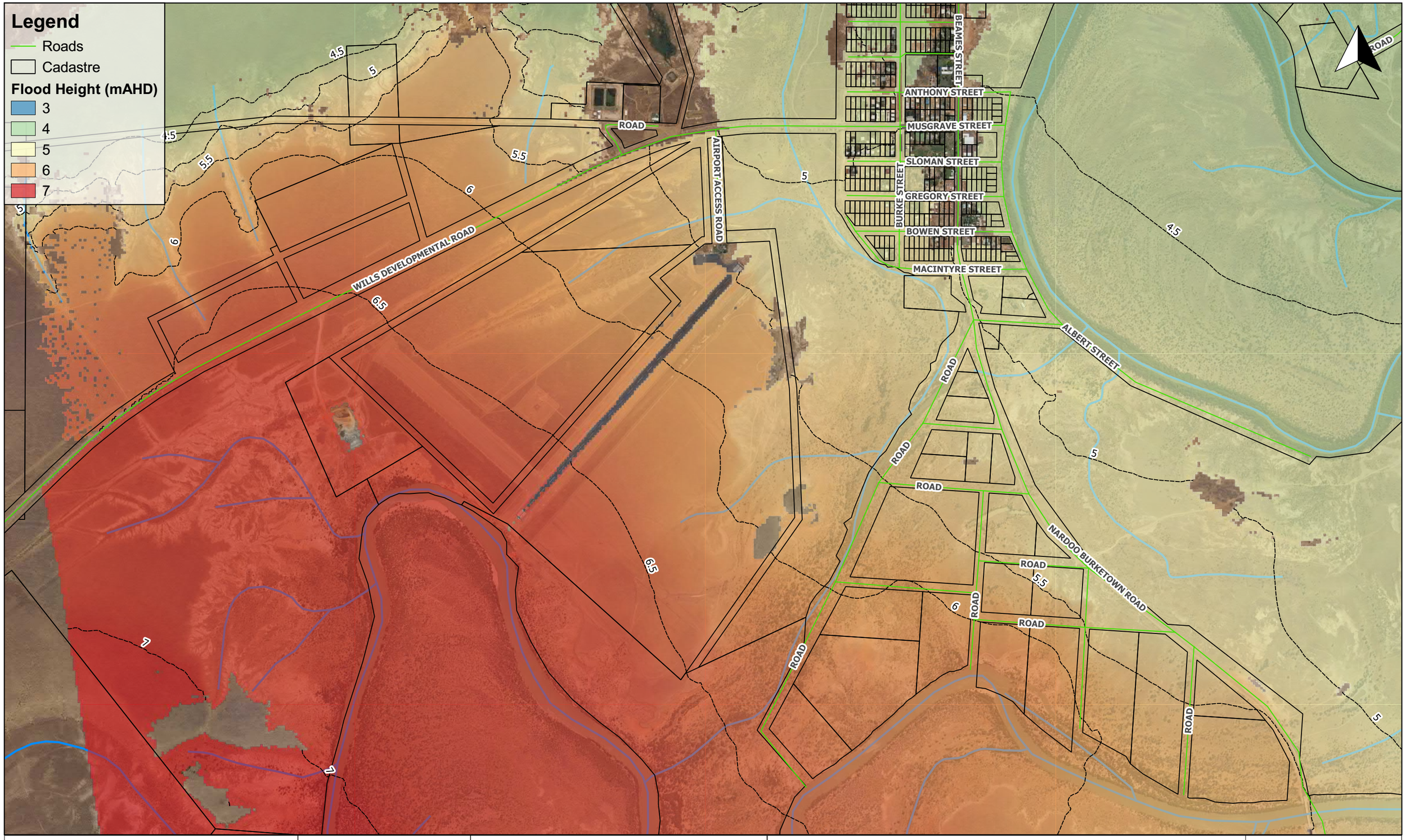
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R4 - Historical Event 2011 Flood Hazard Map (north of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

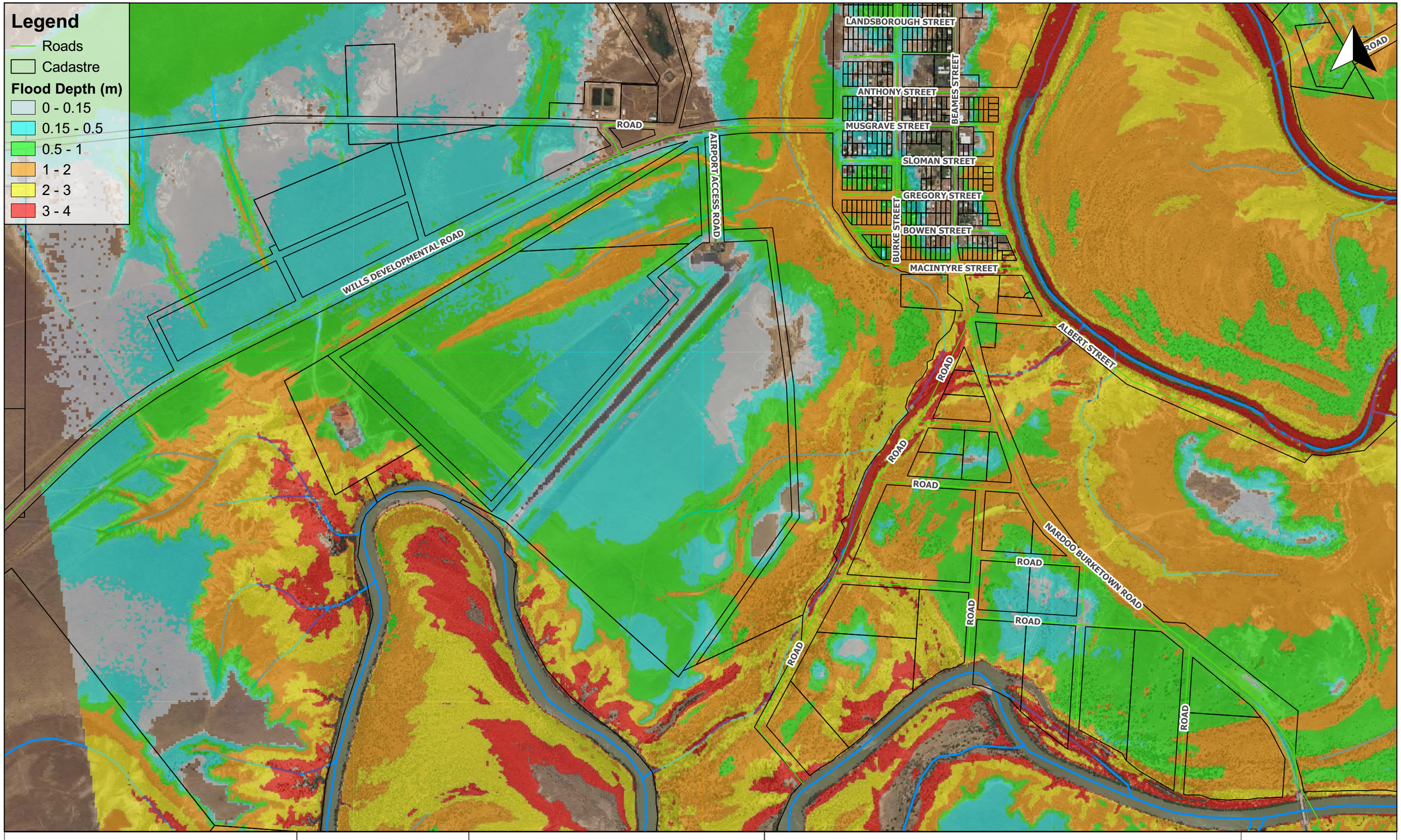
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R5 - Historical Event 2011 Flood Height Map (south of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

