North Central Catchment Management Authority

Donald Flood and Drainage Management Plan

May 2014

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Executive summary

The township of Donald is located in central Victoria on the Richardson River. The catchment of the Avon-Richardson basin is shown on Figure A. The township of Donald has been affected by floods three times in recent years, including September 2010, December 2010 with the most severe in January 2011. North Central CMA estimates that in the order of 20 residences and businesses were inundated in the January 2011 flood event from riverine and local stormwater flooding. Whilst the number of properties inundated was relatively low compared to other townships affected by the same flood event, the impact on the community was significant. This included the closure of the Johnson Goodwin aged care facility and the towns two motels for an extended period (in the order of six months).

The Victorian Minister for Water, Peter Walsh announced funding to undertake the Donald Flood and Drainage Management Plan on 7 September 2011. The North Central Catchment Management Authority in conjunction with the Buloke Shire Council engaged the services of GHD to develop the Donald Flood and Drainage Management Plan.

This report documents the work undertaken to develop the Plan, namely:

- A review of the available data and historic flood information;
- Hydrological assessment;
- Hydraulic Assessment;
- Flood Damage Assessment; and
- Mitigation Option Assessment.

Flood Modelling (Hydrological and Hydraulic Assessment)

A rainfall runoff model (RORB) of the Avon-Richardson catchment was developed to model the rainfall-runoff relationship of the catchment. The RORB model was calibrated to three events, these were:

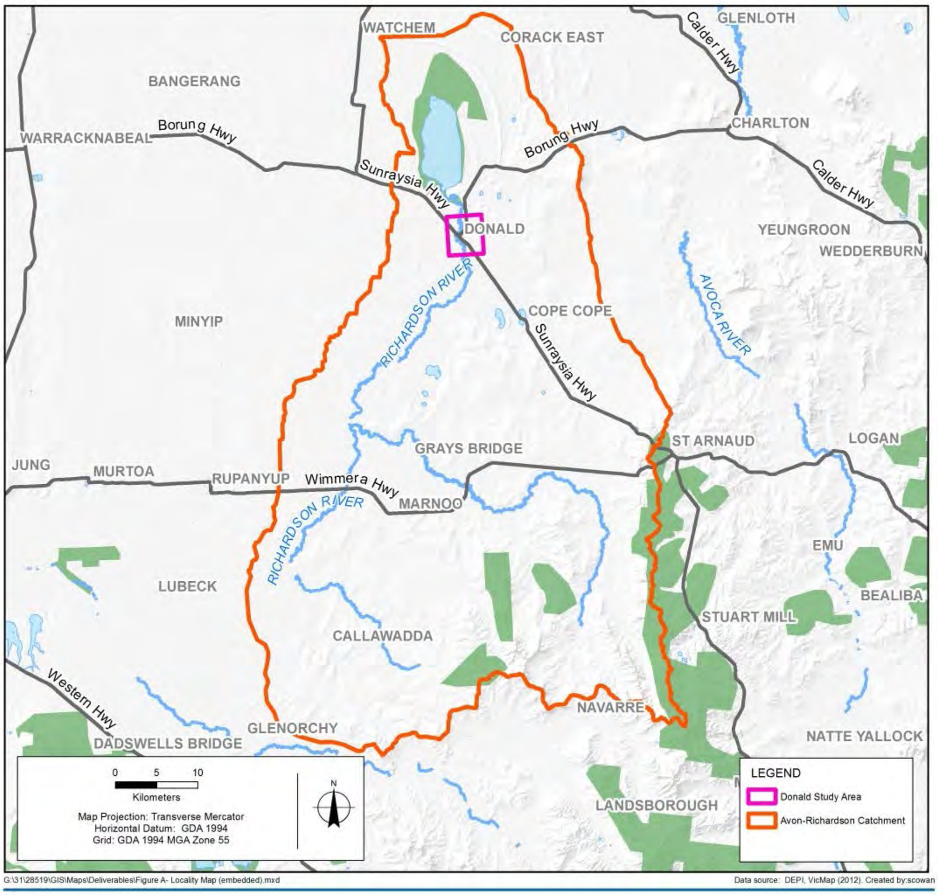
- October 1996 (maximum flow recorded at Donald gauge of 11,200 ML/d – 130 m^3/s);
- September 2010 (maximum flow recorded at Donald gauge of 12,900 ML/d – 149 m^3/s); and
- December 2010 (maximum flow recorded at Donald gauge of 7,706 ML/d – 89 m^3/s).

The calibrated RORB model was then used to estimate the flow at Donald for the January 2011 event (maximum flow estimated at Donald gauge of 33,696 ML/d – 390 m^3/s). The RORB model was also used to establish design hydrographs for a range of flood events (0.5%, 1%, 2%, 5%, 10% and 20% AEP events).

A hydraulic modelling of the Donald study area (refer to Figure A for study area) was completed using a two dimensional model (TUFLOW). The hydraulic model was calibrated to the September 2010 and January 2011 event.

The calibrated hydraulic model was used to produce flood extents for the 0.5%, 1%, 2%, 5%, 10% and 20% AEP events.

Figure A Locality Plan



Flood Mitigation and Flood Damage Assessment

A primary objective of the Plan was to investigate and recommend potential options to reduce the impact of flooding on the township of Donald. Through the community based steering committee, public meetings and community questionnaires a list of options to reduce the risk of flooding in Donald was developed. It is important to note that all options recommended by the community were considered.

Following a preliminary assessment of the options and receiving direction/advice from the steering committee the following two mitigation options were assessed in detail:

- Option 1 – Levees (refer to Figure B for their location)
- Option 2- Additional Culverts at the Sunraysia Highway

A flood damage assessment was undertaken for the existing conditions and assuming that each of the mitigation options were in place. Construction costs for each mitigation option were estimated. From the reduction in flood damages as a result of the mitigation options and the construction cost estimates a benefit cost analysis was undertaken for each mitigation option. From this analysis a number of structural and non-structural works have been recommended for Donald.

Recommendations of the Plan

Structural Flood Mitigation Works

It is recommended for Donald that the following works be undertaken as a first priority:

- Construction of Levee No. 2 (refer to Figure B for location);
- Construction of Levee No. 3 (refer to Figure B for location).

These two levees would protect the retirement village and the central area of Donald from flood events up to and including a repeat of the January 2011 flood event.

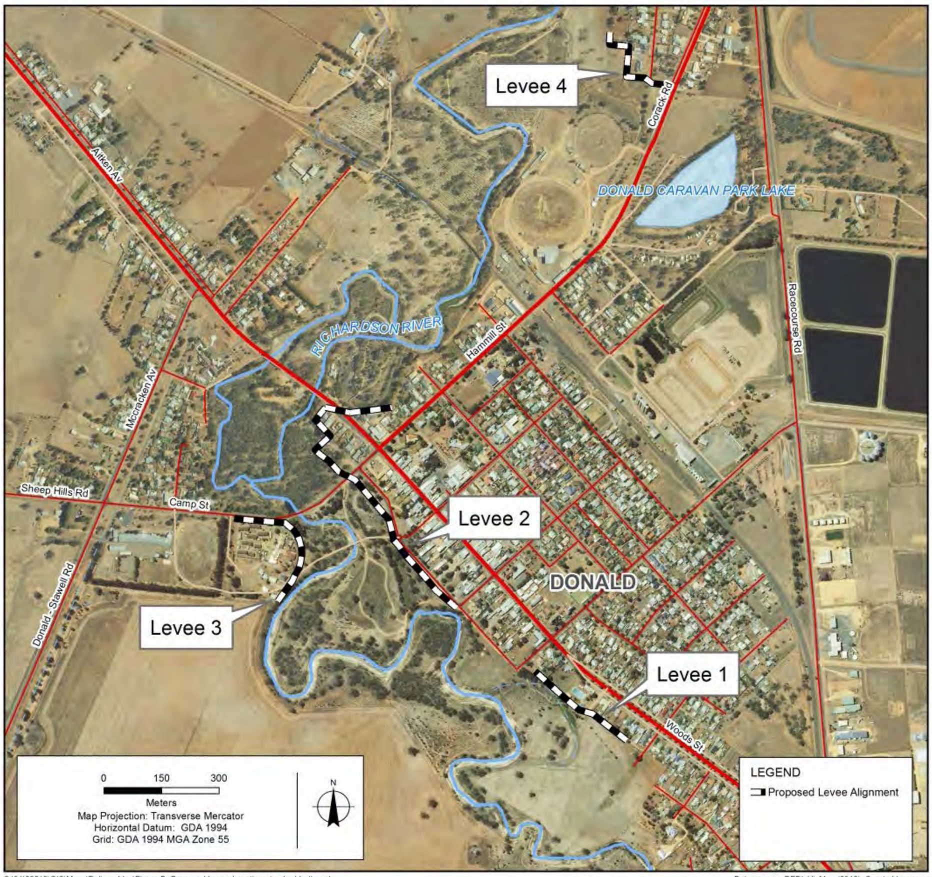
It is recommended that the following works be undertaken as a second priority:

- Construction of Levee No. 1 (refer to Figure B for location)

It is recommended that the following works be considered:

- Construction of Levee No. 4 (refer to Figure B for location). With the construction of Levee 4 consideration should be given to improving the economic viability of the levee by:
  - Providing a lower level of service (in terms of AEP event); and
  - Reaching an agreement with the landowner in regards to maintenance.

Figure B Proposed Levee Locations



G:\31\28519\GIS\Maps\Deliverables\Figure B- Proposed Levee Locations (embedded).mxd

Data source: DEPI, VicMap (2012). Created by:scowan

Non - Structural Flood Mitigation Works

It is recommended for Donald that:

- The Buloke Shire Council uses the information from this study to complete the Municipal Flood Emergency Management Plan with the assistance of the VICSES;
- The Council undertake a detailed investigation into drainage (local non riverine flooding) issues for Donald and develop a stormwater management plan for Donald;
- Information from this investigation be used to improve the flood warning received by Donald during a flood event;
- A gauge board at the Bullocks head or at the Sunraysia Highway bridge is installed to assist in future flood warning;

- Flood awareness in the community is increased and maintained with a public campaign through the implementation of the VICSES Floodsafe program; and
- The Buloke Shire Council undertakes a planning scheme amendment to incorporate flood related provisions to reflect the flood risks identified by this study.

Community Consultation and Feedback

The principle goal of this project was to obtain community support for the recommendations of this Plan. To this end, significant community consultation was undertaken throughout the development of the Plan.

A community based Steering Committee was appointed to oversee the development of the Plan and North Central CMA led a community consultation process to gain feedback and support from the wider community. Two public meetings were held at different stages in the development of the Plan, with each meeting being attended by close to 50 community members at each meeting.

The recommendations of the Plan were presented to the community at a public meeting on 20 February 2013. Following this meeting a community questionnaire and feedback form was sent to each property in Donald and the surrounding rural area. A total of 61 submissions were received from the community, of these 59 submissions supported the construction of levees to reduce the risk of future flooding.

The feedback received indicates a clear level of support in the community for the recommendations of the Plan.

Acknowledgements

The Donald Flood and Drainage Management Plan was led by a community based Steering Committee and supported by a Technical Working Group consisting of representatives from North Central Catchment Management Authority, Buloke Shire Council, VicSES, Department of Environment and Primary Industries, Bureau of Meteorology, VicRoads, VicTrack and Grampians Wimmera Mallee Water.

GHD would like to especially thank the following community members on the Steering Committee for their support in the development of this Plan:

Rob Loats (Chair), Greg Nunn, Anthony Hogan, Trevor Campbell, Lindsay Ezard, Harold Flett, Cr Leo Tellefson and Cr Graeme Milne.

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Glossary of Terms

Annual Exceedence Probability (AEP)	The probability of a rainfall or flood event occurring or being exceeded within a year. For example a 1% AEP can also be referred to as a 1 in 100 AEP event.
Average Recurrence Interval (ARI)	The average period between occurrences equalling or exceeding a given value. The term ARI is often interchanged with AEP, i.e. a 1% AEP equals a 100 year ARI, however the term AEP is a more accurate representation of the potential risk.
Afflux	A rise in the water level immediately upstream of and due to a natural or artificial obstruction
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to provide a common national standard.
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse
Digital Elevation Model (DEM)	A digital elevation model is a representation of the earth's surface
Hydrograph	A graph showing the surface level, discharge, velocity, or some other feature of water, with respect to time
Hydrology	The branch of science concerned with the properties of the earth's water, and especially its movement in relation to land
Hydraulics	The branch of science and technology concerned with the conveyance of liquids through pipes and channels, especially as a source of mechanical force or control
Levee	Is an elongated naturally occurring ridge or artificially constructed bank or wall, which regulates water levels. It is usually earthen and often parallel to the course of a river in its floodplain.
Pluviograph	An instrument for measuring the amount of water that has fallen (i.e. rain gauge), with a feature to register the data in real time to demonstrate rainfall over a short period of time, often an automated graphing instrument
RORB	A computer model used to calculate flood hydrographs from rainfall and other channel inputs
TUFLOW	A hydraulic modelling tool to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement

1. Introduction

1.1 Scope and Purpose

The township of Donald in central Victoria has been affected by floods three times in recent years, including September 2010, December 2010 with the most severe in January 2011.

This study has been funded by the Victorian and Australian Governments under the Natural Disaster Resilience Grants Scheme (NDRGS). The North Central Catchment Management Authority (NCCMA) is leading the development of this Plan in partnership with the Buloke Shire Council.

The study objectives include:

- Engage with the community and stakeholders in order to understand their experiences of flooding and desired outcomes;
- Review available data and historic flood information;
- Determine and document flood levels, extents, velocities and depths (and thus flood risk) for the Richardson River (including overland flow paths within the township) within the study area (Figure 1) for a range of flood events including 0.5%, 1%, 2%, 5%, 10% and 20% AEP events;
- A review of Buloke Shire Council planning scheme current flood zones and overlays for the township/study area/locality and recommendations for appropriate Planning Scheme amendments in the context of study outcomes;
- Preparation of digital and hard copy floodplain maps for 1% AEP flood events showing both floodplain and floodway extents, suitable for incorporation into municipal planning schemes;
- Assessment of flood damages;
- Identification and preliminary feasibility assessment of structural mitigation measures to alleviate intolerable flooding risk;
- Detailed costing and assessment of preferred structural mitigation measures;
- Recommendations for improved flood warning system for the study area;
- Preparation of flood intelligence and consequence information that can be utilised by Emergency Services to improve flood response activities and be incorporated into local flood emergency management plans; and
- A review and update of the Buloke Shire Council Flood Response Plan contained within the Municipal Emergency Management Plan.

This report documents the work undertaken to date, namely:

- A review of the available data and historic flood information;
- Hydrological assessment; and
- Hydraulic Assessment.

1.2 Limitations

This Report has been prepared for the NCCMA by GHD and may only be used and relied on for the purpose agreed between NCCMA and GHD as set out in Section 1.1 of this Report.

GHD otherwise disclaims responsibility to any person other than NCCMA arising in connection with this Report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this Report were limited to those specifically detailed in the Report and are subject to the scope limitations set out in the Report.

The opinions, conclusions and any recommendations in this Report are based on conditions encountered and information reviewed at the date of preparation of the Report.

GHD has prepared this Report on the basis of existing available information provided by numerous sources, as detailed in Section 3 of this report, as well as published methodologies (e.g. Australian Rainfall and Runoff), which GHD has not independently verified or checked beyond the agreed scope of work.

The opinions, conclusions and any recommendations in this Report are based on certain assumptions made by GHD based on the existing available information and methodologies mentioned above and as described in this Report. GHD does not accept liability in connection with such unverified information, including liability arising from incorrect assumptions and errors and omissions in the Report which were caused by errors or omissions in that information.

Some of the assumptions that were made for this investigation relate to:

- The reliability of the calibration data;
- The appropriateness of the design standards;
- The relationship between a rainfall event, the runoff and the flood event;
- Reliability of the topography (LiDAR) data; and
- The effects of climate change.

2. Description of Catchment

The township of Donald is located on the Richardson River. The catchment of the Avon-Richardson basin is shown on Figure 1. The Avon-Richardson catchment encompasses an area of approximately 3000 km^2. The southern and eastern boundaries are surface water divides separating the Avon-Richardson catchment from the Wimmera River and the Avoca River catchments respectively. The northern and western hydrological boundaries of the Avon-Richardson catchment do not have distinct hydrological boundaries.

The tributaries of the Avon and Richardson Rivers originate in the Pyrenees foothills to the south and flow north to Lake Buloke. The Avon and the Richardson Rivers join near Banyena. From Lake Buloke the only surface water disposal mechanisms are evaporation and seepage into the groundwater.

The upper portion of the catchment has some steep sections however, the majority of the catchment has low gradients. The upper portion of the catchment rises to approximately 610 mAHD compared to 100 mAHD at Lake Buloke over a distance of approximately 100 km. The elevation of 610 mAHD drops to 340 mAHD over 4 km a gradient of approximately 14% with the remainder of the catchment having a slope of approximately 0.3% (this slope varies across the catchment). Figure 2 shows the topography across the catchment, which highlights that the majority of the catchment has low gradients.

The average annual rainfall varies from approximately 380 mm/yr in the north to 630 mm/yr in the south (Bureau of Meteorology). Figure 3 shows the spatial variability of average annual rainfall across the Avon-Richardson catchment.

The following information about the Avon-Richardson catchment has been summarised from two reference documents, Avon-Richardson Floodplain Management Plan (Egis, 2000) and Avon-Richardson Floodplain Management Strategy (SKM, 1998).

Only 5% of the Avon-Richardson catchment remains forested. The existing forests of the catchment (predominately box iron-bark) is predominately located in the southern portion of the catchment. The catchment is predominately a broad acre agricultural district with approximately 90% of the land used for grazing and crop production.

The soils of the Avon-Richardson catchment can be grouped into two main types:

- Grey and Brown Cracking Clays occupy approximately 55% of the catchment and are the most productive cropping soils in the catchment;
- Red Duplex soils make up approximately 40% of the catchment and are the dominate soil type in the north eastern and south eastern segments of the catchment.

The remaining 5% is made up of gradational soils and a host of other types.

As mentioned previously the upper portion of the catchment features regions of rolling to steep hills with the drainage in the upper catchment generally well defined. The soils in the upper catchment are predominately hard setting sandy loams leading to high runoff rates.

The mid to lower portions of the catchment are characterised by poor drainage with many low lying areas. It includes the area around Marnoo and York Plains, Avon Plain Lakes, Lake Batyo Catyo and Lake Cope Cope (refer to Figure 1 for location of named features).

Flows in the Avon and Richardson Rivers are highly variable and intermittent. For example in 1996 flow increased from zero or very little to 11,000 ML/d (127 m^3/s) within three days.

At times of flood in the Wimmera River breakout flows can cross the low catchment divide between the Wimmera River and Swedes Creek and contribute to flows in the Avon-Richardson system. The Swedes Creek Cut is a high level connection between the Wimmera River and Swedes Creek. From the Swedes Creek Cut water flows into a channel and into Swedes Creek. The channel was originally constructed to supply water to Donald. The capacity of the cut has been estimated to be in the order of 870 ML/d (10 m^3/s).

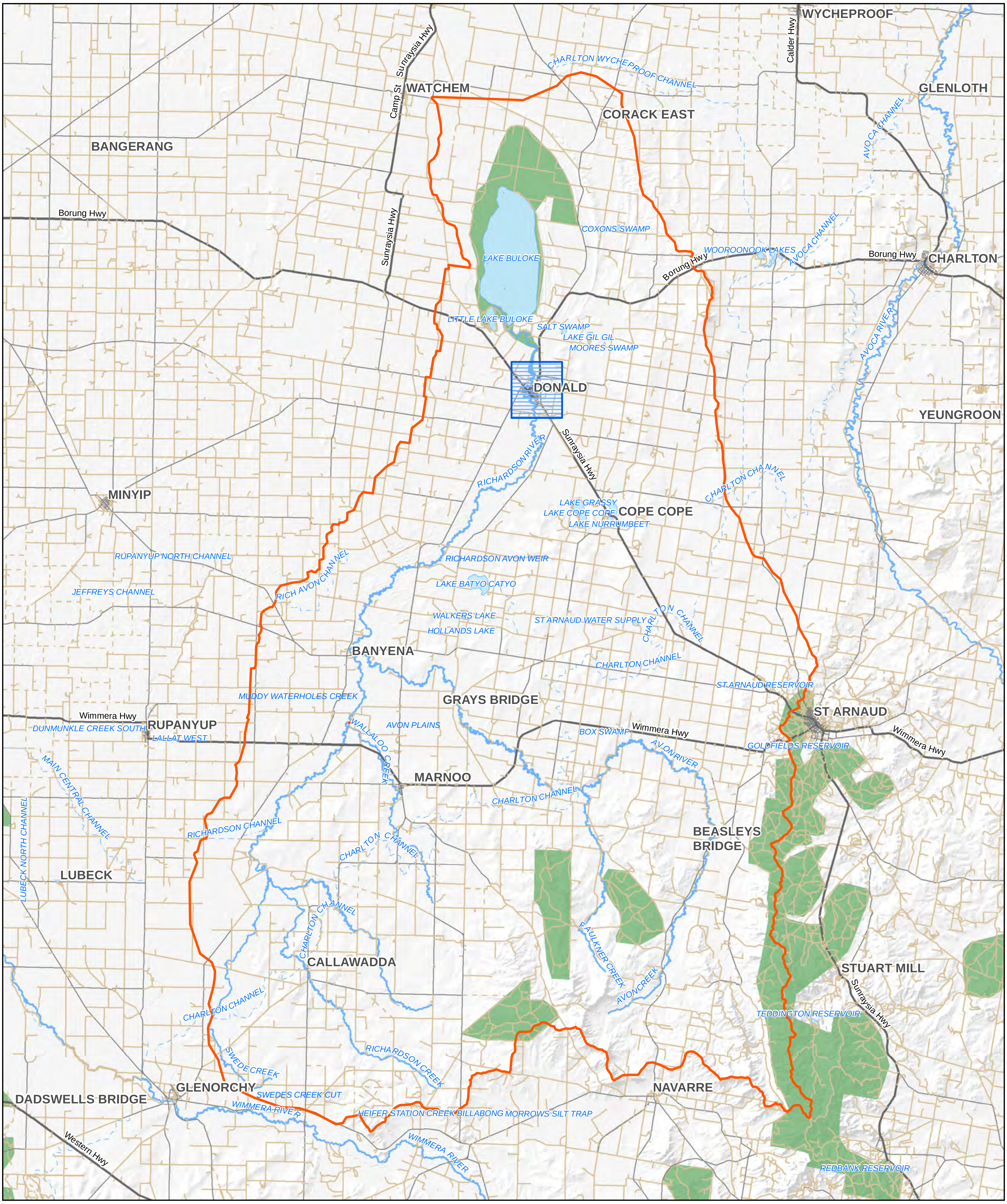
Many levees have been constructed throughout the floodplain. Other works such as roads, railways, water supply channels and drainage works influence the movement of water, to varying degrees, across the catchment. Some discussion on a few of these is given below.

Holland's bank was constructed in 1912 and protects a large area of farmland between Grays Bridge and Lake Batyo Catyo (refer to Figure 1 for location of named features). The Avon-Richardson Floodplain Management Plan looked at the impact of removing the bank. It concluded that if the bank was removed, then during the 1996 flood event the peak flow at Donald would have increased by approximately 250 ML/d (2.9 m^3/s) representing a height differential of 10 to 20 mm.

The Avon-Richardson Floodplain Management Plan also concluded that the effects of removing Holland's bank altogether on flood levels throughout the Avon Plains area would be significant.

The Avon-Richardson catchment contains a network of stock and domestic water supply channels. Water was brought into the Avon-Richardson catchment via four channels: the Rocklands Lubeck, Taylors Lake, Charlton and Main Central.

The Rich Avon weir on the Richardson River (refer to Figure 1 for location) forms part of the channel network and diverts water to Lake Batyo Catyo. Water from Lake Batyo Catyo discharges into the Donald Main Channel. Outflow from Lake Batyo Catyo is limited by channel capacity to approximately 240 ML/d (2.8 m^3/s).



LEGEND

- Donald Study Area
- Avon-Richardson Catchment
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Stream
- Connector
- Channel / drain
- Parks

Paper Size A3
0 1.25 2.5 5 7.5 10 12.5
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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North Central CMA
Donald Flood and Drainage Investigation

Job Number	31-28519
Revision	A
Date	16 May 2014

Locality Plan

Figure 1

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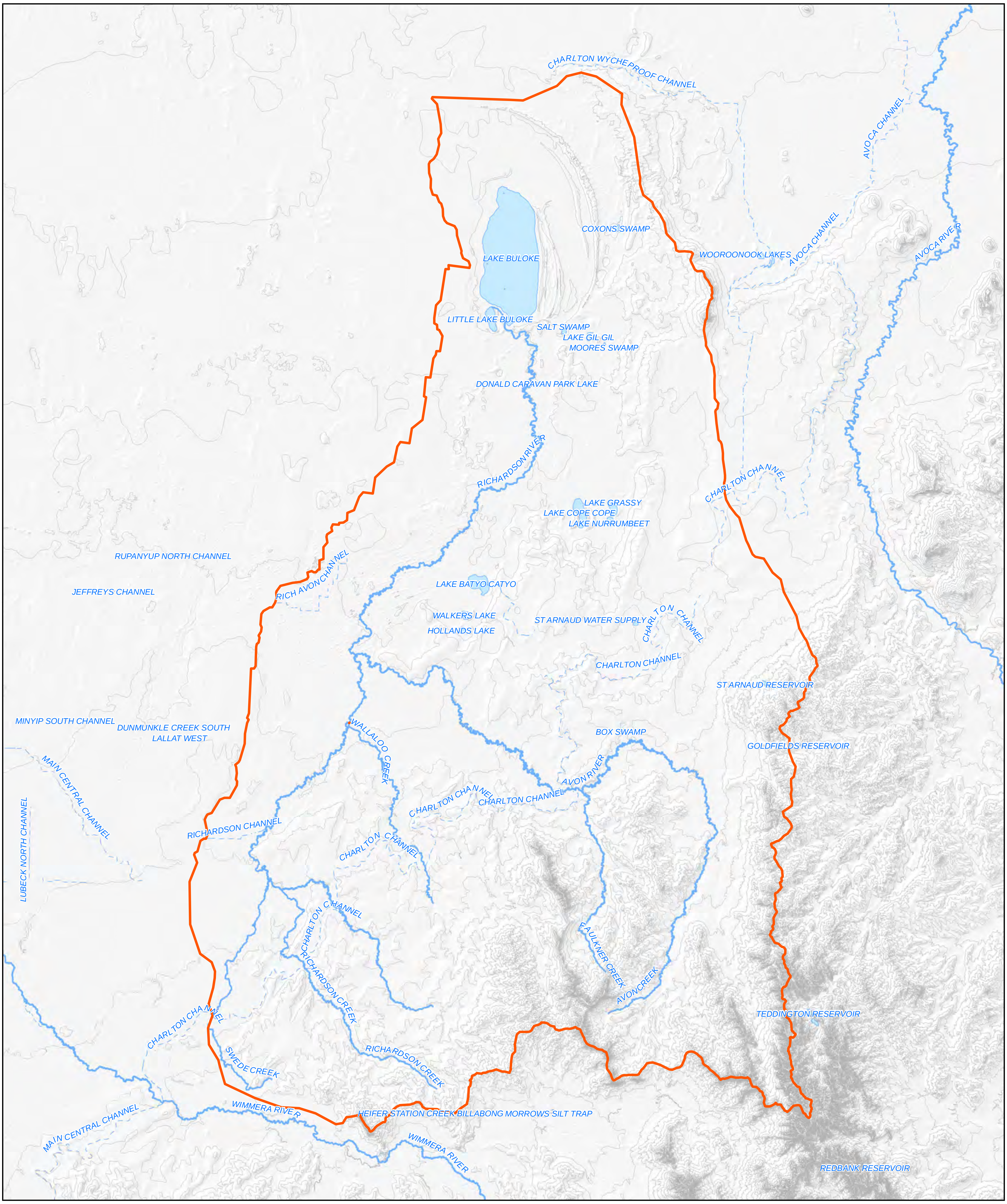
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012). Created by:scowan



LEGEND

- Avon-Richardson Catchment
- Lake
- Flat
- River
- Stream
- Connector
- Channel / drain
- 10m Contour

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Donald Flood and Drainage Investigation

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Revision	A
Date	19 May 2014

Topography

Figure 2

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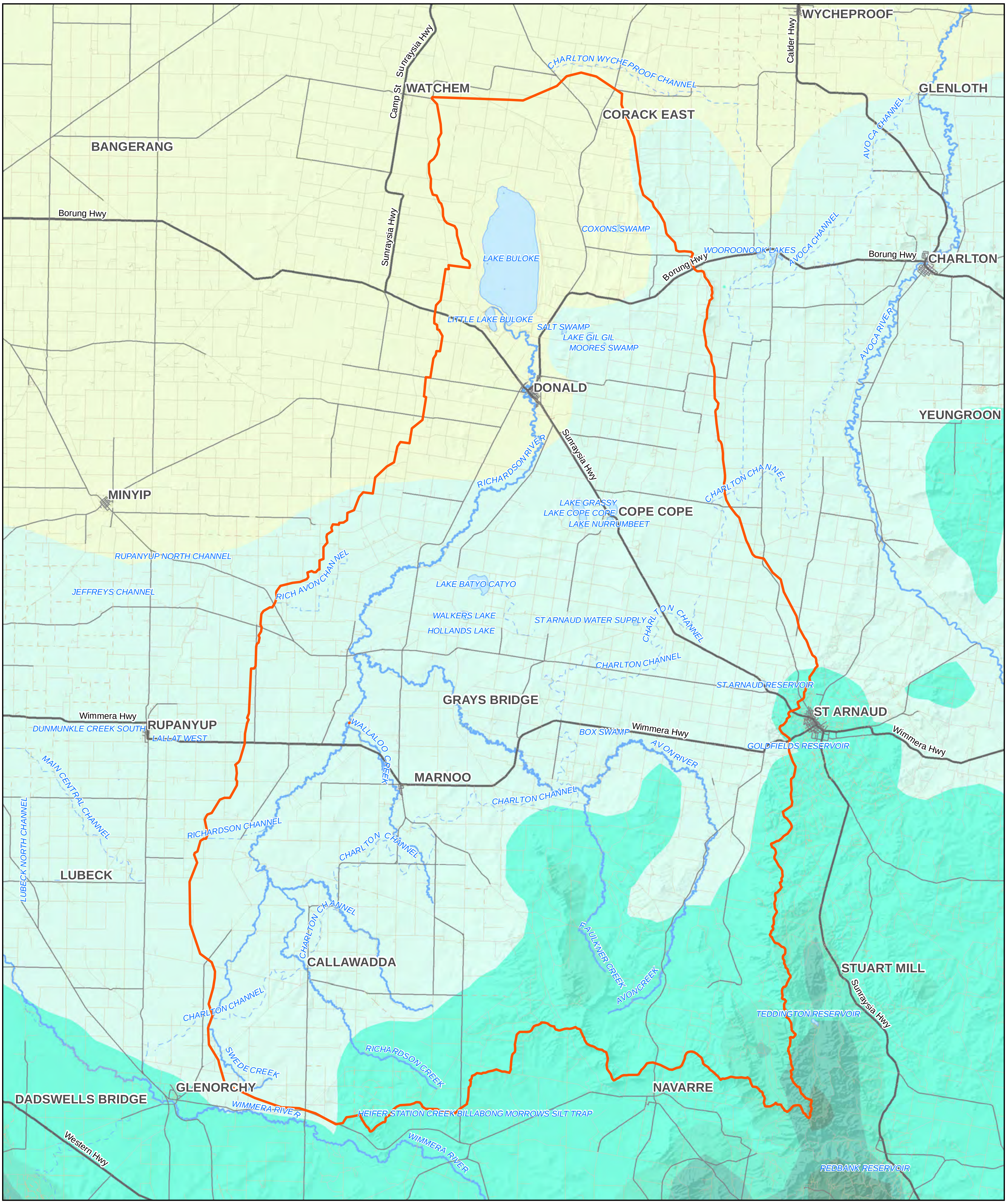
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan



LEGEND

- Avon-Richardson Catchment
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Stream
- Connector
- Channel / drain

Mean Annual Rainfall Depth (mm)

301 - 400 | 400 - 500 | 500 - 600 | 600 - 700 | 700 - 800 | 800 - 900

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Mean Annual Rainfall

Figure 3

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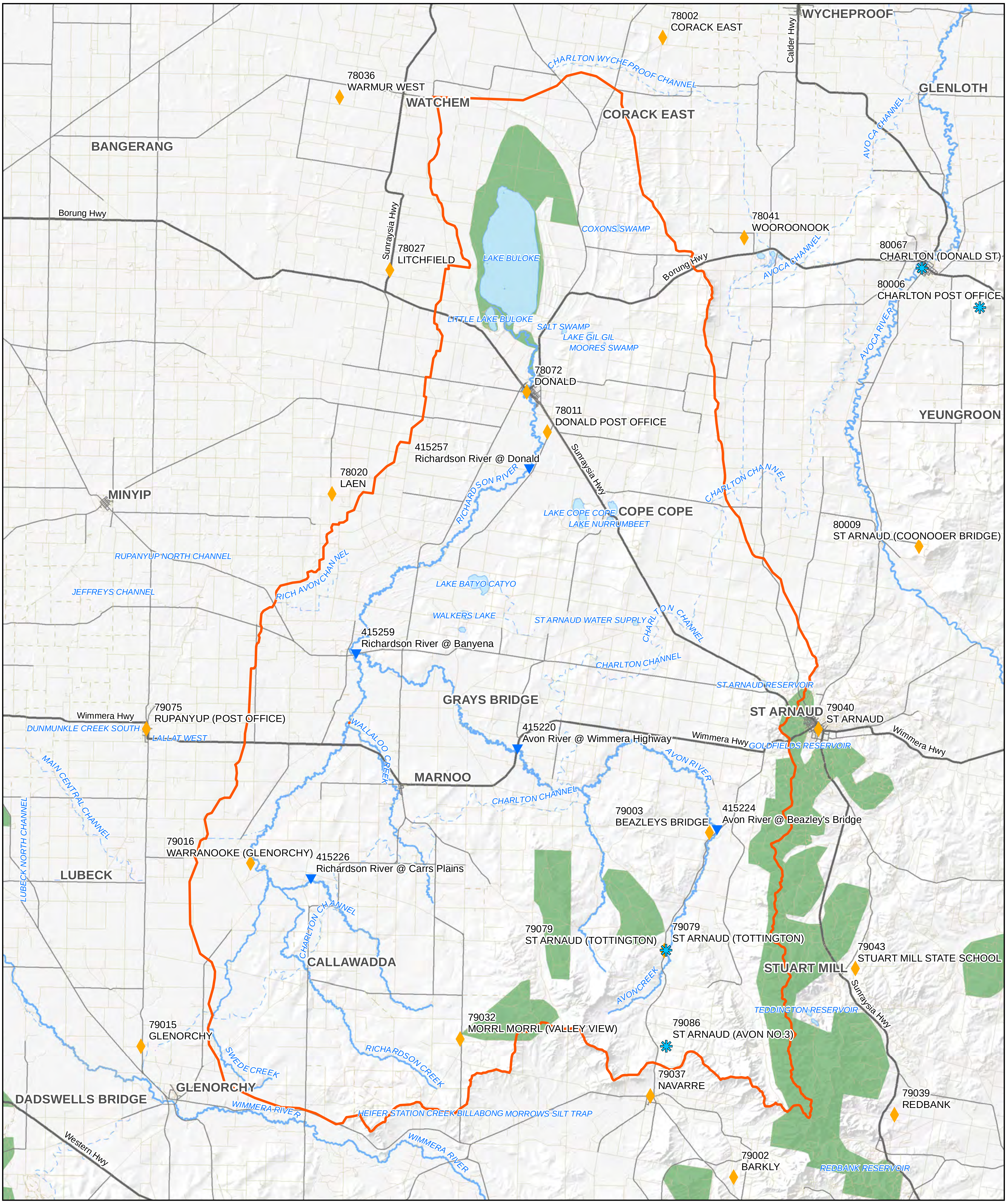
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan



LEGEND

Pluviographs	Sealed road (arterial & local)	River
Daily Rainfall Gauge	Unsealed road	Stream
Stream Gauges	Unsealed track	Connector
Avon-Richardson Catchment	Lake	Channel / drain
Highway	Flat	Parks

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Gauge Locations

Figure 4

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Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan

3. Available Information

3.1 Stream Flow Gauges

There are several stream flow gauge stations located throughout the Avon-Richardson catchment, these are listed in Table 1. The key stream flow gauge stations used in the hydrological investigation are shown in italics in Table 1. The location of the stream flow gauge stations are shown in Figure 4. The stream flow gauge information was downloaded from Victoria Water Resources Data Warehouse (http://www.vicwaterdata.net/vicwaterdata/home.aspx) and supplied by Thiess and Grampians Wimmera Mallee Water (GWMW).

Table 1 Stream Flow Gauging Data

Station Number	Name	Date	Catchment Area (km^2)
415220	*Avon River @ Wimmera Highway*	*1965 - 2011*	*596*
415224	*Avon River @ Beazleys Bridge*	*1969 - 1995*	*263*
415211	Avon River @ Mitchells Hill	1945 – 1955	*544*
415257	*Richardson River @ Donald^*	*1989 - 2011*	*1831*
415259	*Richardson River @ Banyena*	*1993 - 2011*	*1532*
415210	Richardson River @ Banyena South	1944 – 1962	*658*
415226	*Richardson River @ Carrs Plains*	*1971 - 2011*	*130*
415219	Richardson River @ Warrandoke	1963 – 1973	*388*
415260	*Richardson River @ U/S RichAvon Weir*	*2005 - 2011*	*1677*
*415609**	*Lake Batyo Catyo*	*2000 - 2011*	*138*

* Stage only i.e. no rating table

^ Gauge failed during January 2011 event

In addition to the stream flow gauge information, Thiess undertook a gauge reading during the January 2011 event (Saturday evening 15/1/11) from the Sunraysia Highway bridge in the town. The total measured flow, which was not the peak, was 28,587 ML/d (330 m^3/s).

3.2 Daily Rainfall Gauges

A number of daily rainfall gauges are scattered throughout the catchment and surrounds. Daily rainfall data was sourced from the SILO Patched Point Dataset. The SILO Patched Point Dataset (PPD) provides continuous daily climate data for around 4,600 meteorological stations around Australia, including a number of stations within the Avon-Richardson region. The SILO PPD uses original Bureau of Meteorology measurements for a particular meteorological station, but with interpolated data used to fill any gaps in the observation record. The dataset is maintained by the Queensland Department of Environment and Resource Management (DERM), with all data publicly available (at a low cost) via the department's website (www.longpaddock.qld.gov.au/silo/).

The daily rainfall gauges were used to determine the spatial distribution of rainfall across the catchment. The key daily rainfall gauges used in the hydrological investigation are shown in Table 2. The location of the daily rainfall gauge stations are shown in Figure 4.

Table 2 Daily Rainfall Gauges

Station Number	Name	Station Number	Name
78002	CORACK EAST	79016	WARRANOOKE (GLENORCHY)
78011	DONALD POST OFFICE	79032	MORRL MORRL (VALLEY VIEW)
78020	LAEN	79037	NAVARRE
78027	LITCHFIELD	79039	REDBANK
78036	WARMUR WEST	79040	ST ARNAUD
78041	WOOROONOOK	79043	STUART MILL STATE SCHOOL
78072	DONALD	79075	RUPANYUP (POST OFFICE)
79002	BARKLY	79079	ST ARNAUD (TOTTINGTON)
79003	BEAZLEYS BRIDGE	79080	STAWELL
79015	GLENORCHY	80009	ST ARNAUD (COONOOER BRIDGE)

3.3 Pluviograph Data

Only two pluviographs are located within the Avon-Richardson catchment. The two pluviographs are St Arnaud (Tottington) and St Arnaud (Avon No. 3). Both of these pluviographs are located in the southern part of the catchment. The closest pluviograph in the northern part of the catchment is Charlton (Donald St). These three pluviographs were used to determine the temporal pattern of rainfall. Details on the pluviographs are shown in Table 3. The pluviograph locations are shown in Figure 4. Information for each pluviograph was supplied by the Bureau of Meteorology.