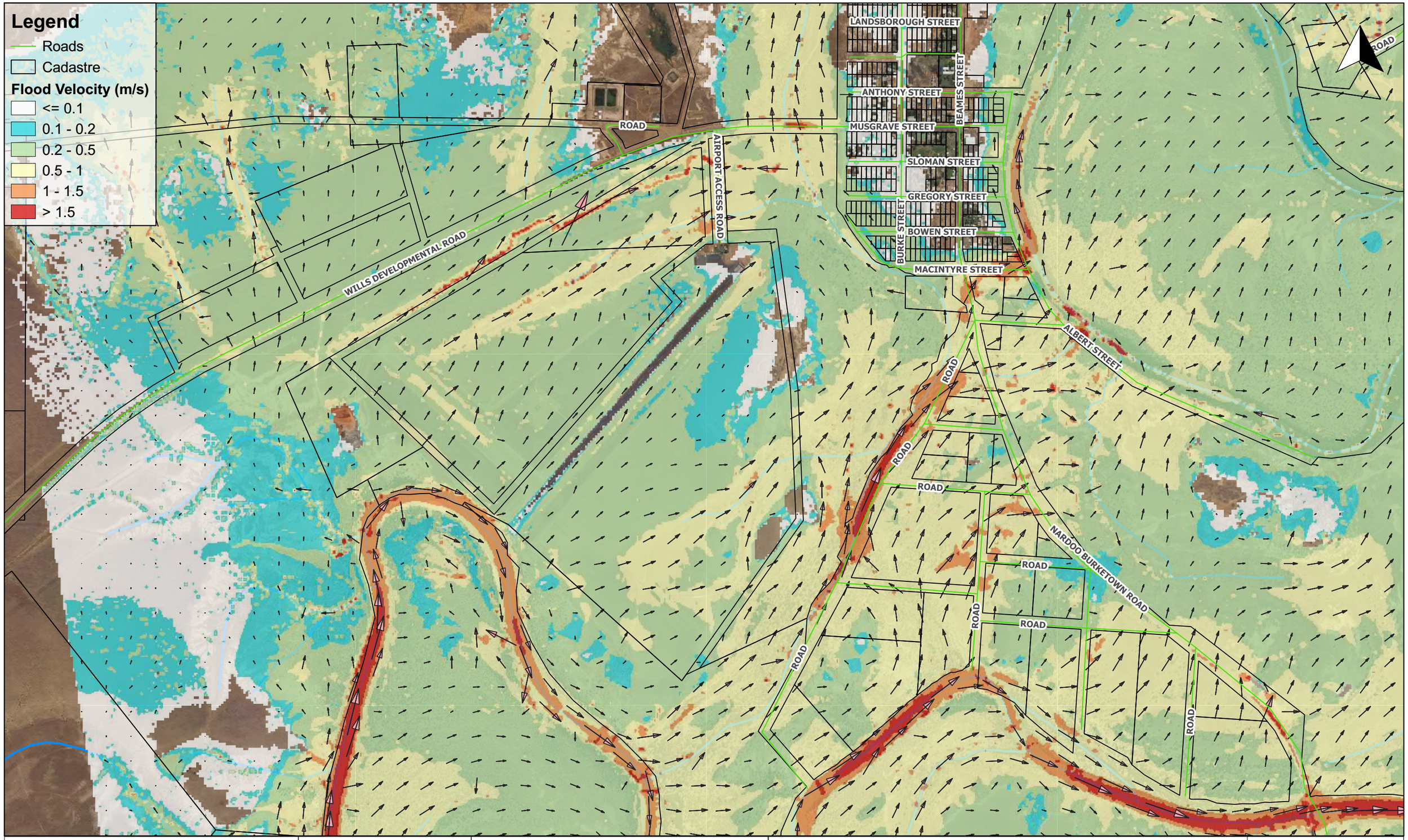
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R6 - Historical Event 2011 Flood Depth Map (south of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