Table 3 Pluviographs

Station Number	Name	Date
79079	St Arnaud (Tottington)	1973 – to date
79086	St Arnaud (Avon No. 3)	1973 – to date
80067	Charlton (Donald Street)	1951 – to date

3.4 Historical Flood Level Data

Within the township of Donald the three events where recorded flood level information is available are August 1909, September 2010 and January 2011. Appendix A shows the location of the recorded flood level information. The flood level information was supplied by the NCCMA.

In addition to the recorded flood level information some anecdotal information was supplied by the community of Donald and GWMW.

The flood level data was used to calibrate the hydraulic model.

3.5 Topographical Information

The NCCMA supplied the following topographical data:

- VicMaps 10 metre contours;
- GWMW 2 metre Digital Elevation Model (DEM); and
- DSE Rivers LiDAR 1 metre DEM.

The VicMaps data covers the entire catchment. The GWM Water 2 metre DEM covers approximately two thirds of the catchment (northern section). The DSE Rivers LIDAR covers a strip along the Richardson River approximately 3 kilometres wide for the entire length of the study area. The area covered by each of the DEM's is shown in Appendix B.

3.6 Field Survey Data

In June 2012 Price Merrett undertook survey of the bridge crossing at the Sunraysia Highway and the railway line. They also undertook survey of the footbridge at the end of McCulloch Street and the one at the end of Houston Road.

3.7 Aerial Photos

The NCCMA supplied an aerial photo of approximately one third of the catchment, including the study area. Also an aerial photo of the flood in September 2010 was supplied by the NCCMA. However, the view of the flood waters is significantly obscured by clouds.

3.8 Flood Photos

Numerous flood photos were supplied by the:

- Community
- NCCMA
- Buloke Times
- Thiess

Most of the photos supplied were of the January 2011 event. A sample of the flood photos supplied is shown in Appendix D.

3.9 Previous Reports

The NCCMA supplied a number of reports relating to the Avon-Richardson catchment which have been prepared by others. Below is a list of the key reports referred to during this investigation. The list below is not the full list of reports supplied.

- Avon Richardson Land and Water Plan, Surface Water Management in the Avon-Richardson Catchment, Victorian Salinity Program, 1992;
- Department of Conservation and Environment, Avon-Richardson Floodplain Management Strategy, SKM, 1998;
- NCCMA, Avon Plains Lakes Water Management Plan, SKM, 2006; and
- NCCMA, Avon-Richardson Floodplain Management Plan, Egis Consulting, 2000.

4. Hydrological Analysis

4.1 General

This section of the report summarises the hydrologic investigation undertaken on the Avon-Richardson catchment. The work involved:

- A review of available hydrological information;
- Development and calibration of a hydrologic catchment model (RORB);
- Verification of the RORB parameters against historical data; and
- Development of design flood estimates.

A RORB model of the Avon-Richardson catchment was developed to model the rainfall-runoff relationship of the catchment. In general terms, development of a RORB model entails:

- Sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storages; and
- Determination of the model parameters kc and m, which represent respectively the effect of the catchment in delaying the runoff response from the rainfall, and the non-linearity of the catchment's response to rainfall excess. These parameters are assigned based on calibration of the model against historical storm events. Parameters are also required to represent rainfall losses.

4.2 RORB Model Configuration

For the Avon-Richardson catchment, the RORB model subareas were delineated to model the rainfall-runoff conversion process; taking into account watershed boundaries, stream junctions and the location of stream gauging stations and storages. Initially an automated process was undertaken to delineate the catchment into subareas. The program Encom Discover was used to delineate the catchment using the GWM Water 2 metre DEM. These subareas were then manually adjusted to remove anomalies. For the remainder of the catchment, not covered by the DEM, subareas were delineated using the VicMaps 10 metre contour data.

Storages were placed into RORB model at:

- Lake Batyo Catyo
- Walkers and Hollands Lake
- Lake Cope Cope

GWM Water supplied a stage storage relationship for Lake Batyo Catyo which was placed into the RORB model. For the other storages a stage storage relationship was derived using the GWM Water 2 metre DEM.

The RORB model layout is shown in Appendix C.

Flow distribution within the Avon River floodplain between the Wimmera Highway and Banyena is complex. A detailed description of the flow regime in the region is available in the Avon-Richardson Floodplain Management Plan (2000). In addition to the information available in the Avon-Richardson Floodplain Management Plan a hydraulic model (TUFLOW) was established for this area to gain a greater understanding of the flow regime and establish flow distribution relationships to place into the RORB model. More detail on the hydraulic model results are shown in Appendix E.

As mentioned in Section 2 at times of flood in the Wimmera River breakout flows can cross the catchment divide and contribute flows into the Avon-Richardson system. An allowance was made for this in the RORB model. This is discussed further in Section 4.3.4.

4.3 Calibration

4.3.1 General

The RORB model was calibrated where there was continuous streamflow and pluviograph records. The RORB model was calibrated against the following gauging stations:

- 415220 Avon River @ Wimmera Highway;
- 415224 Avon River @ Beazleys Bridge;
- 415257 Richardson River @ Donald;
- 415259 Richardson River @ Banyena; and
- 415226 Richardson River @ Carrs Plains.

The gauge 415257 (Richardson River @ Donald) was the focus of the investigation as it is the closet to the study area and captures approximately sixty percent of the total catchment. Figure 5 shows the flows recorded at 415257 (Richardson River @ Donald).

The calibration for this investigation was undertaken by setting up historic storm files and running the RORB model with parameters and losses such that a match was achieved against the recorded flood hydrographs.

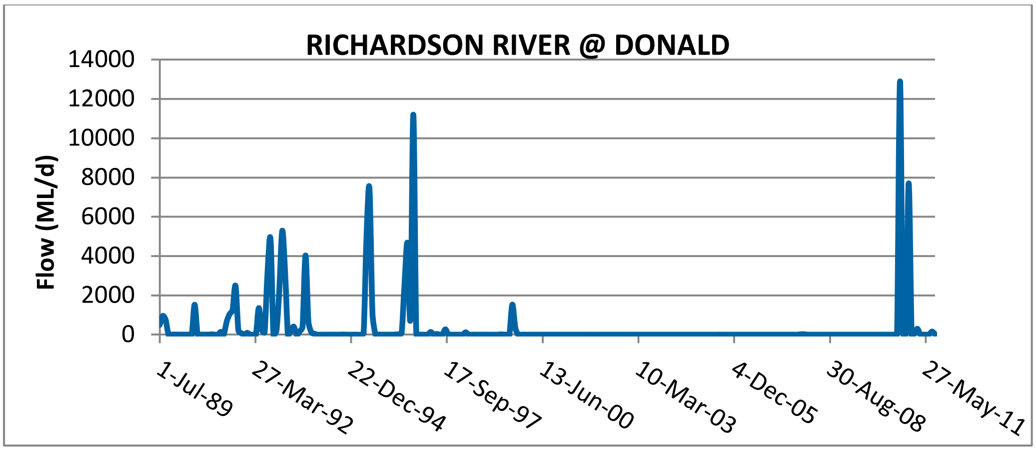
The three events chosen for calibration of the RORB model were:

- October 1996 (maximum flow recorded at Donald of 11,200 ML/d – 130 m^3/s);
- September 2010 (maximum flow recorded at Donald of 12,900 ML/d – 149 m^3/s); and
- December 2010 (maximum flow recorded at Donald of 7,706 ML/d – 89 m^3/s).

The events listed above were chosen because continuous streamflow data and pluviograph data was available electronically. Also these are the three largest floods, as defined by peak flow, recorded at the gauge site 415257 (Richardson River @ Donald).

The January 2011 was larger than all of the events listed above, however, no streamflow data is available for this event at 415257 (Richardson River @ Donald). The calibrated RORB model was used to estimate the flow at Donald for the January event. This is discussed in further detail in Section 4.4.

Figure 5 Flows Recorded at 415257 (Richardson River @ Donald)



The RORB program allows catchment losses to be modelled either using the initial/continuing loss approach or the initial/runoff coefficient approach. The latter approach is generally recommended for partly urbanised catchments. For this investigation the initial/continuing loss approach was used.

An m value of 0.8 was adopted which is in agreement with typical m values recommended in Australian Rainfall and Runoff 1999 (ARR99).

4.3.2 Subarea Rainfalls

For each of the calibration events the rainfall depths were estimated for each subarea to account for the spatial variation of rainfall across the catchment. Rainfall depths across the catchment were established for each of the calibration events from the daily rainfall stations and the rainfall depth on each subarea was then estimated.

Once the rainfall depth was estimated for each subarea, the temporal distribution of rainfall was estimated by assigning the pattern from either St Arnaud (Tottington) (79079), St Arnaud (Avon No. 3) (79086) or the Charlton (Donald Street) (80067) pluviograph. For the 2010 events with multiple pluviographs available, the pluviograph within the catchment produced the best fit to the recorded flow information and was adopted.

4.3.3 Baseflow Separation

The RORB model transforms the rainfall excess of a given storm event into a flood hydrograph. In order to compare the RORB model's generated hydrograph with the recorded hydrograph, it is necessary to remove the baseflow component from the recorded hydrograph.

For the events considered, baseflow is an insignificant component compared to the rainfall runoff component. For each of the calibration events the flow recorded at 415257 (Richardson River @ Donald) prior to the flood event was less than 86.4 ML/d (1 m^3/s). For the December 2010 event removal of baseflow was undertaken at 415259 (Richardson River @ Banyena) and 415220 (Avon River @ Wimmera Highway). However, the amount removed was still insignificant (less than one percent of the peak flow). The methodology adopted for removing baseflow was that described in Australian Rainfall and Runoff. Baseflow separation is arbitrary and may produce errors in the volume and shape of the calibration hydrograph. However, the results of Bates and Davies (1988) indicate that the sensitivity of model predictions to differences in baseflow separation procedures lessens with increasing magnitude of the event. Baseflow was considered for the calibration process but as baseflow appears to be insignificant it was not considered during the validation or design event process.

4.3.4 Wimmera River Breakouts

A detailed analysis of the Wimmera River and its interaction with the Richardson River is beyond the scope of this investigation. However, some allowance for breakout flows from the Wimmera River into the Avon-Richardson River catchment has been including in the RORB model.

The amount of breakout flow from Avon-Richardson River was based on information from the following sources:

- Avon-Richardson Floodplain Management Plan (Egis, 2000);
- Glenorchy Flood Study (Water Technology, 2006);
- Information supplied by the Wimmera Catchment Management Authority;
- Information supplied by Water Technology from the Glenorchy Flood Study;
- LIDAR information supplied by the NCCMA; and
- Stream flow gauge information at 415201 (Wimmera River @ Glenorchy).

From the Avon-Richardson Floodplain Management Plan the following comment was made about flow from the Wimmera River into the Avon-Richardson catchment via Swedes Creek Cut, "anecdotal advice from Wimmera - Mallee Water is that estimated peak flow in the Cut during October 1996 was only 100 ML/d. The peak flow in the Wimmera River for this event can therefore be adopted as a threshold of flow in the cut."

Two dimensional modelling results from the Glenorchy Flood Study indicate that flow begins to break out of the Wimmera River, around Swedes Creek, for a flow of 19,000 ML/d (220 m^3/s) in the Wimmera River. However, the modelling indicated that for a flow of 19,000 ML/d in the Wimmera River, no or very little water, flows into the Avon-Richardson Catchment.

A flood depth in Swedes Creek for different flow events was supplied from the Glenorchy Flood Study. Using the depths supplied and the Manning's equation an estimate of flow in Swedes Creek for various flow events was calculated. The cross section and slope of Swedes Creek was taken from the LIDAR data. A Manning's n value of 0.07 was used. From the literature (Chow, 1959), a Manning's n value of 0.07, represents a channel which is not maintained, weeds and brush, which from the photos available of the site appears to be appropriate. Table 4 shows the flows in Swedes Creek calculated for various flows in the Wimmera River.

Table 4 Peak Flow through Swedes Creek

Flow in Wimmera River (ML/d)	Depth of Flow in Swedes Creek (m)	Peak Flow Through Swedes Creek (ML/d)
23,000	1.00	206
29,000	1.25	340
33,000	1.50	510
36,000	1.75	717

For the three calibration events the peak flows in the Wimmera River at the Glenorchy gauge (415201) was:

- 14,780 ML/d (171 m^3/s) in October 1996
- 28,000 ML/d (324 m^3/s) in September 2010
- 11,360 ML/d (131 m^3/s) in December 2010

October 1996 Event

Based on the results from the hydraulic modelling undertaken for Glenorchy, in 1996 no flow would have broken out of the Wimmera River into Swedes Creek during this event. This is contrary to the anecdotal advice stated in the Avon-Richardson Floodplain Management Plan. For this investigation, to remain consistent with the Avon-Richardson investigation, for the October 1996 event a peak flow of 100 ML/d was entered into the RORB model at Swedes Creek. The shape of the hydrograph for the 1996 event was taken from the Avon-Richardson Floodplain Management Plan.

Even though the hydraulic modelling undertaken for Glenorchy indicated that no flow would have entered Swedes Creek during the 1996 event, a flow of 100 ML/d at Swedes Creek cut compared to a flow recorded at the Donald gauge of 11,580 ML/d indicates that the break out flow at Swedes Creek would have a minor impact on flood levels in Donald.

December 2010

From the information above it was concluded that no flow contributed from the Wimmera River into the Avon-Richardson catchment during the December 2010 event.

September 2010

The breakout flow from the Wimmera River at Swedes Creek for the September 2010 event was scaled from the recorded event at the Glenorchy gauge (415201). It was assumed that flow began to enter Swedes Creek when flow in the Wimmera River was approximately 19,000 ML/d. From the information supplied on the Glenorchy Flood Study, approximately 9% of the peak flow in the Wimmera River flows into the Dunmunkle Creek system. As the flows recorded on the Wimmera River at the Glenorchy gauge are minus those lost into Swedes Creek and Dunmunkle Creek, flows recorded at the Glenorchy gauge greater than 19,000 ML/d were increased by 9% (referred to as adjusted flows in the Wimmera River). The ratio of flow into Swedes Creek was based on the adjusted peak flow in the Wimmera River and the peak flows in Swedes Creek shown in Table 4. For the September 2010 event it was estimated that the maximum flow into Swedes Creek was 400 ML/d (4.6 m^3/s).

Of note is that all flow that was to break out of the Wimmera River at and around Swedes Creek would be captured by the gauges at Banyena and Donald.

4.3.5 Initial Calibration Results

Initially an attempt was made to try and calibrate the RORB model to the September 2010 and the October 1996 event. In terms of the peak flow at 415257 (Richardson River @ Donald) and the shape of the hydrograph these events are similar. Also both of these events are the largest recorded hydrographs at 415257 (Richardson River @ Donald). The results of the initial calibration of the September 2010 and the October 1996 event are shown in Figure 6 and Figure 7 respectively.

Figure 6 Initial Calibration Results - September 2010

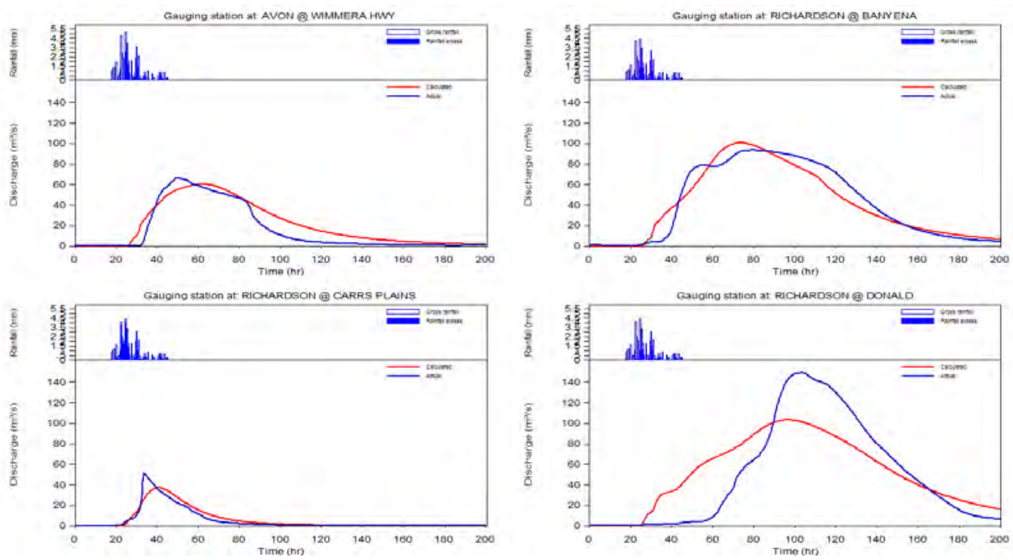
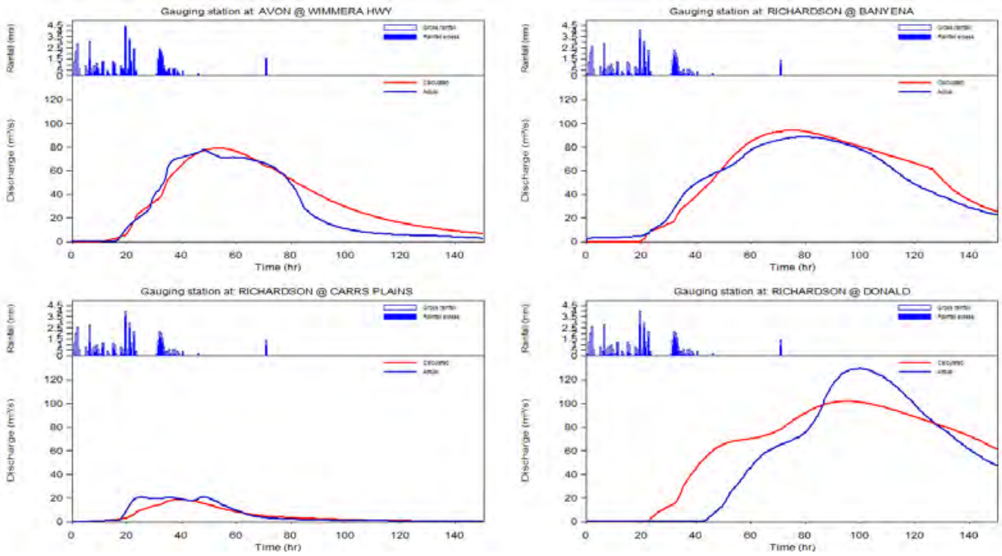


Figure 7 Initial Calibration Results – October 1996



The initial calibration results showed that a reasonable match could be achieved at 415220 (Avon River @ Wimmera Highway), 415226 (Richardson River @ Carrs Plains) and 415259 (Richardson River @ Banyena) but not at 415257 (Richardson River @ Donald). As mentioned in Section 4.3.1 the gauge 415257 (Richardson River @ Donald) was the focus of the investigation as it is the closet to the study area and captures approximately sixty percent of the total catchment. Therefore further investigation on the flow regime between 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) was undertaken.

Of note is that in the Avon-Richardson Floodplain Management Plan (2000) a similar result for the 1996 event was reported i.e. a reasonable match at each of the gauges except for 415257 (Richardson River @ Donald) where the modelled flow was less than the recorded flow.