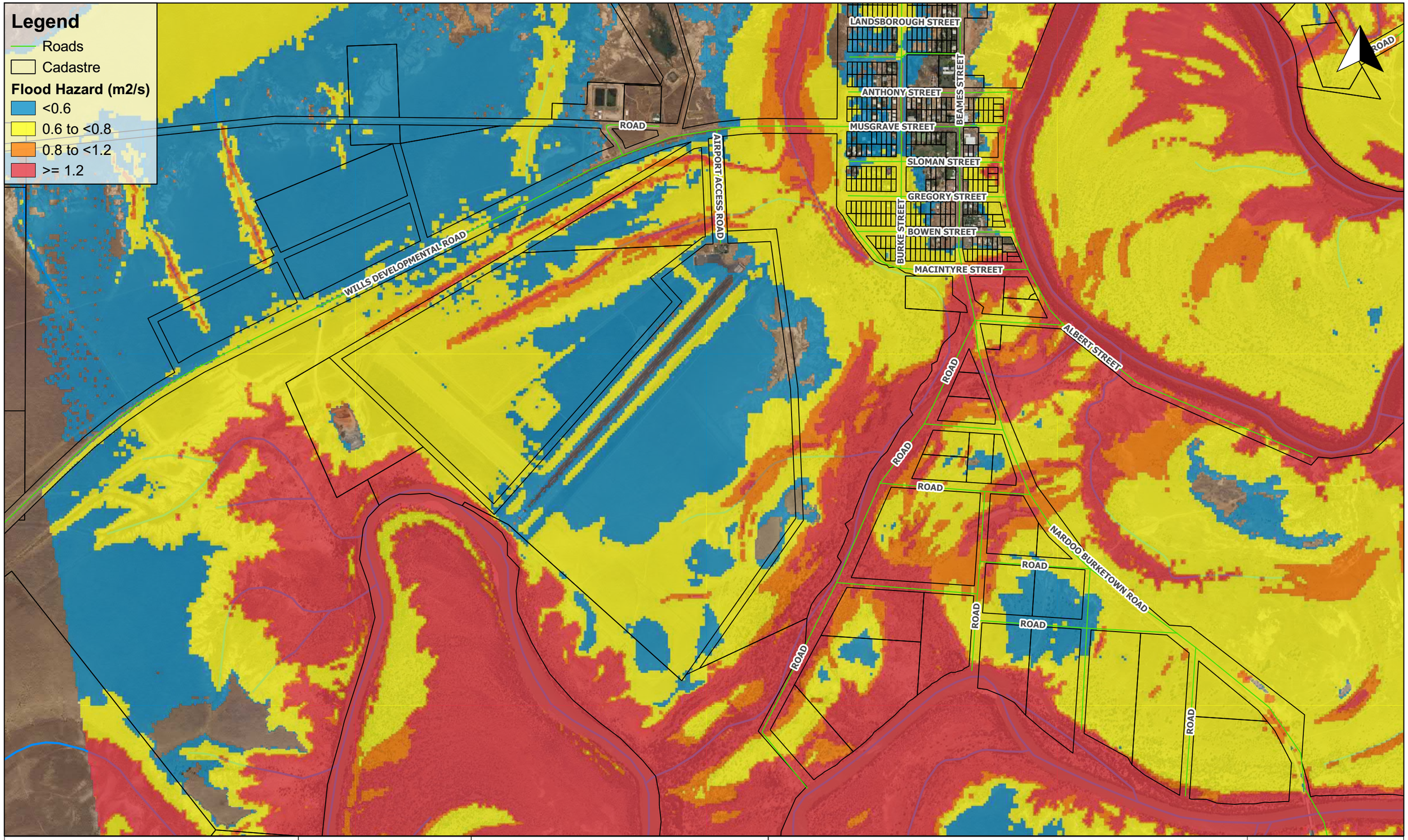
Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R7 - Historical Event 2011 Flood Velocity Map (south of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 200 400 600 800 m

Scale in metres (1:14000 @ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure R8 - Historical Event 2011 Flood Hazard Map (south of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020

APPENDIX F

Local Flood Mapping

Level 7, 500 Queen Street, Brisbane
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
E: admin@engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
ENGENY WATER MANAGEMENT

BURKE SHIRE Council

200 0 200 400 m

Scale in metres (1:6000 @ A1)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure L1 - Local Flood Depth Map, 10% AEP (town centre)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020

Level 7, 500 Queen Street, Brisbane

PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

E: admin@engeny.com.au

P: 07 3221 7174

F: 07 3236 2399

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

200 0 200 400 m

Scale in metres (1:6000 @ A1)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure L2 - Local Flood Depth Map, 1% AEP (town centre)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020

ROAD
WILLS DEVELOPMENTAL ROAD
AIRPORT ACCESS ROAD
ANTHONY STREET
BEAMES STREET
MUSGRAVE STREET
SLOMAN STREET
GREGORY STREET
BURKE STREET
BOWEN STREET
MACINTYRE STREET
ALBERT STREET
ROAD
ROAD
ROAD
NARDOO BURKETOWN ROAD
ROAD
ROAD
ROAD
ROAD
ROAD

Legend

- Watercourse
- Cadastre

Flood Depth (m)

- <= 0.05
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- > 0.50

Level 7, 500 Queen St Brisbane QLD 4000

PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 300 600 m

Scale in metres (1:12500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Burketown Flood Risk Management Study

Figure L3 - Local Flood Depth Map, 10% AEP (south of Wills Development Road)

Job Number:
M7106_002
Revision: 0
Drawn: SW
Date: 10 /3 /2020

Level 7, 500 Queen St Brisbane QLD 4000

PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 300 600 m

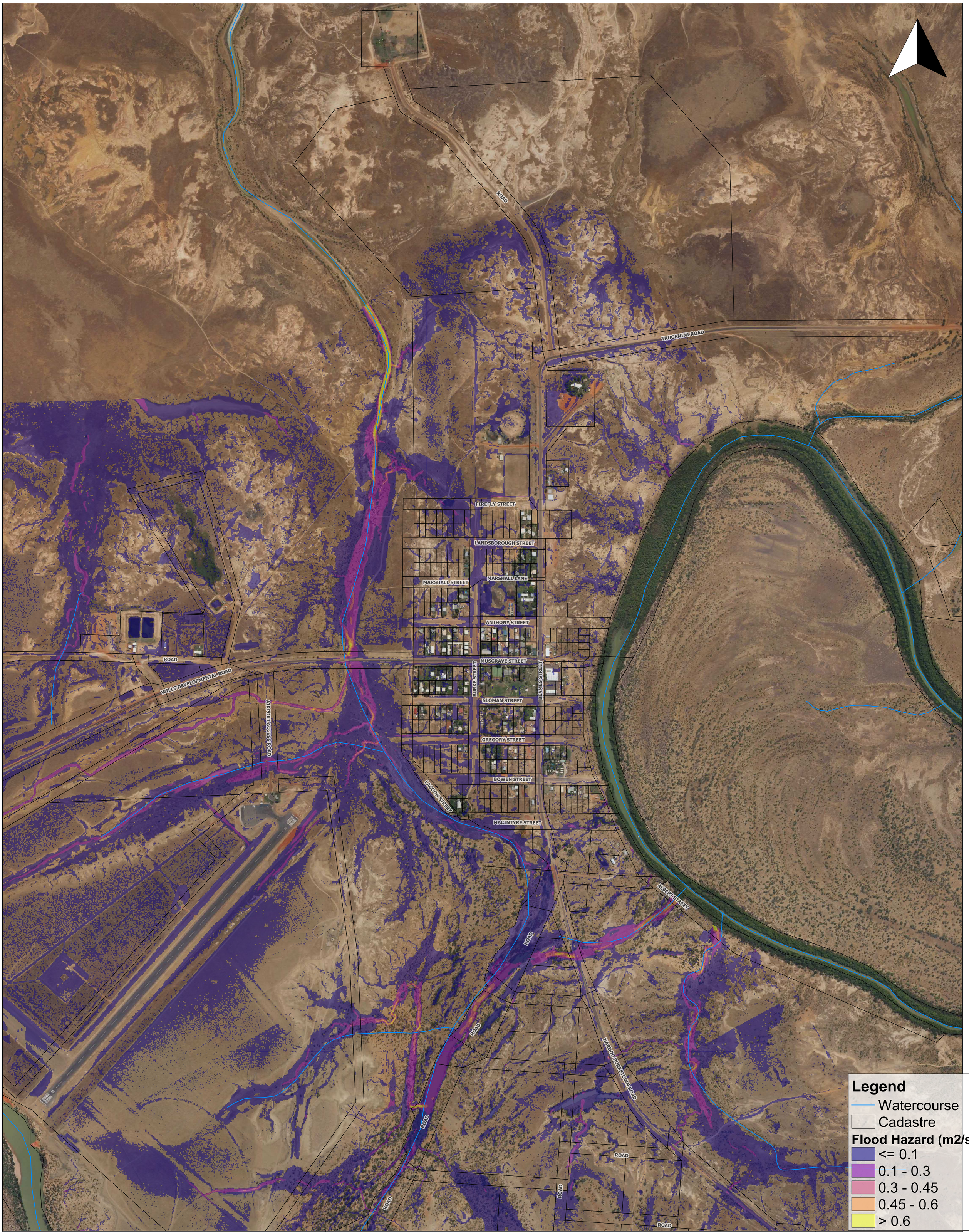
Scale in metres (1:12500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Burketown Flood Risk Management Study