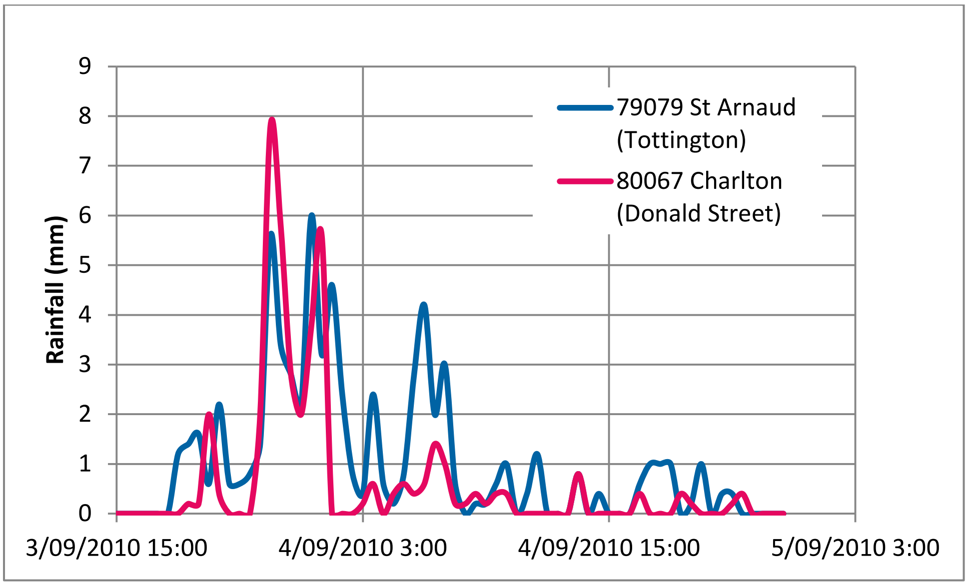
The results in Figure 6 and Figure 7 indicate that the RORB model produces a significant amount of flow at 415257 (Richardson River @ Donald) earlier than that recorded at the gauge. Originally it was hypothesised that flow from either the Lake Batyo Catyo catchment or the Lake Cope Cope catchment was delaying runoff more than was being modelled in the RORB model and if the flow from these catchments was delayed to coincide with the hydrograph from 415259 (Richardson River @ Banyena) a better match may be achieved. This hypothesis was put to the Technical Steering Committee (TSC) and the Community Reference Group (CRG).

Discussions with the CRG revealed that most, if not all, of the runoff from the Lake Cope Cope catchment enters into the Richardson River downstream of 415257 (Richardson River @ Donald) and is therefore not recorded by the gauge so this catchment was ruled out and the RORB model was adjusted to suit. This was also confirmed by re-analysing the GWMW 2 metre DEM following discussions with the CRG.

GWMW provided recorded data at Lake Batyo Catyo which included the September 2010 event. The recorded data at Lake Batyo Catyo indicated that at the start of the modelled event the Lake was approximately 80% full on 3 September and 85% full by the end of the modelled event on 12 September. Indicating that the Lake did not discharge any flow into the Richardson River during the modelled September 2010 event. Therefore the recorded information indicates that the flow from the Lake Batyo Catyo catchment does not explain the discrepancy between the flows recorded at 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald).

Another hypothesis for the discrepancy between the flows recorded at 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) was the temporal distribution of rainfall. Perhaps the storm travelled from south to north with the runoff from the south arriving at a similar time to the runoff north. For the September 2010 event there is pluviograph graph data in the south i.e. 79079 St Arnaud (Tottington) and in the north i.e. 80067 Charlton (Donald Street). Figure 8 shows the two pluviographs plotted together. Figure 8 shows that there is a similar rainfall pattern in the south as there is in the north. Therefore the available rainfall information does not indicate that the rainfall pattern would explain the discrepancy between the flows recorded at 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald).

Figure 8 Pluviograph Data – September 2010



Next an examination of the stream flow gauges at 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) was undertaken. Considering the September 2010 event the recorded peak flow at 415259 (Richardson River @ Banyena) is approximately 8070 ML/d (93 m^3/s). The catchment area at Banyena is approximately 1530 km^2 which is a rate of runoff of approximately 0.06 $m^3/s/km^2$. For the September 2010 event the recorded peak flow at 415257 (Richardson River @ Donald) is approximately 12900 ML/d (149 m^3/s). Therefore the increase in peak flow from 415259 (Richardson River @ Banyena) to 415257 (Richardson River @ Donald) is 4830 ML/d (56 m^3/s). Ignoring the Lake Batyo Catyo catchment, as discussed previously it doesn't appear to contribute much to the peak flow at 415257 (Richardson River @ Donald), then the additional catchment between 415259 (Richardson River @ Banyena) to 415257 (Richardson River @ Donald) is 256 km^2. Therefore, the portion of the catchment between 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) has a rate of runoff of approximately 0.22 $m^3/s/km^2$. This is three (3) times higher than the catchment upstream of 415259 (Richardson River @ Banyena). A similar result is observed for the October 1996 event.

The rainfall data (refer to Appendix F) does not indicate that in either the October 1996 or the September 2010 event that the portion of the catchment between 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) received a significantly higher proportion of rainfall than the catchment upstream of 415259 (Richardson River @ Banyena). Also as mentioned in Section 2 the upper portion of the catchment features regions of rolling to steep hills with the drainage in the upper catchment generally well defined and the soils in the upper catchment are predominately hard setting sandy loams leading to high runoff rates. This does not support the result that the catchment between 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) would have a rate of runoff of three (3) times that upstream of 415259 (Richardson River @ Banyena).

Thiess were contacted to provide additional information on 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald). The anecdotal evidence given by Thiess was that there was more 'confidence' in the rating curve at 415257 (Richardson River @ Donald) compared to 415259 (Richardson River @ Banyena). The highest flow measured at 415259 (Richardson River @ Banyena) is 5484 ML/d (63 m^3/s) at a level of 3.67 m. The highest flow measured at 415257 (Richardson River @ Donald) is 10043 ML/d (116 m^3/s) at a level of 3.8 m. The rating curve at 415259 (Richardson River @ Banyena) extends up to 16000 ML/d (185 m^3/s) at a level of 5.9 m. The rating curve at 415257 (Richardson River @ Donald) extends up to 13000 ML/d (150 m^3/s) at a level of 3.9 m. At 415259 (Richardson River @ Banyena) water begins to break the banks of the river at a level of approximately 3.8 m. At 415257 (Richardson River @ Donald) water begins to break the banks of the river at a level of approximately 3.2 m.

The maximum levels recorded at each of the gauges during the September 2010 and October 1996 events are shown in Table 5. The levels in Table 5 indicate that during both events flow broke the banks of the river around the gauge, which makes estimation of flow more difficult as it is not confined to the channel. It also indicates that the maximum flow measurement taken at 415257 (Richardson River @ Donald) i.e. 10043 ML/d (116 m^3/s) at a level of 3.8 m, is close to the maximum level recorded at this gauge during the 2010 and the 1996 event which means that less extrapolation of the rating curve is required to estimate the maximum flows during these events. This gives more confidence in the flow estimation at 415257 (Richardson River @ Donald) which is consistent with the anecdotal evidence from Thiess.

Table 5 Maximum Levels Recorded at 415259 and 415257 in September 2010 and October 1996

Event	Maximum Level Recorded	
	415259 Richardson River @ Banyena	**415257 Richardson River @ Donald**
October 1996	4.35	3.84
September 2010	4.47	3.90

To validate this conclusion a simple one-dimension model (HECRAS) was established at each of the stream gauge stations to determine an elevation discharge relationship (rating curve) at each site and compare this to that provided by Thiess. The rating curves produced using the HECRAS model are not designed to replace the existing curves but to verify which one we have more confidence in. Discussion with Thiess indicated that there is uncertainty around the extension of the rating curve for both gauges. The cross sections used in the hydraulic model were taken from GWMW 2 metre DEM. The roughness values in the HECRAS model were adjusted to match the recorded flow levels. The results from the HECRAS model are shown in Figure 9 and Figure 10 for 415259 (Richardson River @ Banyena) and 415257 (Richardson River @ Donald) respectively. Figure 9 indicates that the hydraulic model matches the recorded flows reasonably well up to a level of approximately 3.8 m. Above a level of 3.8 m the flow begins to break the banks of the river at 415259 (Richardson River @ Banyena) and it is at this point that the HECRAS model indicates that more flow is passing the gauge for the same height when compared to the Thiess rating curve.

Figure 10 indicates that the hydraulic model matches the recorded flows reasonably well, but not as well as the current rating curve. It also shows that the hydraulic model is a closer match to the Thiess rating curve than that for Banyena for larger flows.

The above discussion led to the conclusion that the calibration should focus on matching peak flows at 415257 (Richardson River @ Donald) and not at 415259 (Richardson River @ Banyena). However, as the rating curve at Banyena appears reasonable up to approximately 3.8 m (≈5900 ML/d) the calibration should try and match the general shape of the rising limb of the hydrograph.

Figure 9 415259 (Richardson River @ Banyena)

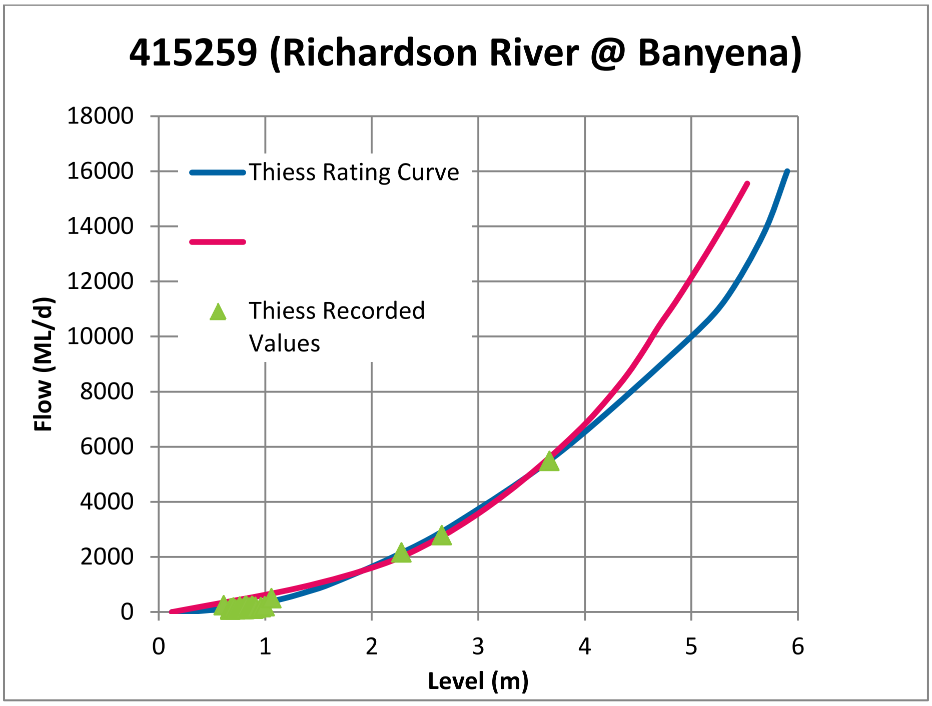
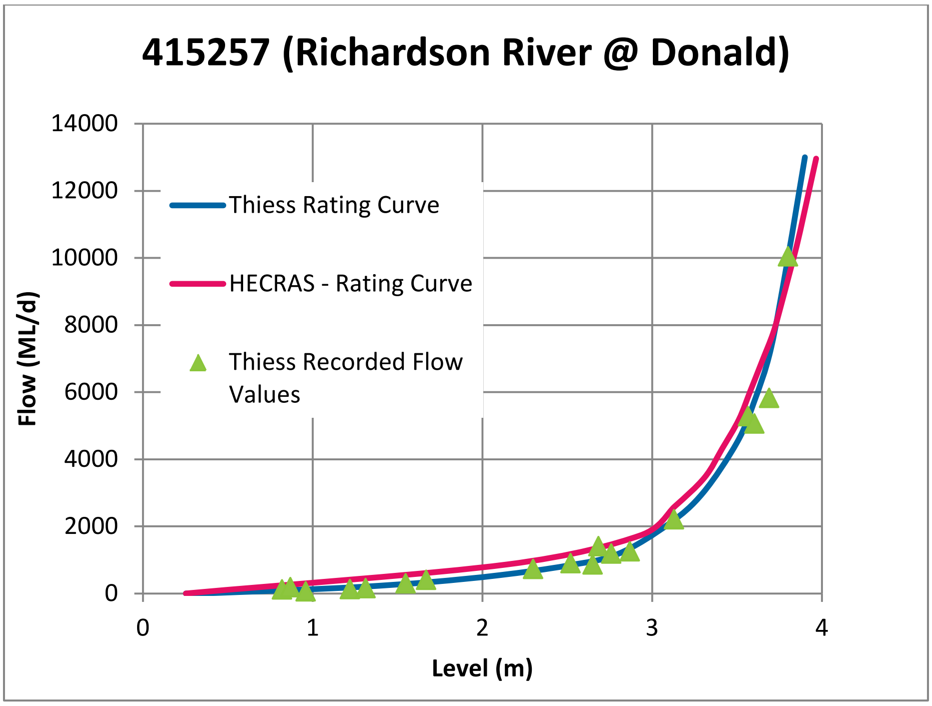


Figure 10 415257 (Richardson River @ Donald)



4.3.6 Final Calibration Results

As before, the RORB model was run with the derived temporal and spatial pattern for the final calibration. The spatial patterns were determined from the gridded daily rainfall stations distributed over the catchment and the temporal patterns from the pluviograph stations. Changes were made to the RORB model to reflect the discussion in the above sections. It was found that in general the shape of the hydrographs could be reproduced but not the timing at 415259 (Richardson River @ Banyena) and consequently at 415257 (Richardson River @ Donald). Australia Rainfall and Runoff (AR&R) mentions that when calibrating RORB to recorded events, "in some cases, especially on catchments whose lower reaches are very flat, the shape of the hydrograph can be reproduced but not its timing. A translation may then be adopted for that catchment." This is certainly the case for the Avon-Richardson catchment i.e. the lower reaches are very flat. It was found that for each of the calibration events a translation of 12 hours at 415259 (Richardson River @ Banyena) helped to reproduce the timing. A summary of the calibration results at 415257 (Richardson River @ Donald) are shown in Table 6. All the hydrographs from the calibration process are shown in Appendix G.

Table 6 Summary of Calibration from this Investigation

Event	Average Initial Loss (mm)	Average Continuing Loss (mm/hr)	Peak Discharge (m^3/s) At Donald (415257)		RORB Parameters	
			Observed	Predicted	k_c	m
October 1996	22	0.5	134	130	160	0.8
September 2010	38	0.5	149	143	160	0.8
December 2010	33	1.9	89	93	160	0.8

Discussion of October 1996 Calibration Event

In general a good calibration was achieved for the October 1996 flood event. The rising limb and the peaks were matched well (except for the Banyena gauge (415259) – as discussed). However, the recession limb of the calculated hydrograph at the Wimmera Highway, Banyena and Donald receded slower than the recorded hydrograph. The variation between the predicted and observed recession limb could be due to lack of pluviograph data and/or direction of the rainfall event. For this event there was only pluviograph data available at pluviograph 79079.

Discussion of September 2010 Calibration Event

In general a good calibration was achieved for the September 2010 flood event particularly at Carrs Plains, Banyena (except for peak – as discussed) and Donald. A reasonable match was achieved at the Wimmera Highway with the recorded hydrograph rising and falling quicker than the calculated hydrograph. Both pluviographs, 79079 and 80067, were available for this event and produced a similar result.

Discussion of December 2010 Calibration Event

In general a reasonable calibration was achieved for the December 2010 event. This event was about 40 to 60 m^3/s less than the other two events discussed above. This event also followed on from a significant event in September which meant that there was still flow in the Avon-Richardson catchment when this event occurred. The recorded hydrograph at Banyena and to a lesser degree Donald show a double peak which is not registered by the RORB model. It is thought that the lack of pluviograph information is the most likely cause of this discrepancy. However, it could also be due to other factors. Both pluviographs, 79079 and 80067, were available for this event and produced a similar result. However, 79079 produced a slightly better match.

4.3.7 Selection of RORB Model Parameters

The preferred method of assigning the RORB parameters k_c and m is by calibration of a RORB model against historical storm events. As a result the RORB parameters chosen were based on the calibration process, not regional equations.

As mentioned previously, k_c and m, represent respectively the effect of the catchment in delaying the runoff response from the rainfall, and the non-linearity of the catchment's response to rainfall excess. The m value of 0.8 was adopted for all calibration events. This value is in agreement with typical m values recommended in Australian Rainfall and Runoff. In general if the catchment conditions remain the same i.e. vegetation cover, soil type, development levels etc., then in theory the runoff response from rainfall should be similar between rainfall events. What will change is the antecedent conditions of the catchment between "flood" events. The variability in the antecedent conditions is in part represented by the loss parameters. The calibration approach adopted for this study was to run each of the calibration events with the same k_c value and vary the losses between events until a reasonable match was achieved for each of the calibration events. The k_c value of 160 was found to achieve this objective.

It was discovered during the calibration process that different k_c values achieved a better match for one calibration event but not as good for another calibration event. The variation in k_c can be as a result of a number of things i.e. change in catchment conditions, data errors, baseflow separation errors, rainfall variability and the lack of adequate data to represent the variability across the catchment and the RORB model being only a representation of complex rainfall runoff processes.

In view of the result of the calibration runs, it was concluded that RORB model parameters of k_c = 160 and m = 0.8 were appropriate for the Avon - Richardson River catchment and were adopted.

4.3.8 Regional RORB Model Parameters

As mentioned above the choice of k_c was based on the calibration. However, this value was compared to the estimate of the regional k_c using the equations in Australian Rainfall and Runoff.

For Victorian catchment there are two regional equation, one for catchments with average annual rainfall of greater than 800 mm and one for catchments less than 800 mm. As mentioned in Section 2 the average annual rainfall varies from approximately 380 mm/yr in the north to 830 mm/yr in the south (Bureau of Meteorology). However, Figure 3 indicates that most of the catchments average annual rainfall is less than 800 mm.

For regions where the mean annual rainfall is greater than 800 mm k_c is calculated by the following equation:

$k_c = 2.57 A^{0.45}$

where A = catchment area in km^2

The standard error associated with this regional prediction equation +32% and -24%.

For regions where the mean annual rainfall is less than 800 mm, k_c is calculated by the following equation:

$k_c = 0.49 A^{0.65}$

The standard error associated with this regional prediction equation +50% and -33%.

From the equation above the regional estimate of k_c is 94 for areas with average annual rainfall greater than 800 mm and 89 for areas less than 800 mm. The value chosen for k_c of 160 is outside the range predicted by the regional equations. However, two of the catchments used in the derivation of the regional equations were on the Avon River. One on the Avon River at the Wimmera Highway and one on the Avon River at Beazley's Bridge. Factoring the k_c values up based on the average flow distance in the channel network of sub area inflows (d_{av}) then the k_c value for the Avon-Richardson catchment based on the Avon River at the Wimmera Highway would by 110. Based on the Avon River at Beazley's Bridge the k_c value would be 123. Neither of these areas include the Richardson River or the area on the Avon River downstream of the Wimmera Highway which has a lot of floodplain storage.

From the Avon-Richardson Floodplain Management Plan (2000) the average k_c value adopted was 120 with an m value equal to 0.9. This equates to a k_c of approximately 190 with m equal to 0.8.

The previous studies indicate that the current adopted value of k_c is consistent with previous investigations.

4.4 Estimation of January 2011 Event

As mentioned in Section 3.1, in January 2011 the gauge at Donald (415257) failed to record any flow data. As a result an estimate of the flow at Donald in January 2011 had to be calculated in another way. An estimate was made using the calibrated RORB model.

A storm file using the available rainfall gauge information was established for the January 2011 event. Appendix F shows the rainfall depths recorded across the catchment for the January 2011 event. Pluviograph information was available at 79086.

Streamflow information is available at:

- 415220 Avon River @ Wimmera Highway
- 415226 Richardson River @ Carrs Plains
- 415259 Richardson River @ Banyena

GWM Water recorded levels at Lake Batyo Catyo during the January 2011 event.

In addition Thiess recorded a flow at the Sunraysia Highway bridge in Donald on the Saturday evening of the 15/1/11 at approximately 1900 hours. The total measured flow, which was not the peak, was 28,587 ML/d (330 m^3/s). According to discussions and information supplied by the community the peak arrived at the bridge approximately 6 to 12 hours later.

Some slight modifications were made to the catchment model such as the starting level of Lake Batyo Catyo was taken from the GWM Water records which indicated that the Lake was close to full at the beginning of the event. The Lake Cope Cope system was also assumed to be close to full following the September 2010 and the December 2010 events. The k_c value of 160 was entered into the RORB model and losses were adjusted to match the recorded events (except the peak at Banyena as discussed in Section 4.3.5). The average initial loss across the catchment adopted was 50 mm and the average continuing loss was 2.7 mm/h. Results from the RORB model are shown in Appendix G. In general the RORB model matched the recorded hydrographs. The RORB model indicates that the peak flow of the January 2011 event at the Sunraysia Highway bridge in Donald is 409 m^3/s which is consistent with the flow recorded by Thiess. This is discussed further in Section 5.3.5.

The contribution from the Wimmera River at Swedes Creek was calculated in the same way as described in Section 4.3.4. The peak flow in January 2011 recorded at Glenorchy was 31,520 ML/d (365 m^3/s). The peak flow into Swedes Creek was calculated to be 600 ML/d (6.9 m^3/s).

In 2006 an Avon Plains Lakes Water Management Plan was undertaken by SKM. The management plan included the following, "observations of local landholders are that Holland's Bank has not been overtopped during at least the last thirty years. It is therefore likely that it would take a flood with an AEP of somewhere between 1 in 20 and 1 in 40 for Holland's Bank to be overtopped."

Anecdotal evidence supplied by the Community indicated that Holland's bank overtopped in January 2011 but not September 2010. According to the stream flow gauge on the Avon River at the Wimmera Highway the January 2011 event had an AEP of approximately 1 in 30. Therefore, this is consistent with the information supplied in the Avon Plains Lakes Water Management Plan.

As part of the Avon Plains Lake Management Plan an estimate of the amount of volume which would pass over Holland's bank for different AEP events was calculated. For a 1 in 30 AEP event an estimated 100 ML was calculated. The RORB model for the January 2011 event was adjusted to direct a volume of approximately 100 ML towards Hollands / Walkers Lake for the January 2011 event.

4.5 Verification of RORB Model Parameters

4.5.1 General

In Section 4.3.7, RORB model parameters were selected to match recorded flood hydrographs. To verify the RORB parameters determined during calibration these parameters were combined with losses and design rainfall information from Australian Rainfall and Runoff to produce design flows which were compared to the results of a frequency analysis of recorded peak flows at the gauging stations:

- 415220 Avon River @ Wimmera Highway
- 415226 Richardson River @ Carrs Plains
- 415257 Richardson River @ Donald

The gauge 415220 and 415226 were chosen as they have the longest period of recorded on the Avon and Richardson River respectively. The gauge 415257 was also considered as it is the gauge closest to the study area.

Separate runs were undertaken for each gauge location to enable an appropriate Aerial Reduction Factor (ARF) for that gauge location to be applied. The aerial reduction factor applied at the Donald Gauge was also applied when determining input design hydrographs for the hydraulic modelling or riverine flooding at Donald.

4.5.2 Flood Frequency Analysis at Gauging Station 415220 Avon River @ Wimmera Highway

A flood frequency analysis was undertaken of the recorded peak flows at the gauging station 415220 Avon River @ Wimmera Highway. The period of record at the gauge station 415220 Avon River @ Wimmera Highway is from 1965 to date.

Since the publication of Australian Rainfall and Runoff there has been substantial research into flood frequency analysis. There are several probability distributions that may be useful for flood frequency analysis some of these are, Log Pearson III (LP3), Generalised Extreme Value (GEV), Gumbel and Exponential. For annual flood data LP3 and GEV are usually the distributions to start with.

FLIKE was used to perform the flood frequency analysis. FLIKE uses a different fitting procedure to that outlined in Australian Rainfall and Runoff. Australian Rainfall and Runoff recommends the 'methods of moments' fitting algorithm while FLIKE offers a choice of either the Global Probabilistic or Quasi-Newton fitting algorithms.

A flood frequency analysis using the LP3 and the GEV distributions was undertaken. Table 7 and Table 8 summarises the result of the historical flood frequency analysis. Appendix H shows the historical flood frequency curve.

Table 7 Flood Frequency Analysis 415220 Avon River @ Wimmera Highway – LP3

ARI	Flow (m^3/s)	90% Confidence Limits (m^3/s)	
		Upper	Lower
5	70	83	59
10	83	97	74
20	93	109	84
50	103	131	91
100	109	146	94

Table 8 Flood Frequency Analysis 415220 Avon River @ Wimmera Highway – GEV

ARI	Flow (m^3/s)	90% Confidence Limits (m^3/s)	
		Upper	Lower
5	70	85	59
10	85	112	72
20	98	145	82
50	113	202	90
100	124	257	95

4.5.3 Flood Frequency Analysis at Gauging Station 415226 Richardson River @ Carrs Plains

A flood frequency analysis was undertaken of the recorded peak flows at the gauging station 415226 Richardson River @ Carrs Plains. The period of record at the gauge station 415226 Richardson River @ Carrs Plains is from 1971 to date.

A flood frequency analysis using the LP3 and the GEV distributions was undertaken. Table 9 and Table 10 summarises the result of the historical flood frequency analysis

Table 9 Flood Frequency Analysis 415226 Richardson River @ Carrs Plains – LP3

ARI	Flow (m^3/s)	90% Confidence Limits (m^3/s)	
		Upper	Lower
5	42	59	31
10	60	87	44
20	78	121	57
50	101	190	71
100	118	247	80

Table 10 Flood Frequency Analysis 415226 Richardson River @ Carrs Plains – GEV

ARI	Flow (m^3/s)	90% Confidence Limits (m^3/s)	
		Upper	Lower
5	41	60	31
10	59	101	43
20	81	171	54
50	117	335	69
100	151	566	79

4.5.4 Flood Frequency Analysis at Gauging Station 415257 Richardson River @ Donald

A flood frequency analysis was undertaken of the recorded peak flows at the gauging station 415257 Richardson River @ Donald. The period of record at the gauge station 415257 Richardson River @ Donald is from 1989 to date.

All probability distributions tried for Donald provided a poor fit. This is not surprising as there is only 22 years of data, half of which (11 years) have a maximum flow recorded of less than 1 m^3/s. The best fit obtained was using a GEV probability distribution with some prior information from the Avon River @ Wimmera Highway. Table 11 summarises the result of the historical flood frequency analysis. Due to the poor nature of the fit, it was decided that the flood frequency analysis at this location should not be used to adjust the design flows.

Table 11 Flood Frequency Analysis 415257 Richardson River @ Donald - GEV

ARI	Flow (m^3/s)	90% Confidence Limits (m^3/s)	
		Upper	Lower
5	62	77	50
10	92	122	72
20	127	196	93
50	185	362	120
100	241	570	139

4.5.5 Storm Files

Design storm files were then established. The temporal patterns assigned for each AEP event and each duration were those recommended in Australian Rainfall and Runoff. Point rainfall magnitudes were estimated using IFD rainfall analysis as described in Australian Rainfall and Runoff. The areal rainfall for the design flood events were derived using areal reduction factors (ARF). The ARF values were determined according to the factors derived for Victoria (Siriwardena and Weinmann, 1996).

Uniform spatial patterns were used.

4.5.6 Verification of RORB Design Parameters

Having determined the k_c and m RORB parameters, for the Richardson River at the gauging station 415257 (Richardson River @ Donald) by calibration, appropriate design rainfall losses were determined for design events up to and including the 200 year ARI event by comparing the design flood discharges from the RORB model with the historical flood frequency results at the gauging station 415220 (Avon River @ Wimmera Highway) and 415226 (Richardson River @ Carrs Plains). Design rainfall depths, temporal and spatial patterns, as described above, were combined to create storm files. The RORB model used for verification did not include any contribution of flow from the Wimmera River or spilling of flow over Hollands bank. This assumption is discussed further at the end of this section.

Initially design losses were derived using the equation developed by the Cooperation Research Centre for Catchment Hydrology (CRCCH, 1996).

The initial loss is determined as either storm initial loss (IL_s) or burst initial loss (IL_b). The storm initial loss is assumed to be the depth of rainfall prior to the commencement of surface runoff. The burst initial loss is the portion of the storm initial loss which occurs within the burst with the burst referred to as the intense part of the storm. The relationship developed by the CRCCH to calculate losses are as follows:

IL_S = -25.8 BFI + 33.8;

$$IL_B = IL_S \left\{ 1 - \frac{1}{1 + 142 \frac{\sqrt{duration}}{MAR}} \right\}$$; and

CL = 7.97 BFI + 0.00659 PET – 6.0

Where;

BFI = the baseflow index is defined as the volume of the baseflow divided by the total stream flow volume. A value of 0.1 was adopted from the Low Flow Atlas for Victoria Stream (1993) for 415220 (Avon River @ Wimmera Highway).

Duration = the burst duration.

MAR = the mean annual rainfall for the catchment. The MAR of 470 mm was taken from information available from the Bureau of Meteorology.

PET = the mean annual potential evapotranspiration (mm). The PET of 1000 mm was taken from information available from the Bureau of Meteorology.

Table 12 summarises the losses calculated using the equations from the CRCCH.

Table 12 Losses Calculated using CRCCH

CL (mm/h)	1.4					
IL_s (mm)	31					
	Duration (hr)					
	6.0	12.0	24.0	36.0	48.0	72.0
IL_b (mm)	13.4	16.1	18.8	20.3	21.3	22.6

The continuing loss was adjusted to achieve consistency between the RORB model estimates and the historical flood frequency curve for events up to and including the 20 year ARI. The 50 year ARI and the 100 year ARI event was also reviewed but the losses were only adjusted to match events up to and including the 20 year ARI event (focusing on the 20 year ARI as this is the larger event) as this is approximately the limit of when the flood frequency curves are preferable compared to rainfall runoff estimates.

The results of the verification runs are shown in Table 13.

Table 13 RORB Results for Verification Runs – 415220 Avon River @ Wimmera Highway

ARI	RORB Parameters			Critical Storm Duration (hrs)	Peak Flow at 415220 (Avon River @ Wimmera Highway)		
	IL_b (mm)	CL (mm/hr)	k_c		Historical Flood Frequency Analysis (m^3/s) - LP3	Historical Flood Frequency Analysis (m^3/s) - GEV	Calculated using RORB (m^3/s)
5	20	1.1	160	30	71	71	42
10	20	1.1	160	30	83	85	61
20	20	1.1	160	30	93	98	90
50	20	1.1	160	30	103	113	128
100	20	1.1	160	30	108	123	161

Table 14 RORB Results for Verification Runs – 415226 Richardson River @ Carrs Plains

ARI	RORB Parameters			Critical Storm Duration (hrs)	Peak Flow at 415226 (Richardson River @ Carrs Plains)		
	IL	CL (mm/hr)	kc		Historical Flood Frequency Analysis (m^3/s) – LP3	Historical Flood Frequency Analysis (m^3/s - GEV	Calculated using RORB (m3/s)
5	20	1.1	160	30	42	41	26
10	20	1.1	160	30	60	59	37
20	20	1.1	160	30	78	81	53
50	20	1.1	160	30	101	116	72
100	20	1.1	160	30	118	150	89

The continuing loss adopted is consistent with that reported in Australian Rainfall and Runoff that is for the Avon River at Beazleys Bridge (415224) a medium value loss value of 1.7 mm/h and a mean loss 1.8 mm/h is reported.

The validation runs indicated that a lower continuing loss to that reported in Australian Rainfall and Runoff achieved a closer match overall to the flood frequency curves. However, it also indicates that different losses would achieve a better match in certain sections of the catchment compared to others. For example at 415226 Richardson River @ Carrs Plains a better match would be achieved with lower losses. Also a greater emphasis was placed on the flood frequency analysis on the Avon River @ Wimmera Highway as it represents a much large portion of the catchment, that is 596km^2, compared to 130 km^2 at Richardson River @ Carrs Plains. In addition the flood frequency analysis fitted the data better at Avon River @ Wimmera Highway as shown by the 90% limits. As mentioned previously the RORB model used for the validation process did not include any contribution of flow from the Wimmera River or spilling of flow over Hollands bank. As the parameters were being validated to the more frequent events, that is the 1 in 10 and the 1 in 20 AEP, it was considered reasonable not to include them as the Wimmera River only starts to contribute flow at approximately a 1 in 20 AEP event (refer to Section 4.3.4) and Hollands bank only start to spill in events less frequent than the 1 in 20 AEP event (refer to Section 4.4).

The impact that any contribution of flow from the Wimmera River or spilling of flow over Hollands bank was tested for the 1 in 200 AEP event. The contribution calculated from the Wimmera River and that which was calculated to have spilt over Hollands bank for the January 2011 event was entered into the RORB model used for the validation process. Flow at 415257 Richardson River @ Donald increased from 402 m^3/s to 404 m^3/s indicating that the contribution from the Wimmera River has a minor impact on peak flows at Donald. However, it is acknowledged that there is uncertainty around the contribution of flow from the Wimmera River and it is possible that there is more (or less) flow contributing than calculated.

4.6 Flood Volume

Flood volume and hydrograph shape is an important flood characteristic influencing flood behaviour. To check the ability of the RORB model to produce realistic hydrograph shapes, the estimated design hydrographs for Donald were compared against historic events recorded at the gauge. The critical design events estimated for the 1 in 10 AEP, 1 in 20 AEP, 1 in 100 AEP and 1 in 200 AEP at the gauging station 415257 Richardson River @ Donald were plotted against calibration events to compare the shape and volume. The starting time of hydrographs was adjusted such that the peaks coincided. Appendix I shows the plot of the hydrographs. The hydrographs in Appendix I indicate that:

- The design hydrographs provide a reasonable estimate of hydrograph shape;
- The volume calculated in RORB at 415257 Richardson River @ Donald for the 1 in 100 AEP and the 1 in 200 AEP was 104,000 ML and 124,000 ML respectively. For the January 2011 event the RORB model estimated that volume at 415257 Richardson River @ Donald as 130,000 ML which is a reasonable match given the difference between a design event and a calibration event.

Potential differences between a design event and a calibration event includes, but is not limited to:

- The design temporal pattern is different to each actual rainfall event;
- The Australian Rainfall and Runoff design rainfalls represent rainfall bursts (rather than complete storms),
- Design rainfall depths;
- Spatial distribution of rainfall;
- Different antecedent conditions, and
- Different starting levels in the storages throughout the catchment.

4.7 Sensitivity Analysis

The discussion above on the verification of the RORB model leads to a “best estimate” of the design floods based on the data available. However, there is uncertainty in all of the inputs used in the hydrological model (RORB). In order to test the impact that certain inputs have on the flow estimates a sensitivity analysis was undertaken. In this case the three inputs thought to have the largest impact on the flow estimates are the design rainfall, the adopted k_c (160) and CL (1.1 mm/h) values.

From Australian Rainfall and Runoff the uncertainty in the design rainfall intensity is probably in the order of 10%. From the calibration process the k_c value appears to be relatively well defined. A standard error of 10% was assumed for the k_c value i.e. a range of k_c between 144 and 176. The uncertainty in the CL after reconciliation with the historical flood frequency analysis (Section 4.5.6) was assumed to be in the order of 20% i.e. a range of CL between 0.9 mm/h and 1.3 mm/h.

An “upper” and a “lower” error bound for the 1 in 50 AEP and the 1 in 100 AEP estimate was determined by varying the rainfall depths, k_c and CL as described above. Variation in each of the parameters was considered separately. The result of the sensitivity analysis are summarised in Table 15.

Table 15 Sensitivity Analysis

ARI	k_c	CL (mm/h)	Design Rainfall Depth % Change	Peak Flow at 415257 (Richardson River @ Donald)
50	160	1.1	0	259
50	160	1.3	0	238
50	160	0.9	0	283
50	144	1.1	0	293
50	176	1.1	0	232
50	160	1.1	+10	314
50	160	1.1	-10	209
100	160	1.1	0	331
100	160	1.3	0	308
100	160	0.9	0	358
100	144	1.1	0	375
100	176	1.1	0	296
100	160	1.1	+10	389
100	160	1.1	-10	269

From the sensitivity analysis summarised in Table 15 it appears that rainfall depth has the largest impact on the peak flow estimate at the gauge. The difficultly with a sensitivity analysis is choosing an event, or combination of events which is “reasonable” given the recorded data available and adopting parameters that are “AEP neutral” i.e. ensuring that the resulting flood has the same annual exceedance probability as the causative rainfall. Adopting a combination of the “extreme” values to give an estimate of the worst case of peak discharge (either lowest or highest) was not considered reasonable.

The possible variations in k_c and CL are estimates only. The possible variation in design rainfall, which has been gleaned from Australian Rainfall and Runoff, has been based on analysis of the rainfall data used to produce the design rainfall. Therefore it is considered appropriate to consider the positive variability in rainfall in this study as indicating an “upper” estimate of the design flood flow based on RORB.

It should be noted that these flood estimates do not make allowance for climate change impacts. There is some conjecture on climate change and the impact that climate change may have on rainfall. The Victorian Government released a document titled Climate Change in Victoria: 2008 summary. In this document it is quoted that “Annual average rainfall is expected to decrease by around 4% by 2030, however the full range of model uncertainty ranges from -9% to +1%. The greatest decreases in rainfall are likely to occur in winter and spring, while heavy rainfall intensity is most likely to increase in summer and autumn”. Whilst it is difficult at present to estimate the likely impacts of climate change on floods with any degree of confidence, the positive variability in rainfall shows the possible increase in runoff with an increase in rainfall depth.

4.8 Design Parameters and Events

Based on the results of the calibration and validation runs of the RORB model, the parameters as detailed in Table 16 were adopted for estimating design flows at Donald.

Table 16 Adopted Design Parameters and Design Peak Flow

Parameter		Value			
m		0.8			
k_c		160			
		Duration (hr)			
		24	36	48	72
IL_b (mm)		18.8	20.3	21.3	22.6
CL (mm/hr)		1.1			
Rainfall		Australian Rainfall and Runoff			
Temporal Pattern		Australian Rainfall and Runoff Vol. 2			
		Peak Flow (m^3/s)			
ARI	**Richardson River @ Donald**	**Richardson River @ Carrs Plain***		**Avon River @ Wimmera Highway***	
5	82	19		35	
10	121	28		52	
20	181	41		76	
50	259	57		109	
100	331	71		140	
200	403	86		170	

*Note that the flows shown for Richardson River @ Carrs Plain and Avon River @ Wimmera Highway are the flows from the model for critical event on the Richardson River @ Donald

A discussion was held with the CRG about the community's expectations in terms of flood mitigation works. A strong preference to protect the town against a similar event to that which occurred in January 2011 was expressed.

As a result the following approach for assessment of mitigation options is recommended:

- Adopt the estimated flows from the parameters listed in Table 16;
- Where relevant, add 600 mm freeboard to the estimated flood levels from the hydraulic model (refer to Section 5 for discussion on the hydraulic model); and
- Test the mitigation options against the January 2011 event.

The adopting of 600 mm freeboard is in part to account for the uncertainties involved in any modelling process.

5. Hydraulic Modelling

5.1 Overview

The hydraulic modelling of the Donald study area (refer to Figure 1 for study area) was completed using a two dimensional model (TUFLOW). The council drains and associated flow paths within the township were modelled. The hydraulic model was created using drainage details, survey data and DEM based terrain data.

The hydraulic model was calibrated to the September 2010 and January 2011 event.