Figure L4 - Local Flood Depth Map, 1% AEP (south of Wills Development Road)

Job Number:
M7106_002
Revision: 0
Drawn: SW
Date: 10 /3 /2020



Level 7, 500 Queen Street, Brisbane
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
E: admin@engeny.com.au
P: 07 3221 7174
F: 07 3236 2399
ENGENY WATER MANAGEMENT

BURKE SHIRE Council

200 0 200 400 m

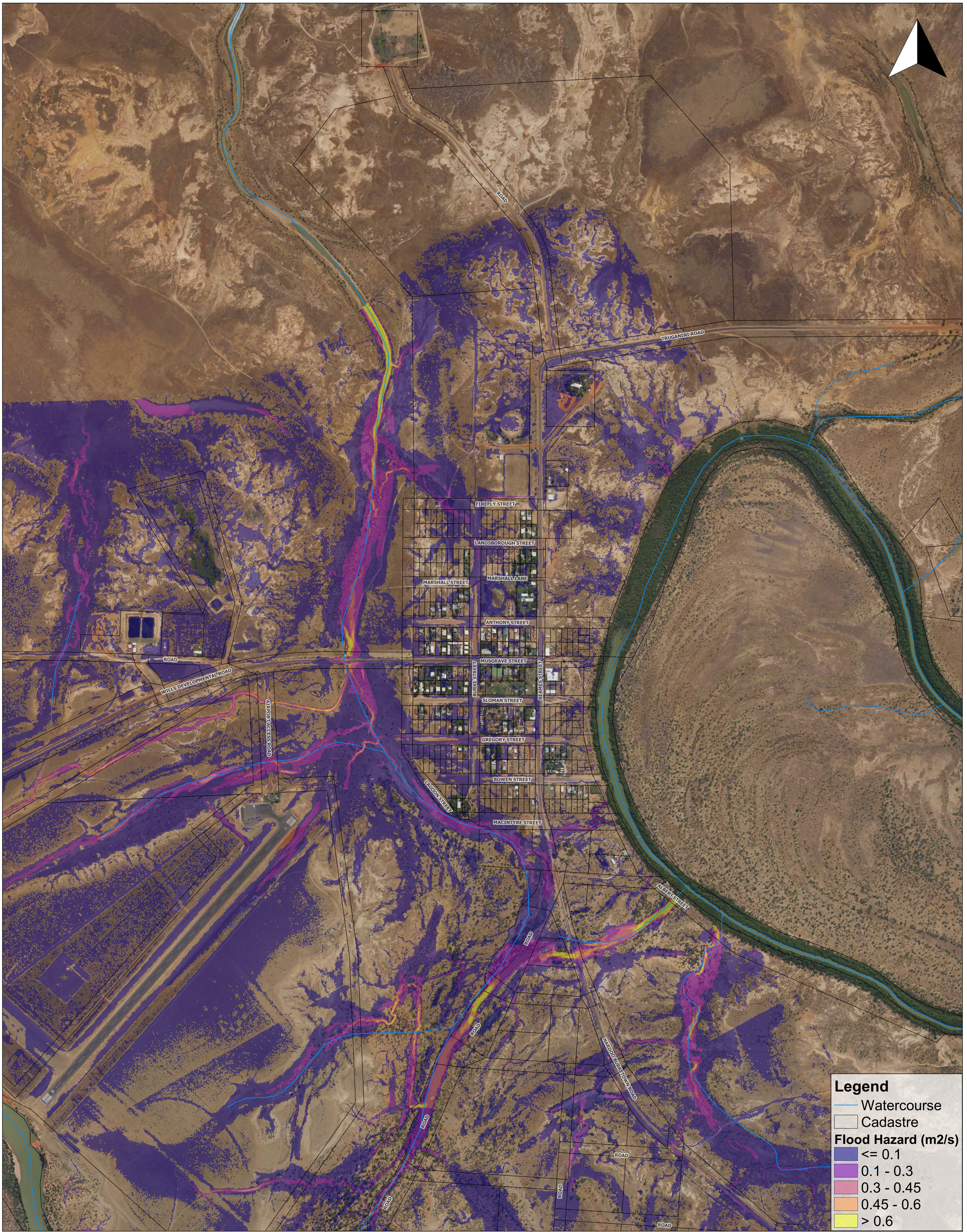
Scale in metres (1:6000 @ A1)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure L5 - Local Flood Hazard Map, 10% AEP (town centre)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen Street, Brisbane

PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

E: admin@engeny.com.au

P: 07 3221 7174

F: 07 3236 2399

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

200 0 200 400 m

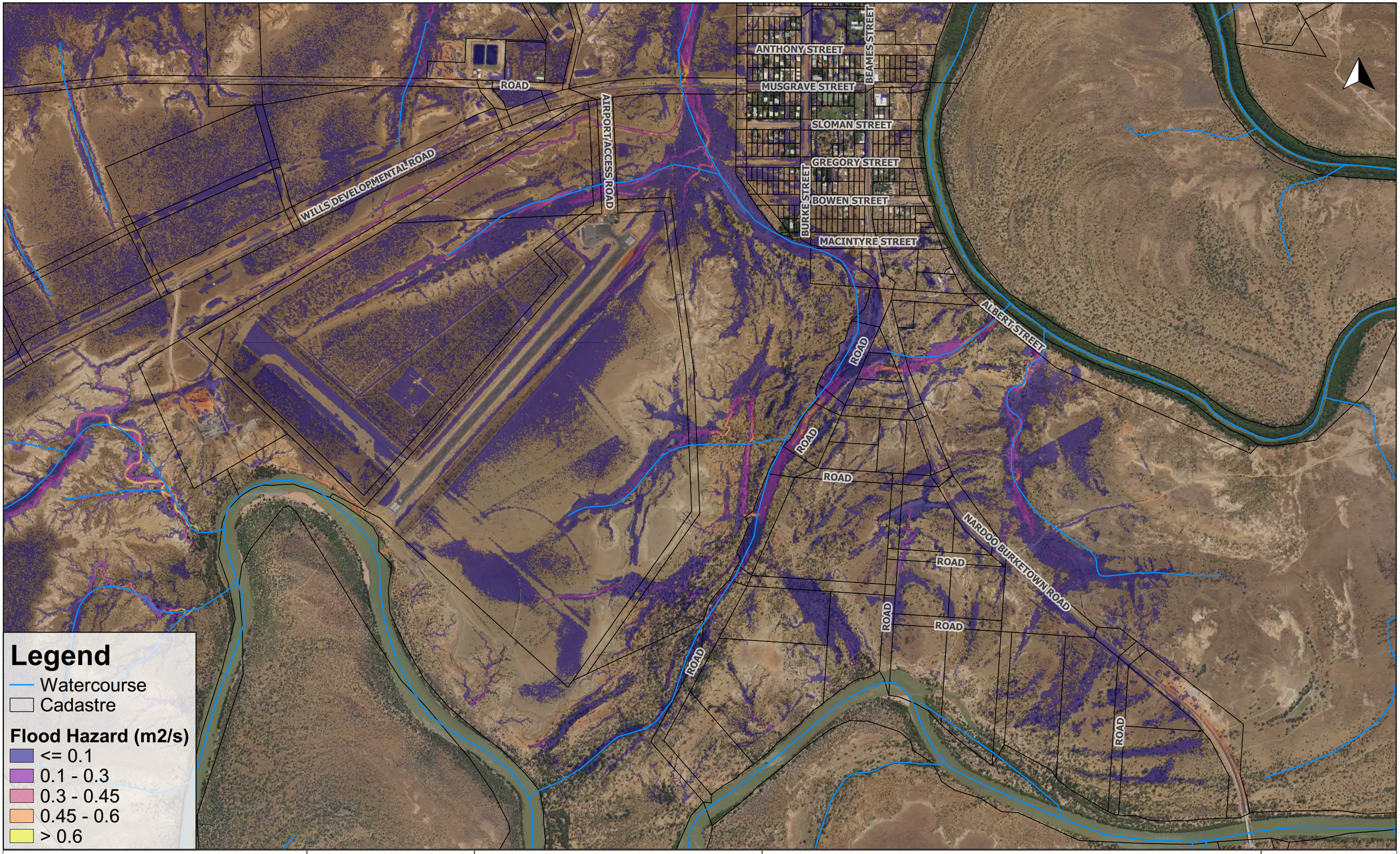
Scale in metres (1:6000 @ A1)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Burketown Flood Risk Management Study

Figure L6 - Local Flood Hazard Map, 1% AEP (town centre)

Job Number: M7106_002
Revision: 0
Drawn: SW
Checked: KU
Date: 10/3/2020



Level 7, 500 Queen St Brisbane QLD 4000
PO Box 10183 Brisbane QLD 4000
www.engeny.com.au
P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

0 300 600 m

Scale in metres (1:12500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Burketown Flood Risk Management Study

Figure L7 - Local Flood Hazard Map, 10% AEP (south of Wills Development Road)

Job Number: M7106_002
Revision: 0
Drawn: SW
Date: 10 /3 /2020

ROAD
AIRPORT ACCESS ROAD
WILLS DEVELOPMENTAL ROAD
ANTHONY STREET
BEAMES STREET
MUSGRAVE STREET
SLOMAN STREET
GREGORY STREET
BURKE STREET
BOWEN STREET
MACINTYRE STREET
ALBERT STREET
ROAD
ROAD
ROAD
NARDOO BURKETOWN ROAD
ROAD
ROAD
ROAD
ROAD

Legend

Watercourse
Cadastre

Flood Hazard (m2/s)