5.2 Digital Elevation Model (DEM)

As mentioned in Section 3.5 there were two sources of DEM available to use in the hydraulic model, namely:

- GWMW 2 metre DEM
- DSE Rivers LiDAR 1 metre DEM

The GWMW 2 metre DEM supplied covered the entire study area the DSE Rivers LiDAR supplied covered most of the study area. For simplicity it was decided that one DEM should be used to create the terrain data of the hydraulic model to avoid discrepancies between data sets.

Both sets of data were compared to the survey data that was available. Based on the comparison with the available survey data it was decided that the GWMW 2 metre DEM be used. It should be noted that the survey data available is limited and only covers a small section of the study area. It should also be noted that some of the survey data matched the DSE River DEM better than the GWMW DEM, however, overall the GWMW DEM appeared to better match the available survey data.

The reported vertical accuracy of the GWMW 2 metre DEM is "± 0.15 meters SE" (sic). The reported vertical accuracy of the DSE Rivers LiDAR 1 metre DEM is "± 0.2 meters RMSE".

Appendix J shows the comparison between the DEM's and the survey data.

5.3 TUFLOW

5.3.1 Introduction

TUFLOW is a hydrodynamic model used for simulating one-dimensional (1D) and two-dimensional (2D) flows. The model is based on the solution to the free-surface flow equations. It links 1D network (ESTRY) domains to 2D (TUFLOW) domains to represent the catchment terrain and its drainage system. The TUFLOW model consists of a 2D domain representing the catchment terrain, a 1D network representing the pipe system and a set of boundary conditions.

TUFLOW modelling was undertaken to determine the peak water levels along the Richardson River for the September 2010 and January 2011 events.

Plans showing the layout of the TUFLOW model, as described below, are included in Appendix K.

5.3.2 2D Domain

The 2D domain represents the surface terrain of all major overland flow paths within the study are. Using the DEM, a 7 500 m by 6 000 m grid comprising 10 metre square cells was formed. Each cell is made up of nine points, with each point having an elevation corresponding to the surface elevation at that location. The grid was orientated to align with the major road networks within the study area.

The roughness value was allocated to each cell as a Manning's n value based on land use type. The roughness values were based on the aerial photo and information gathered during the site visit. Residential properties and community buildings (e.g. schools) have typically been assigned a Manning's n value of 0.2, due to structures such as buildings and fences obstructing flow through the property. The adopted Manning's n values are tabulated in Table 17. The values shown in Table 17 are the adopted values following adjustment within documented limits (e.g. Chow, 1959), during the calibration to match the surveyed flood levels (refer to Section 5.3.5).

Table 17 Bed Resistance Values

Land Use	Manning's n
Waterway	0.04
Floodplain	0.065
Road	0.02
Residential / Commercial	0.2
Paddock / Open Space	0.05
Sports Field	0.04
Railway line	0.05
Channel	0.027

The Sunraysia Highway bridge, railway bridge and the two pedestrian bridges (one near McCulloch Street and one near Houston Street) were modelled as flow constrictions in the 2D domain with the bridge parameters based on the survey data.

5.3.3 1D Network

The one-dimensional network comprised of the main underground pipes and culverts within Donald. Pipe sizes and inverts were taken from survey data supplied by Buloke Shire. Underground pipes were mostly modelled as circular or rectangular culverts. Concrete pipes were modelled with a Manning's n value of 0.013.

Appropriate losses were estimated throughout the pipe network, based on standard pit loss tables (VicRoads, 1992). Each pit loss value was generally assigned to the downstream pipe as a form loss, rather than in the pits themselves. For culverts or ends of pipes, a typical entrance loss of 0.5 and exit loss of 1.0 were applied.

Pits were modelled as 1.9 m wide weir pit channel inlets, typically allowing pipe capacity, rather than pit inlet capacity, to restrict the flow within the 1d network.

1D open channels were modelled from the downstream boundary of the study area to Lake Buloke. Open channel cross sections were generated from the DEM. Manning's n values consistent with those shown in Table 17 were used.

5.3.4 Boundary Conditions

Upstream

For the September 2010 event the flows recorded at the Donald gauge were entered into the model. For the catchment between the Donald gauge and Lake Buloke the inflows placed into the hydraulic model were taken from the calibrated rainfall runoff model (as described in Section 4). For the January 2011 event all flows were taken from the calibrated rainfall runoff event.

Downstream

As Lake Buloke is a terminal lake, flow was allowed to enter the lake and "fill up". For the September 2010 event it was assumed that the lake was close to empty as this event was preceded by a long period of drought. For the January 2011 event it was assumed that there was some water in the lake from the September 2010 and December 2010 event. Subsequent sensitivity testing indicates that the flood levels in Donald are not sensitive to small variations in the assumed level of Lake Buloke.

5.3.5 Calibration Results

The calibration process requires a comparison of the hydraulic models representation of flooding in the study area with observed flooding behaviour. For Donald this involved a comparison between observed maximum flood levels, aerial photography and information gathered from the Community for the January 2011 and the September 2010 events.

January 2011

Given the magnitude and available data for the January 2011 it was chosen as the principal hydraulic model calibration event.

The approach to the calibration process was iterative and involved:

- Adjusting the Manning's 'n' roughness values within the TUFLOW model;
- Running the model; and
- Comparing the results to the observed levels.

The calibrated Manning's n values adopted for the model are shown in Table 17. A comparison between the calibrated modelled water levels and the observed water levels is presented in Appendix L. The following comments are made regarding the calibration results:

- The calibrated Manning's 'n' values were considered to be within the ranges expected for the modeled area based on literature such as Chow, 1959; and
- Generally a reasonable calibration was achieved. The 2011 event observed flood levels are generally within 100 mm of the observed levels. There are some locations where the difference is greater (general discussion on potential reasons for differences between the model and observed levels is provided below).

Due to the potential inaccuracies associated with the observed flood levels and localised effects, achieving greater agreement between the model and the observed levels can be difficult and sometimes counterproductive. Problems associated with calibrating a model to observed flood levels generally fit into two broad categories:

- Hydraulic Modeling Uncertainty; and
- Errors in Recorded Data.

Hydraulic modeling uncertainty includes uncertainty in the:

- Terrain / Survey Data;
- Roughness Estimates;
- Flow estimates;
- Unique Event Conditions such as operator controls e.g. releases from a dam or blockages of a culvert; and
- Erosion or Deposition of a waterway changing the hydraulic parameters.

Errors in recorded data includes

- The accuracy of the observed flood level can vary widely if it is based on flood debris or water marks;
- The technique used to peg the flood level. In January 2011 the adopted pegging method is understood to have been to drive the peg in until the top of the peg matches the flood level. While this can produce good results the outcome is more dependent on the operator and the peg not being disturbed. It is generally considered, particularly in flat areas such as Donald, that pegging the edge of the flood extent is easier and more reliable; and
- The timing of the record (peak or otherwise).

A particular comment is made on a number of the flood levels below (refer to Appendix L for location).

The surveyed flood level at Peg 3 (112.58 mAHD) appears to be low. This observation is based on the recorded levels upstream at Peg 2 (113.24 mAHD) and downstream at Peg 4 (113.18 mAHD). There appears to be no hydraulic constriction at Peg 3 that would cause the water level to reduce by this amount.

The modelled levels downstream of the Sunraysia Highway are generally lower than those recorded. During the calibration process several reasons were explored to examine these differences, namely;

- Downstream boundary conditions;
- Roughness values; and
- Blockage of the railway bridge due to debris.

The level in Lake Buloke at the start of the January 2011 event is unknown. An estimate was made of the starting level based on the volume of the September 2010 and December 2010 events. The sensitivity of the hydraulic model to the starting level in Lake Buloke was tested by varying the starting level in Lake Buloke. It was found that the levels in Donald where not particularly sensitive to the starting level in Lake Buloke.

Increasing the roughness values downstream of the Sunraysia Highway bridge was considered. However, there is no justification for increasing the roughness values as this section of the floodplain is not rougher than upstream of the Sunraysia Highway.

It is difficult to predict the debris load in a flood event and the impact it may have. During the January 2011 event the Sunraysia Highway bridge was overtopped increasing the chance of debris blockage (due to the handrail). However, as the railway bridge has a larger clear opening than the Sunraysia Highway bridge it would not be expected that the railway bridge would have experienced significant blockage due to debris compared to the Sunraysia Highway bridge.

Also of note is that there appears to be an inconsistency between Peg 8, 9 and 10. Peg 9 and 10 are downstream of Peg 8 but both are higher than Peg 8.

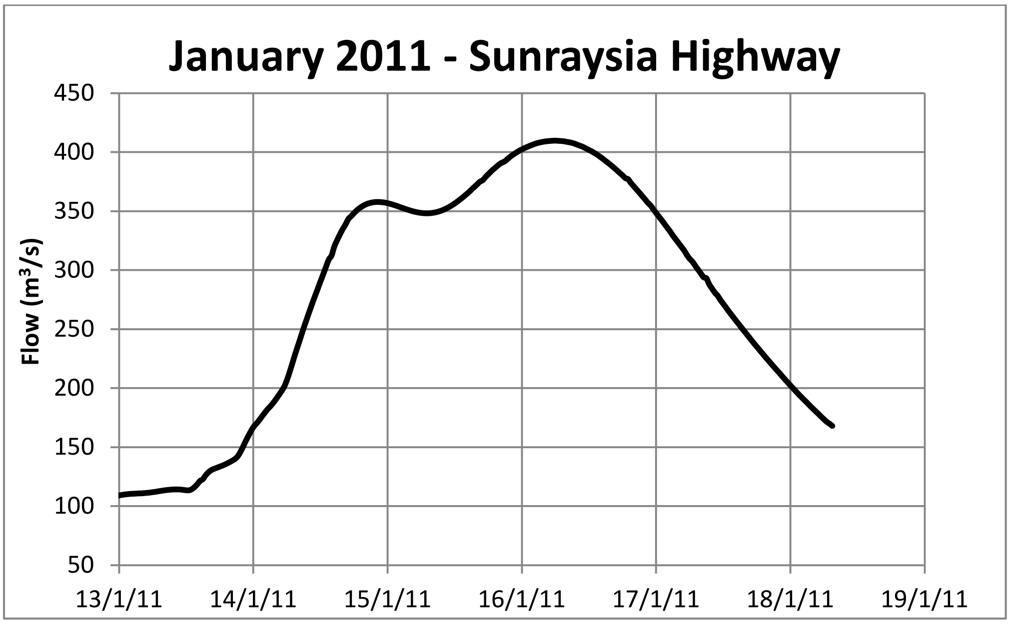
Peg 14 is another location where the difference between the modelled and recorded level is greater than 0.1 meter. Nearby high water marks and Peg 16 which is upstream of Peg 14 has a lower recorded level than Peg 14 suggesting that Peg 14 may be too high. Alternatively, perhaps local runoff, which ponded behind the bridge, contributed to a higher level at Peg 14.

Another point to note is flood levels taken on structures are more susceptible to localised effects as structures deflect flow resulting in flow contraction, expansion and redirection influencing flow behaviour and flood levels.

One more source of uncertainty is the estimation of flow. Figure 11 shows the hydrograph at the Sunraysia Highway in the hydraulic model. As mentioned in Section 3.1 Thiess recorded a flow at the Sunraysia Highway bridge in Donald on the Saturday evening 15/1/11 at approximately 1900 hours. The total measured flow, which was not the peak, was 28,587 ML/d (330 m^3/s). According to discussions and information supplied by the community the peak arrived at the bridge approximately 6 to 12 hours later.

The peak in the hydraulic model at the Sunraysia Highway is approximately 35,420 ML/d (410 m^3/s). Six to twelve hours earlier is approximately 32,400 ML/d (375 m^3/s). This is consistent with the flow recorded by Thiess considering the uncertainties with this flow reading.

Figure 11 January 2011



September 2010

To verify the hydraulic model, in particular the roughness values, the recorded flows at the Donald gauge during the September 2010 event were entered into the hydraulic model. Flows between the Donald gauge and Lake Buloke were taken from the calibration rainfall runoff. The only other change made was that it was assumed that Lake Buloke was close to empty at the start of the flood event. The results from the September 2010 are shown in Appendix L.

In general the modelled levels were higher than recorded levels. Reducing the roughness (Manning's n) value was considered. However, reducing the roughness value would have meant the modelled levels in January 2011 event would also be reduced, which was not desired. As January 2011 is considered the event to focus on the roughness values were not reduced.

5.4 Design Flood Modelling

The calibrated hydraulic model was used to generate design flood extents for riverine flooding for the 5, 10, 20, 50, 100 and 200 year ARI event. Each ARI event was run for the 12 hour, 18 hour, 24 hour, 30 hour, 36 hour, 48 hour and 72 hour (shorter duration design storms were not run as they are not critical for the Richardson River catchment) design storm events and the maximum value from each duration adopted. The flood extents for each ARI event are shown in Figure 12.

LEGEND

- 200 Year ARI Flood Extent
- 100 Year ARI Flood Extent
- 50 Year ARI Flood Extent
- 20 Year ARI Flood Extent
- 10 Year ARI Flood Extent
- 5 Year ARI Flood Extent

Paper Size A1

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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Design Flood Extents

Figure 12

G:\31\28519\GIS\Maps\Working\3128519_006_Design_Extents_A1P.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: North Central CMA, Aerial Photography, 2012; GHD, Flood Extents, 2013. Created by:scowan

5.5 Design Flood Behaviour

The following section gives a brief description of the riverine flood characteristics in Donald for each design event.

5 year ARI Event

- Water overtops Camp Street
- No properties flooded above floor level

10 year ARI Event

- Swimming pool infrastructure inundated
- Properties along Byrne Street are inundation affecting some external buildings
- Sport field inundation
- No properties flooded above floor level
- Flood extent comparable to the December 2010 event

20 year ARI Event

- Swimming pool inundated
- Two properties flooded above the floor level, one being the Donald Motor Lodge
- Flood extent comparable to the September 2010 event

50 year ARI Event

- Four properties flooded above the floor level, one being the Riverside Motel

100 year ARI Event

- Goodwin Village inundated with above floor flooding
- Ten properties flooded above the floor level, including the garage and the Chinese restaurant

200 year ARI Event

- Sunraysia Highway overtopped
- The flood levels increase by approximately 200 – 300 mm compared to the 100 year ARI
- Additional units in the Goodwin Village experience over floor flooding
- Fourteen properties flood above the floor level

5.6 Stormwater Flooding

In January 2011 the township of Donald received approximately 180 mm over a four day period. Approximately forty five percent i.e. 81 mm fell in one day which, from information available from the Bureau of Meteorology, is approximately a 20 year ARI rainfall event. This caused a significant amount of localised flooding, before Donald was flooded by riverine flooding. The areas hardest hit by localised flooding were the properties along the Sunraysia Highway on the western side of town, the area to the east of Racecourse Road and the area to the north east of Donald Lake.

A detailed assessment of the stormwater system was beyond the scope of this investigation. However, information gathered during this investigation could be used to assist in developing a stormwater management plan for Donald. A number of the mitigation options (refer to Section 6) suggested by the community, e.g. increase the size of Donald Lake, would be explored in a stormwater management plan.

6. Flood Mitigation Options

This section provides an overview of the mitigation options considered to reduce the flood risk and flood damages at Donald. The mitigation options were compiled based on feedback received by from the Community (at the community meeting held on 27 February 2012 and the community questionnaire). Initially a prefeasibility assessment of each option was undertaken. The community reference group emphasised that the mitigation options should focus on "protecting the town" for an event of similar magnitude to the January 2011 event. Therefore the January 2011 event was the focus of the prefeasibility assessment. The focus was also on riverine flooding. The results of the prefeasibility assessment were discussed with the technical steering committee and the community reference group on 10 September 2012 and from that meeting two structural mitigation options were to be investigated further. The results of the detailed investigation were discussed with the technical steering committee and the community reference group on 23 January 2013 and to the public on 20 February 2013.

6.1 Prefeasibility Assessment – Structural Options

This section documents the prefeasibility assessment undertaken for all the structural mitigation options proposed by the Community. Each mitigation option was assessed against a number of criteria, potential reduction in flood damage, capital cost, social impact, environmental impact and ongoing costs. The score for each criterion was based on a ranking system of 1 to 3, with 1 being the worst score and 3 the best.

Table 18 shows the criteria used to rank each option. Reduction to flood damage and cost to implement the options were weighted higher than social and environmental impacts as reduction in flood damages is a significant objective for the project.

Table 19 summarises the outcomes of the prefeasibility assessment. The scores shown in Table 19 are subjective, particularly social and environmental impacts. Detailed hydraulic, costing, social and environmental studies have not been undertaken for each option. The rankings applied were a collaborative approach between GHD staff and the NCCMA incorporating comments provided by the community reference group.

Table 18 Ranking Criteria for Mitigation Options

Score	Reduction in Flood Damages	Capital Cost ($)	Social Impact	Environmental Impact	Ongoing Cost ($)
Weighting	2	2	1	1	1
1	Minor (e.g. one or two dwellings)	Major (e.g. greater than $2M)	Major (e.g. long term impact, say greater than 100 people affected)	Major (Significant impact on a large area)	Major (e.g. say greater than $5K)
2	Medium (e.g. 2 to 10 dwellings)	Medium (e.g. $1M - $2M)	Medium	Medium	Medium
3	Major (e.g. greater than 10 dwellings)	Minor (e.g. less than $1M)	Minor (e.g. short term impact, say less than 10 people affected)	Minor (localised short terms, say less than a year, impact)	Minor (e.g. say less than $1K)

Table 19 Prefeasibility Results – Structural Options

No.	Description	Reduction in Damages	Capital Cost	Social Impact	Environmental Impact	Ongoing Cost	Comments	Weighted Score
1	Increase or modify bridge opening on Sunraysia Hwy and/or Railway	1	1	3	3	3	• High cost • Estimated to lower levels upstream by ≈ 100 mm • Potential minor reduction in road closure • Possible increase in flood levels downstream • Localised environmental impact during construction	13
2	Clear out waterway	1	2	2	2	2	• Significant environmental impact (habitat and erosion) • Constant maintenance required • Estimated to lower levels upstream by ≈ 100 mm	12
3	Dredge out deepen/widen waterway	3	1	1	1	1	• Significant works would be required to reduce impact of January 2001 event. To lower January 2011 to September 2010 ≈ 0.5 m deep and 340 m wide or to lower January 2011 by 0.3 m ≈ 0.5 m deep and 100 m wide (note these number are indicative only a detailed investigation was not undertaken). • Significant environmental impact (habitat and erosion) • High sediment loads in catchment mean the solution would be short term and waterway would "fill up" over time • Constant maintenance required	11

No.	Description	Reduction in Damages	Capital Cost	Social Impact	Environmental Impact	Ongoing Cost	Comments	Weighted Score
4	Increase capacity of pedestrian walkway leading to Goodwin Village	1	1	3	3	3	• Localised impact only	13
5	Levees	3	2	2	3	1	• 100 year ARI protection depending on height • Loss of Visual Amenity • Ongoing maintenance required • Loss of floodplain storage and obstruction to flood flows • Inequality due to increased flood levels elsewhere within the floodplain • Flooding from localised events (behind the levee) • Risk of failure during large flood event (overtopping or piping)	16
6	Increase capacity of Browns Lake & Lake Batyo Catyo	1	2	3	3	1	• Minor benefit with respect to Riverine Flooding. For example at Donald volume of hydrograph in January 2011 was ≈162,000 ML compared to current capacity at Lake Batyo Catyo ≈ 300 ML • To be effective as a flood retardation storage would needs to be operated as one i.e. empty at start of event • Needs to be maintained in accordance with ANCOLD consequence category	13

No.	Description	Reduction in Damages	Capital Cost	Social Impact	Environmental Impact	Ongoing Cost	Comments	Weighted Score
7	Increase size of Donald Lake	1	2	3	3	1	• Issues as above option (No. 6) • Could be viable for localised flooding issues	13
8	Build a lake on west side of town	1	1	3	2	1	• Issues as Option No. 6 • Could be viable for localised flooding issues • Loss of land	10
9	Increase Lake Buloke	1	1	3	3	1	• Issues as Option No. 6 • Would have little impact on flood levels in Donald	11
10	Revegetate the catchment	1	1	1	3	1	• May reduce flood peak in some events. Difficult to quantify the impact • Large scale project to have an impact • Long term project • Could Decrease Rate of Runoff • Catchment wide collaborative approach required	9

Using the prefeasibility assessment shown in Table 19, the identified mitigation options are listed in order of total weighted score in Table 20.

Table 20 Ranked Mitigation Options

Rank	Description	Weighted Score
1	Levees	16
2	Increase or modify bridge opening on Sunraysia Hwy and/or Railway	13
3	Increase capacity of pedestrian walkway leading to Goodwin Village	13
4	Increase capacity of Browns Lake & Lake Batyo Catyo	13
5	Increase size of Donald Lake	13
6	Clear out waterway	12
7	Dredge out deepen/widen waterway	11
8	Increase Lake Buloke	11
9	Build a Lake on West Side of Town	10
10	Revegetate the catchment	9

As mentioned above the results of the prefeasibility assessment were discussed with the technical steering committee and the community reference group on 10 September 2012 and from that meeting it was decided that two structural mitigation options were to be investigated further. The community reference group emphasised that the mitigation options should focus on "protecting the town" for an event of similar magnitude to the January 2011 event and discussion on potential funding led to the focus on mitigation from riverine flooding. The community reference group also mentioned that there was a general perception in the community that the Sunraysia Highway bridge was undersized. As a result this option should be investigated to verify or otherwise this perception.

The two structural mitigation options investigated further were:

- Mitigation Option 1 - Levees
- Mitigation Option 2 – Increase or modify bridge opening on Sunraysia Highway

6.2 Mitigation Option 1 – Levees

Four levees were considered to protect the township of Donald from riverine flooding. The level of the levees was set to the 1% AEP flood levels plus 600 mm freeboard (providing approximately 300 mm of freeboard above the January 2011 event). The locations of the levees are shown in Figure 13 and long sections are shown in Figure 14.

Levee 1 is a completely new earthen levee. Levee 2 is mostly an earthen levee following the existing levee/walking path on the eastern side of the river. Downstream of the Sunraysia Highway, behind the Riverside Hotel, a retaining wall structure is required. Levee 3 is an extension and topping up of existing landscaping works around the Goodwin Village. Levee 4 is an individual house levee which would connect into the existing levee off Elizabeth Street.

A brief description of each levee is given below in Table 21.

Table 21 Summary of Levees Considered

Description	Length (m)	Average Height (m)
Levee 1 – Donald Swimming Pool	290	1.8
Levee 2 – Township Levee	900	1.8
Levee 3 – Goodwin Village	370	0.9
Levee 4 – Elizabeth Street	290	1.3

Legend

Highway	Unsealed track	River
Sealed road (arterial & local)	Lake	Channel / drain
Unsealed road	Flat	Proposed Levee Alignment

Paper Size A3

0 30 60 120 180 240

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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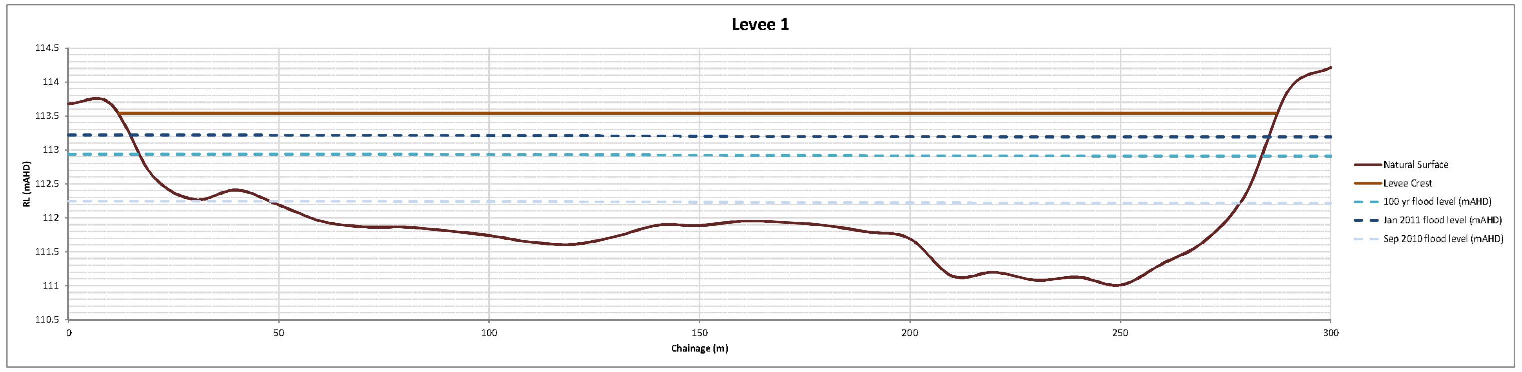
Proposed Levee Locations

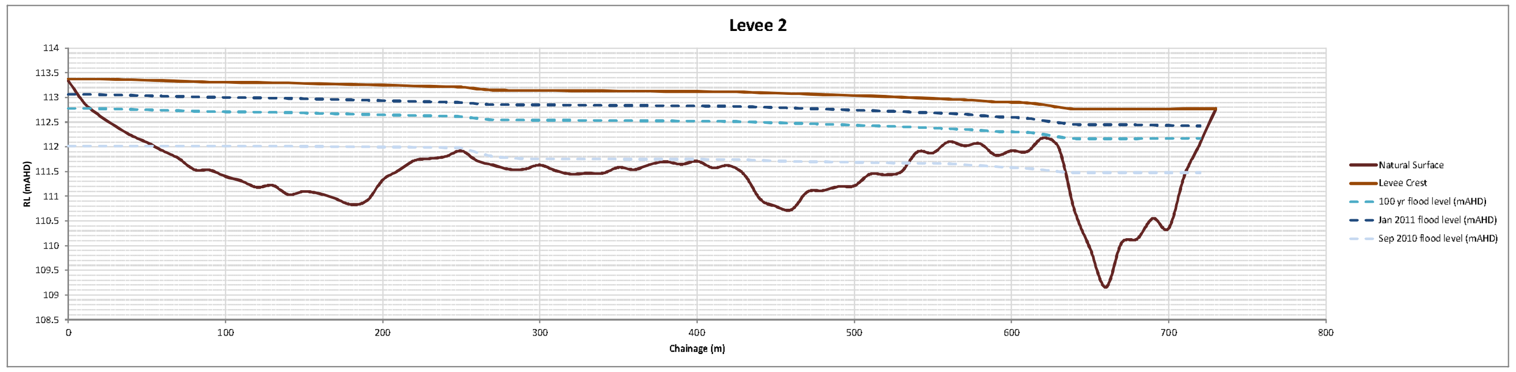
Figure 13

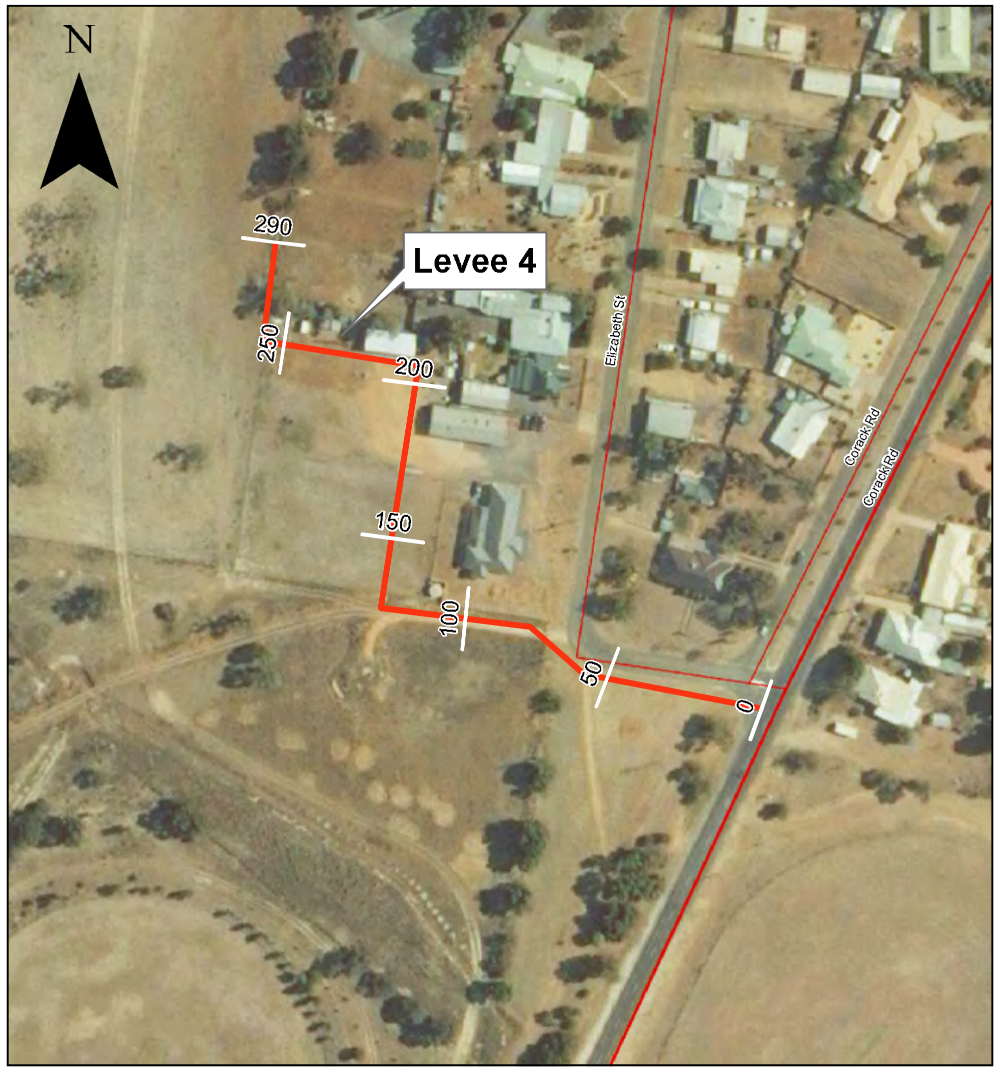
G:\31\28519\GIS\Maps\Deliverables\Levee Plan.mxd

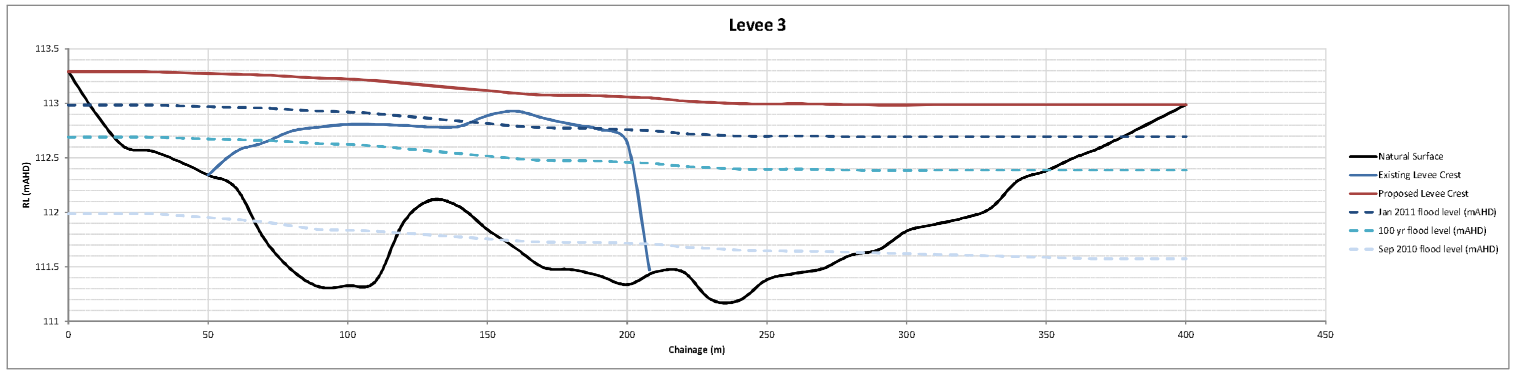
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

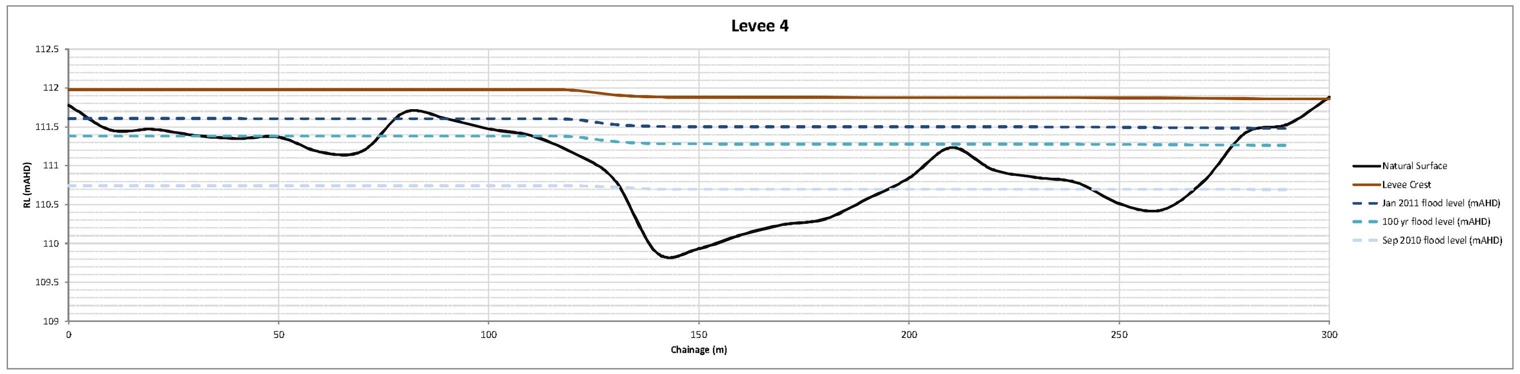
Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Levee Alignments (2012). Created by:scowan











Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 54

Legend

- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain
- Proposed Levee
- Temporary Levee
- Proposed Retaining Wall

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Levee Option
Long Section Water Surface Profiles

Figure 14

G:\31\28519\GIS\Maps\Deliverables\Levee Long Sections.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE: Vicmap - Aug 2012. Created by: SC

6.2.1 Discussion on Mitigation Option 1 – Levees

The main advantage of the levee options considered is that the township is protected from over floor flooding (except for one derelict building immediately downstream of the Sunraysia Highway and the sports field and associated infrastructure). For the levee considered it provides protection for the:

- 100 year ARI plus 600 mm freeboard; and
- January 2011 plus approximately 300 mm freeboard.

Some of the issues which need to be considered in regards to levees are:

- The loss of visual amenity;
- Requirement for ongoing inspection and maintenance;
- Loss of floodplain storage and obstruction to flood flows;
- Inequality due to increased flood levels elsewhere within the floodplain;
- Flooding from localised events (behind the levee);
- The suitability and need for permanent or temporary flood barriers; and
- Risk of failure during large flood event (overtopping or piping).

The loss of visual amenity was discussed with the TSC and the CRG and raised at the Community meeting on 20 February 2013. The general consensus was that the loss of visual amenity does not have to be a negative if the levees are landscaped. The landscaping works undertaking at the Goodwin Village were mentioned as an example (refer to Figure 15). With Levee 2 there is already a levee/walking track (refer to Figure 16) along most of the length of the proposed levee. It is proposed that Levee 2 will remain as a walking track, higher than the existing track. In addition most of the properties along the proposed location of Levee 2 do not front on to the levee. A sketch of how the levee may look is shown in Appendix M.

For Levee 1, Goodwin Village raised concerns about making the landscape works undertaken, following the January 2011 event, any higher, due to loss of visual amenity. The existing landscape works are approximately at the January 2011 flood level. If the landscape works were not raised then should a similar event to January 2011 occur some temporary work e.g. sandbagging would be required particularly if Levee 2 is constructed (as flood levees will increase, this is discussed further below).

Figure 15 Goodwin Village Landscaping Works

Figure 16 Existing Levee/Walking Path

Ongoing inspection and maintenance of a levee is required. Tasks include:

- Regular (once every 6-12 months) visual assessments, checking for erosion and subsidence of the levee, tree growth within the levee, rabbit or fauna burrowing into the levee.
- Regular (couple of months) mowing of the grass and spraying of weeds on the levee.

As there is an existing walking path along most of the proposed Levee 2 alignment some of these inspection and maintenance tasks are already taking place.

The construction of levees within the floodplain does alter the flow regime. By reducing the floodplain area, through the construction of levees, the flood levels increase. The proposed levees were placed into the hydraulic model and the model was rerun with several flood events. For the January 2011 event the modelling indicated that from the Sunraysia Highway to approximately Camp Street the water level would increase by up to 100 mm with the levees in place. Water levels would increase by up to 150 mm between Camp Street and between Blair and Campbell Street and up to 100 mm upstream of this location. For the 1% AEP event the modelling indicates an increase upstream of the Sunraysia Highway of up to 100 mm. For the events modelled, the modelling indicates that the proposed works would not result in any additional over floor flooding. The results for the January 2011 event are shown in Figure 17. Additional events are shown in Appendix N.

With the construction of a levee, consideration needs to be given about localised flood events (behind the levee). Some culverts will need to be placed under the levees to allow local stormwater to drain into the river. Mechanisms such as flap gates on the end of these pipes will be required to prevent riverine flooding backing up through the pipes.

With the levees in place temporary works would be required on Camp Street (both sides of the river) and to a lesser degree across the Sunraysia Highway. Documentation of what needs to be done during a flood to close off the levees and by whom is required. In broad terms there are three options available for temporary works to close off the levees:

- Flood Walls;
- Earthfill; and
- Sandbags.

Legend

- Levee Alignment
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain

Afflux (mm)

<-100 | -100-0 | 0-100 | >100

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Afflux-Levee Option
100 yr Flood Event

Figure 17

G:\31\28519\GIS\Maps\Deliverables\Figure 17- Donald_Township_Afflux_100yr_Levee.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

6.3 Mitigation Option 2 – Increase or Modify Bridge Opening on Sunraysia Highway

To test the validity of this option, an initial scenario with the largest number of culverts that could fit between the existing bridges was modelled, that is, 53 No. 1500 x 1200 box culverts. Depending on the reduction in flood levels with 53 No. culverts, additional culvert options would be considered. The location of the proposed culvert works is shown in Figure 18.

Other options raised by the community in relation to modifying the bridge opening on the Sunraysia Highway included increasing the freespan bridge and raising the bridge. Increasing the freespan bridge was not modelled as it was estimated to be more costly than the installation of culverts and would achieve a similar hydraulic outcome. Raising the bridge was not modelled as it was considered to be more costly than the installation of culverts, particularly with the need to regrade the road, and the bridge would need to be raised substantially to achieve any significantly hydraulic advantage.

The modelling indicates that during the January 2011 flood there was a difference in water levels of up to approximately 0.25 meters across the bridge. The additional culverts (53 No. 1500 x 1200 Box Culverts) were conceptually placed into the hydraulic model between the two existing bridges and the model was rerun with several flood events. The modelling indicates that for the January 2011 event the additional culverts would lower the flood levels upstream of the bridge by approximately 100 mm (up to the golf course). It also indicates that there would be a 100 mm increase downstream of the bridge (on the western side of the floodplain) for approximately 90 metres. For the 100 year ARI event the modelling indicates that the flood levels would decrease by approximately 100 mm up to approximately Athol Ct. For the September 2010 event the modelling indicates the culverts would have a localised impact only.

Figure 18 shows the difference in water level (afflux) with the mitigation option in place compare to existing conditions. A negative number indicates that the flood levels would be lower with the mitigation option in place for the same flow event. Additional events are shown in Appendix O.