- <= 0.1
- 0.1 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- > 0.6

Level 7, 500 Queen St Brisbane QLD 4000

PO Box 10183 Brisbane QLD 4000

www.engeny.com.au

P: 03 3221 7174
F: 03 3236 2399
E: admin@engeny.com.au

ENGENY WATER MANAGEMENT

BURKE SHIRE Council

0 300 600 m

Scale in metres (1:12500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

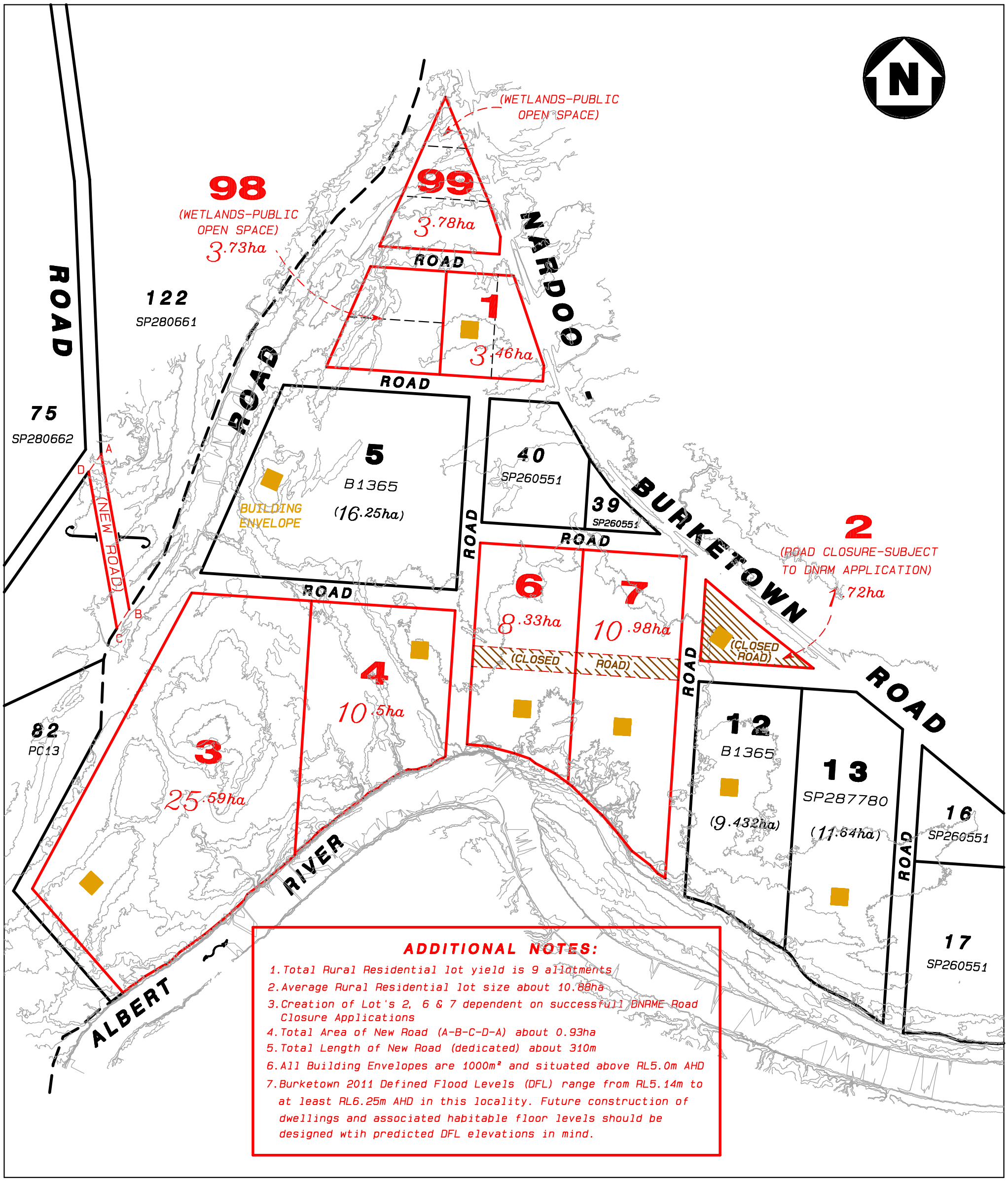
Burketown Flood Risk Management Study

Figure L8 - Local Flood Hazard Map, 1% AEP (south of Wills Development Road)

Job Number:
M7106_002
Revision: 0
Drawn: SW
Date: 10 /3 /2020

APPENDIX G

Proposed Subdivision Plans (Pre-FRMS)



ADDITIONAL NOTES:

1. Total Rural Residential lot yield is 9 allotments
2. Average Rural Residential lot size about 10.88ha
3. Creation of Lot's 2, 6 & 7 dependent on successfull DNRME Road Closure Applications
4. Total Area of New Road (A-B-C-D-A) about 0.93ha
5. Total Length of New Road (dedicated) about 310m
6. All Building Envelopes are 1000m² and situated above RL5.0m AHD
7. Burketown 2011 Defined Flood Levels (DFL) range from RL5.14m to at least RL6.25m AHD in this locality. Future construction of dwellings and associated habitable floor levels should be designed wtih predicted DFL elevations in mind.

EXPLANATORY NOTES:

1. Boundaries shown hereon are approximate only and are shown here for planning purposes only.
2. Final bearings, distances and areas subject to field survey.
3. Contours and topography vide 2010 Burketown LiDAR vide DNRME.
4. This plan has been prepared to aid in the Local Government evaluation of a Development Application and must not be used for any other purpose.

.....
Date

.....
Cadastral Surveyor/
Director

PO Box 38
MACHANS BEACH QLD 4878
B: (07) 4037 0144
F: (07) 4037 0166
M: 0427 570 100
E: B.Lane@ausnorth.com.au

SURVEYING
PLANNING
MAPPING
MINING
PROPERTY
ENGINEERING

This plan depicts a proposed subdivision design only and as such is not registered. Subsequent registered or other surveys in the area may affect the boundary definition shown on the plan. Any such boundary definition differences are beyond the control of Ausnorth Consultants Pty Ltd who can accept no responsibility or liability for such differences.

AUSNORTH CONSULTANTS

PROPOSED SUBDIVISION OF LANDS
LOTS 1-4, 6, 7, 98 & 99

CANCELLING LOT's 6-9 on B1363, LOT's 1-4 on B1365, LOT's 52, 66 & 67 on B1368 and LOT's 51 & 68-70 on SP287780

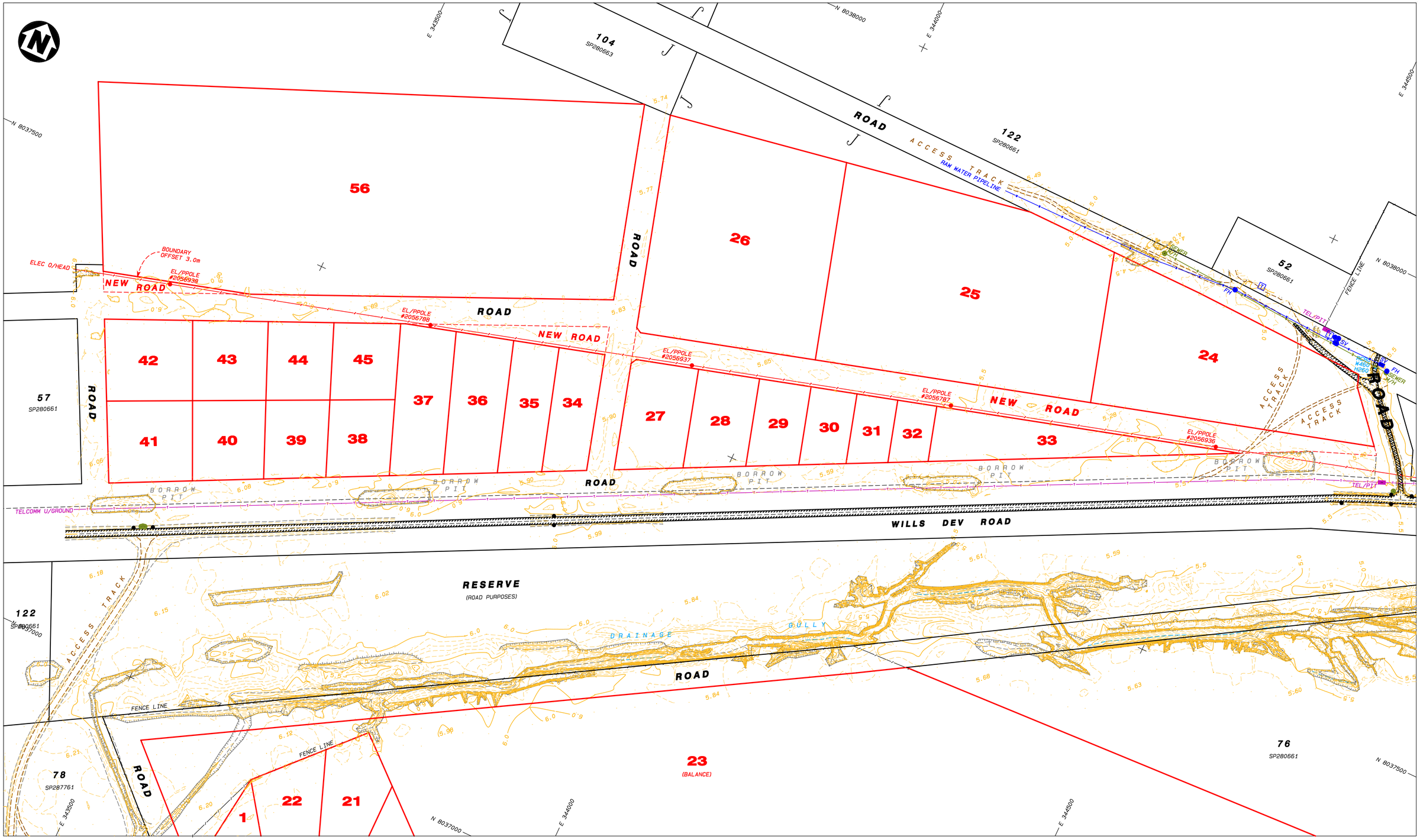
BURKETOWN SOUTH

Parish BURKE
County PORCHESTER
Locality BURKETOWN
LGA Burke SC

Dwg. No **17055/ROL/04**

Rev.

MGA94 (Zone 54) VIDE GNSS MERIDIAN	1 of 1 SHEET	CONTOUR INTERVAL 500mm	6862-34411 MAP REF	1: 7500 (A3) SCALE	2017/17055 BKT ROL A ARCHIVED



ADDITIONAL NOTES

1. Boundaries depicted hereon are derived from the Digital Cadastral Database (DCDB) and minimal connections to selected survey marks in the local area. Therefore the true location of all boundaries are subject to field survey.
2. The existence and location of all underground and overhead services must be verified with the relevant authorities prior to any excavation, demolition or construction works.
3. This plan and the associated survey data has been prepared for the purposes of identifying site opportunities and development constraints for a future development project and should not be used for any other purposes.

. . . . . .
Brian Lane LS

. . . . . .
Date

FEATURE LEGEND

- Road Line Pavement Marking & Signage
- Access Track/Road Shoulder
- Bituman Road/Conc Pavement & Road Centreline
- Railway Line
- Telcomm Pit, U/G Telcomm Cable & Telcomm Pillar (TEL.PIT, TEL.PILL)
- Water Tap, Fire Hydrant Stop Valve & U/G Mains (HYD, SV)
- Elec Box, Elec Light Pole, U/G Cable & Power Pole (E/PILL, E/LP, E/PP)
- Sewer Manhole & U/G Mains (SNH)
- Stormwater Pit & RCP

FEATURE LEGEND

- Fenceline
- Concrete Retaining Wall
- Rock Wall/Line of Rocks
- Building, Eaves & Shed
- Property Boundaries & Boundary Corner & TBM
- Minor Contours & Spot Height Index Contours/Depression
- Embankment & Drainage
- Trees & Edge Vegetation

MAP SHEET KEY

AUSNORTH CONSULTANTS
SURVEYING PLANNING MAPPING MINING PROPERTY ENGINEERING
B: (07) 4037 0144
M: 0427 570 100
F: (07) 4037 0166
PO Box 38
MACHANS BEACH QLD 4878
E: B.Lane@ausnorth.com.au

Rev	Description	Approved	Date

Job No. **17061**

Client **BURKE SHIRE COUNCIL**

SCALE 1 : 2000
(A1 Format)

0 40 80 120 160m

Meridian	MGA94 (Zone 54) VIDE SP280662	Datum	AHD vide PSM80471
Contour Int	100mm	Cad Ref	BTOWN TOTAL DBASE 2812
Surveyed	BJL 08/12/2018	Drafting	BJL 29/12/2018

Parish	BURKE
County	PORCHESTER
Locality	BURKETOWN
LGA	BURKE S.C.
Map Reference	6862-43332
Original Desc.	

PROPOSED ROAD CORRIDOR
FEATURE DETAIL SURVEY
UTILITIES INDUSTRIAL PRECINCT BURKETOWN

Dwg. No. **17061/DTM/03** Rev.

APPENDIX H

Proposed Building Envelopes per revised Sub-Division Plans (post-FRMS)

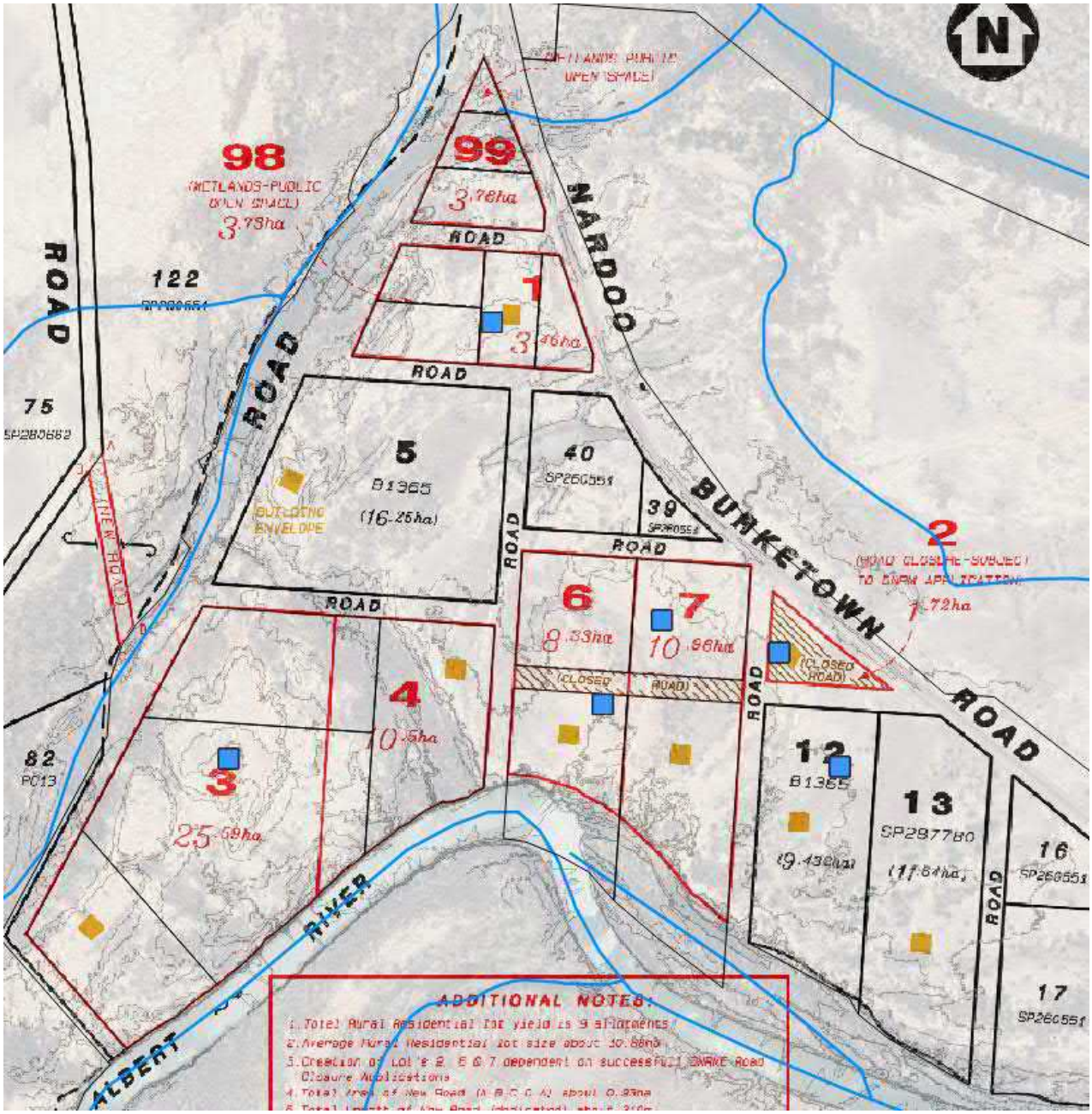


Figure H-1 Potential Building Envelope Location Amendments shown by blue squares (locations by Council depicted by yellow squares)

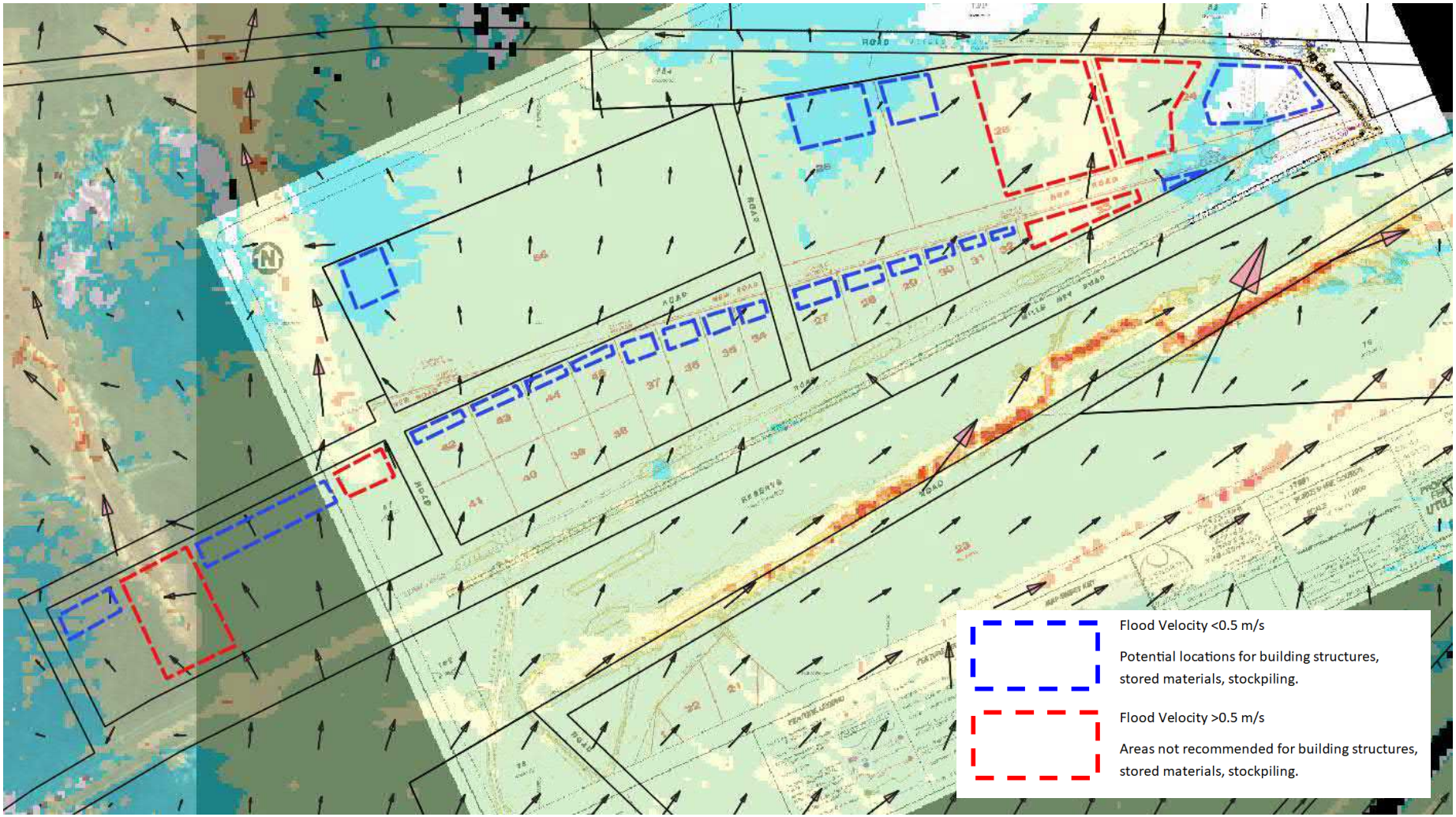


Figure H-2 **West Burketown - Potential Building Structures, Stored Materials and Stockpile Locations.**

APPENDIX I

Site Inspection Photos

Photo I - 1 Airport Access Road culverts

Photo I - 2 Airport Access Road causeway

Photo I - 3 Albert River bridge

Photo I - 4 Caravan Park

Photo I - 5 Communications Tower

Photo I - 6 Nijinda Durlga Community Hall

Photo I - 7 Diesel Plant / Ergon Power Station

Photo I - 8 Fire, SES and Volunteer Marine Rescue shed

Photo I - 9 Council Administrative Office & Library

Photo I - 10 Primary Health Care Clinic

Photo I - 11 Police Station

Photo I - 12 Wills Developmental Road culverts

Photo I - 13 Water Treatment Plant

Photo I - 14 Wastewater Treatment Plant