Legend

Highway	Lake	**Afflux (mm)**
Sealed road (arterial & local)	Flat	<-100
Unsealed road	River	-100-0
Unsealed track	Channel / drain	0-100
		>100

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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Afflux-Culvert Option
January 2011 Flood Event

Figure 18

G:\31\28519\GIS\Maps\Deliverables\Figure 18- Donald_Township_Afflux_Jan2011_Culvert.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

6.4 Non Structural Mitigation Options

This section discusses a number of non-structural flood mitigation measures, and recommends specific measures for inclusion in the floodplain management plan. Non-structural mitigation measures include land use planning, flood warning and flood response.

6.4.1 Land Use Planning

The Victorian Planning Provisions (VPPs) contain a number of controls that can be employed to provide guidance for the use and development of land that is inundated by floodwaters. These controls include the Urban Floodway Zone (UFZ), the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO) and the Special Building Overlay (SBO). This section of the report discusses how each control may be applied in the Buloke Shire Planning Scheme.

Section 6(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Development controls are essential for ensuring that land use on flood-prone land is compatible with flood risk and that the rate of growth of future flood damage is reduced. (ARMCANZ, 2000)

Urban Floodway Zone

Increasing the intensity of land use or a change in land use can increase flood risk, therefore in areas of highest flood risk and with a potential for land use intensification, it may be appropriate that land use is restricted. As with any other zone, the UFZ controls the use of land in identified floodway areas. The UFZ is very restrictive on what uses are permissible, as such, use of the UFZ will severely limit the use and development of land to which it is applied.

The difficulty in using the UFZ is that flooding does not follow cadastral boundaries; hence it may not be possible to apply the zone to a complete parcel of land. Best practice is to ensure that only one zone applies to any given parcel of land. Due to the restrictive nature of the UFZ, it is not recommended for use at Donald. It is considered that other zones can be applied instead, in order to more clearly identify the development potential for land.

Floodway Overlay

The Floodway Overlay (FO) applies to mainstream flooding in both rural and urban areas. These areas convey active flood flows or storage. The FO has an increased focus on the control of development (structures) with the ability to restrict flow while still achieving some control over land use. The function of the overlay is to trigger the need for a planning permit. From the results of this investigation a revised FO, based on a combination of the 10% AEP flood, flood hazard and flood depth, has been developed for Donald. The criteria for the FO were informed by the Advisory Notes for Delineating Floodways (NRE, 1998). The revised FO is shown in Figure 19. It is recommended that the revised FO be introduced to the Buloke Shire Planning Scheme.

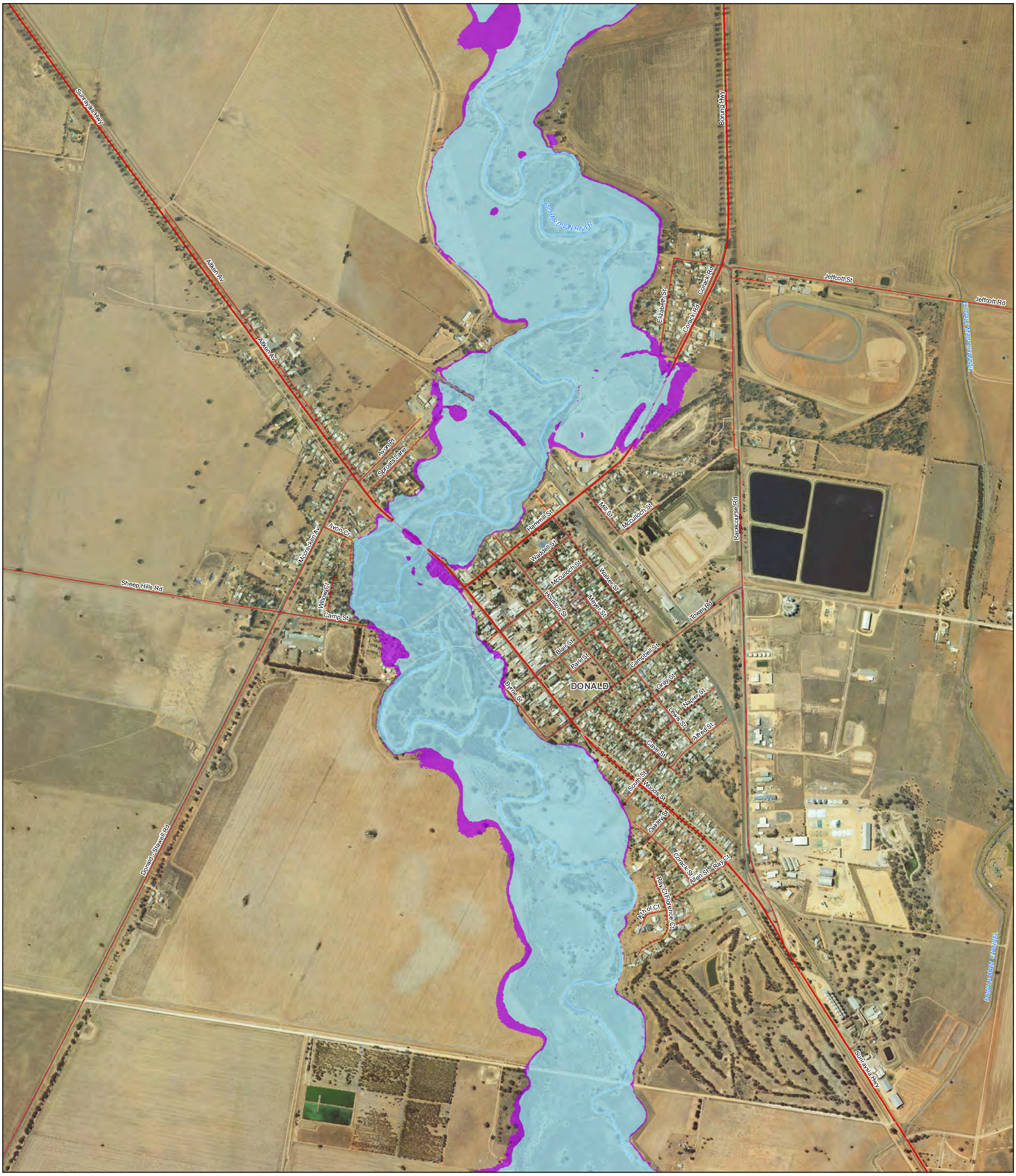
It is noted that if mitigation option 1 (levees) is constructed in order to provide flood protection for the Donald township, the argument supporting introduction of the FO to the Buloke Planning Scheme for Donald will be significantly reduced.

Land Subject to Inundation Overlay

The LSIO applies to mainstream flooding in both rural and urban areas. In general, areas covered by the LSIO have a lower flood risk than FO areas.

The LSIO will act as a trigger for a planning permit. From the results of this investigation a revised LSIO has been developed for Donald. The revised LSIO is shown in Figure 19. It is recommended that the revised LSIO be introduced to the Buloke Shire Planning Scheme.

The LSIO / FO map will identify the land where a permit will be required, while the FO Schedule and the LSIO Schedule will identify various developments within the overlay (identified land) that will be exempt from the need for a permit in each zone.



Legend

- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- River
- Channel / drain
- Draft LSIO
- Draft FO

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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North Central CMA
Donald Flood and Drainage Investigation

LSIO and FO
existing conditions

Job Number	31-28519
Revision	A
Date	19 May 2014

Figure 19

G:\31\28519\GIS\Maps\Deliverables\Flood Overlay Figure A2.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Special Building Overlay

The Special Building Overlay (SBO) applies to stormwater flooding in urban areas only. The SBO is intended to apply to areas / locations where the drainage systems are designed to a lower capacity than what may be required during peak storm events and that result in the overland flow of stormwater. The purpose of the SBO is to manage development in areas that are subject to the overland flow of stormwater.

Common practice throughout Victorian Planning Schemes is to apply the SBO to situations where overland flow occurs once the capacity of drainage pipes is exceeded. Such surcharge flooding from local events was demonstrated during the January 2011 flood in Donald.

It is recommended that the SBO be introduced to the Buloke Planning Scheme, although its extent would need to be determined by an assessment of local (non riverine) flooding issues.

Local Planning Policy - Floodplain Management

The use of local policy can provide greater guidance and clarity in the Planning Permit process and is generally considered to be prudent practice. A Floodplain Management Planning Policy statement could assist in communicating Council's stance on appropriate development within the LSIO, FO and SBO. As such, it could provide guidance to both applicants and Council.

The policy would apply to all permits required under the LSIO, FO and SBO. Applicants will be able to gain guidance from the policy before preparing applications, while Council will be able to rely on the content of the policy to place conditions on permits, or to refuse permits. The policy could also be relied on to defend Council decisions at appeal.

The policy may include objectives to be achieved, policy statements, and performance standards to be met. It could also contain a number of objectives and performance measures that seek to ensure that new development does not reduce or impede the ability of the floodplain to store and convey floodwater.

It is recommended that consideration be given to amending the Buloke Planning Scheme to include a Floodplain Management Local Planning Policy for Donald.

6.4.2 Flood Warning, Response and Awareness

Flood Warning

Due to Donald's location towards the lower end of the catchment some warning time is possible for riverine flooding. The hydrological modelling indicated that a thirty hour storm duration is generally the critical duration for a range of design storms. However, it should be noted that the Richardson River has the potential to rise very quickly only a few hours after the start of heavy rain and remain high for 24 to 36 hours. Modelling also indicated that the travel time for the peak at the Banyena gauge to peak at the Sunraysia Highway in Donald is typically between 20 to 30 hours (depending on the storm event).

The Flood Warning Arrangements for Victoria (VFWCC, 2001) report outlines the following principles for non flash flood warning services:

- For rural Victoria the Bureau has the lead role to provide warnings of minor, moderate and major flooding within its available resources. These warnings are disseminated to State agencies, selected private entities, and media.
- VICSES disseminates the Bureau's warnings to Local Government and relevant regional authorities who in turn disseminate warning information (Bureau and local content) in their community. In some cases the Bureau's warnings are issued direct to relevant regional authorities and some councils (Local Government) where time is limited. VICSES still disseminate the warnings to those same Councils as backup.

During the recent flood events, Donald received little or no warning. Since the January 2011 event the DSE has upgraded a number of existing river level gauges (e.g. Richardson River @ Donald) and the Bureau of Meteorology has put the Avon Richardson @ U/S Rich Avon onto its website (http://www.bom.gov.au/vic/flood/north_central.shtml). Information from this investigation should be used to improve the flood warning received by Donald during a flood event.

Flood Response

The information and understanding gathered during this project regarding the flood behaviour at Donald for a range of flood events is critical to capture in order to improve the flood response at Donald. This includes areas that are likely to be impacted by floods of various magnitudes, areas most at risk, buildings inundated above and below floor, identifying vulnerable communities, the timing and behaviour of flooding through town, access issues and areas that need to be evacuated as a priority. This information should be summarised in the Municipal Emergency Management Plan. It is suggested that a gauge board be installed at an appropriate location in town so that the outputs from this study can be tied back to a common gauge level. An appropriate location for a gauge board may be at the Bullocks Head or the Sunraysia Highway bridge.

Flood Awareness

There are many misconceptions commonly held regarding flooding that may prevent a person from preparing to and then evacuating prior to the arrival of a flood. A strong community awareness campaign will reduce these misconceptions, it will never eliminate them entirely, but it will tend to increase the percentage of the community which is aware and ready to act when a flood is imminent. A flood aware and flood ready community stands a much better chance of reducing their flood damage than a community that is not aware of the flood risk before an event.

Flood awareness can be improved and retained in a number of ways. Some of these include, but not limited to:

- VICSES FloodSafe program;
- Continuing to promote flood related issues through the flood recovery group;
- Installing flood markers of historic and potentially design floods in suitable locations;
- Individual property flood information which includes information such as the link between a flood level at a gauge and the commencement of flooding on the specific property, and the level at which above floor flooding is likely to occur, they also provide basic flood information including contact details and at what level on the gauge they should consider evacuating.

7. Flood Damage Assessment

A flood damage assessment was undertaken for the study area for the existing conditions and separately with each of the two mitigation options in place. The flood assessment estimated the flood damages for design floods, that is, the 5, 10, 20, 50, 100 and 200 year ARI events.

For the existing conditions the flood damage assessment was undertaken using the Rapid Appraisal Method (DSE, 2000) and a combination of damage curves developed utilising other flood studies undertaken by GHD and the Rapid Appraisal Method. Discussion with the NCCMA indicated that there was a preference to use the Rapid Appraisal Method as it has been adopted across Victoria and allows a direct comparison of flood damages across all of the catchments under the NCCMA jurisdiction. In this report only the results from the Rapid Appraisal Method have been presented.

The Rapid Appraisal Method states that, "the mean damage of $20,500[1] for 'buildings' includes external, internal contents and structural damages and should be applied to all inundated properties including those inundated above and below floor level." For Donald there are a number of properties (particularly along Byrne Street) where the external buildings (sheds) are inundated but not the dwelling or the 'main' commercial building. To avoid the damages being potentially artificially high by including them under the strict definition given by the Rapid Appraisal Method a value of $6,700[2] was applied were the external building was inundated but not the 'main' building. The value of $6,700 comes from the Department of Environment and Climate Change (2007) for damage to external buildings during a flood. In keeping with the Rapid Appraisal Method an average value was adopted for the external buildings. Also to try and avoid artificially inflating the damages a property was only included when the flood level came within 250 mm of the floor level.

Information gathered from the TSC and CRG was also used in the damage assessment. Council estimated that the cost of repairing the flood damage to the pool and associated infrastructure was in the order of $40,000 for the September event and $60,000 for the January 2011 event. These values were used in the flood damage assessment.

All dollar values used in the flood damage assessment were adjusted to 2012 dollars using information published by the Bureau of Statistics. Details of the flood damage assessment are shown in Appendix P.

The flood damage assessment for each of the design floods was then used to calculate the Average Annual Damage (AAD). The average annual damage, as defined in Floodplain Management in Australia (CSIRO, 2000), is the total damage caused by floods over a long period of time divided by the number of year in that period. 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 the basis for comparing the economic effectiveness of different management measures.

[1] Note this value is for the year 2000

[2] Note this value is for the year 2007

7.1 Flood Damage Assessment Results

The following section summaries the flood damage assessment results. Table 22 summarises the flood damages estimates for the existing conditions. Table 23 summarises the flood damages estimates with mitigation option 1 (levees) in place. Table 24 summarises the flood damages estimates with mitigation option 2 (culverts) in place. Table 25 summaries the average annual damages calculated. It should be noted that these are estimates only and may not reflect actual damages which could occur as a results of a flood.

Table 22 Flood Damage Assessment for Existing Conditions

Damages	ARI (years)					
	200yr	100yr	50yr	20yr	10yr	5yr
Total Direct Potential Damage to Buildings	$969,928	$834,628	$476,579	$260,099	$108,240	$27,060
Total Direct Damages (0.7 x Potential)	$678,949	$584,239	$333,606	$182,070	$75,768	$18,942
Total Direct Infrastructure Damages	$305,465	$250,644	$223,583	$205,863	$116,308	$28,701
Total Indirect Damages	$295,324	$250,465	$167,157	$116,380	$57,623	$14,293
Total Damages	$1,279,738	$1,085,348	$724,345	$504,312	$249,698	$61,937

Table 23 Flood Damage Assessment for Mitigation Option 1

Damages	ARI (years)					
	200yr	100yr	50yr	20yr	10yr	5yr
Total Direct Potential Damage to Buildings	$108,240	$108,240	$108,240	$81,180	$54,120	$0
Total Direct Damages (0.7 x Potential)	$75,768	$75,768	$75,768	$56,826	$37,884	$0
Total Direct Infrastructure Damages	$80,297	$61,669	$52,580	$43,427	$22,712	$19,772
Total Indirect Damages	$31,213	$27,487	$25,670	$20,051	$12,119	$3,954
Total Damages	$187,278	$164,924	$154,018	$120,303	$72,715	$23,726

Table 24 Flood Damage Assessment for Mitigation Option 2

Damages	ARI (years)					
	200yr	100yr	50yr	20yr	10yr	5yr
Total Direct Potential Damage to Buildings	$915,808	$618,025	$395,399	$135,300	$108,240	$27,060
Total Direct Damages (0.7 x Potential)	$641,065	$432,618	$276,780	$94,710	$75,768	$18,942
Total Direct Infrastructure Damages	$321,167	$266,346	$231,434	$205,863	$107,712	$28,701
Total Indirect Damages	$288,670	$209,689	$152,464	$90,172	$55,044	$14,293
Total Damages	$1,250,902	$908,653	$660,678	$390,744	$238,523	$61,937

Table 25 Summary of Average Annual Damages (AAD)

Option	Average Annual Damages ($)	Reduction in Average Annual Damages ($)
Existing Conditions	67,823	N/A
Mitigation Option 1 - Levees	16,238	51,585
Mitigation Option 2 - Culverts	59,772	8,051

The damage assessment shows that mitigation option 1 (levees) has a significant impact on reducing the AAD in Donald. Mitigation option 2 (additional culverts) has a minor impact on reducing the AAD in Donald.

7.2 Non-Economic Flood Damage

The previous discussion relating to flood damage has been in relation to tangible damage which can be estimated in dollars. Intangible damage cannot be readily quantified in economic terms but are none the less important. According to the RAM intangible damages fit under two broad categories:

- Social (e.g. health, safety and personal impacts); and
- Environmental impacts.

The “Disaster Loss Assessment Guidelines” (EMA, 2002) states that people value the intangible losses from a flooded home principally loss of memorabilia, stress and resultant ill-health as at least as great as their tangible dollar losses.

The Donald community suffered greatly as a result of the recent floods. Anecdotal evidence from the community suggests that a number of lives were lost following the January 2011 flood. This loss of life was attributed to the stress caused by having to evacuate and relocate people in the Goodwin Village.

The mixing of sewage with flood waters was also raised as a health concern by the people of Donald.

The flood damage assessment presented in Section 7.1 has not considered the ‘intangible cost’. However, any decisions made on the works to undertake in Donald need to factor in that the true cost of floods in Donald is greater than the estimated economic damage. Making such an allowance is appropriate and expected to increase the flood damage estimates, increasing the benefit / cost ratio and improving the argument for approving a mitigation scheme at Donald.

8. Benefit Cost Analysis

A benefit cost analysis was undertaken to assess the economic viability of the two (2) mitigation options. A benefit cost ratio is an indicator of the overall value for money of a project expressed in monetary terms, relative to its costs, also expressed in monetary terms. All benefits and costs should be expressed in discounted present values. The benefit cost ratio takes into account the amount of monetary gain realised by implementing a project versus the amount it costs to implement the project. The higher the benefit cost ratio the better the investment.

8.1 Cost of Mitigation Options

The mitigation works were costed based on previous jobs undertaken by GHD and information presented in Rawlinsons Australian Construction Handbook (2012). A summary of the capital cost estimates for the mitigation options is shown in Table 26. Details of the cost estimates are included in Appendix Q.

Table 26 Capital Cost Estimates for Mitigation Options

Option	Capital Costs ($)
Mitigation Option 1 – Levee 1	353,000
Mitigation Option 1 – Levee 2	729,000
Mitigation Option 1 – Levee 3	194,000
Mitigation Option 1 – Levee 4	232,000
Mitigation Option 1 – All Levees	1,508,000
Mitigation Option 2 - Culverts	3,160,000

The cost estimates shown in Table 26 are estimates only. Actual prices, costs and other variables may be different to those used to prepare the cost estimates. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same, more or less than the cost estimates.

8.2 Benefit Cost Analysis

The benefit cost ratios calculated for each mitigation option are shown in Table 27. For the analysis, a net present value (NPV) model was used, applying a 4% discount rate over a 50 year project life. In addition to considering the construction of all the levees (Option 1) an analysis was also undertaken considering the construction of only levee 2 and 3 (Option 1a - levee 2 and 3 must be constructed together) and levee 1, 2 and 3 (Option 1b).

Table 27 Benefit Cost Analysis

	Mitigation Option 1 – All Levees	Mitigation Option 1a – Levees 2&3	Mitigation Option 1b – Levees 1,2&3	Mitigation Option 2 - Culverts
Benefit				
Reduction in AAD ($)	51,585	41,410	50,047	8,051
NPV ($)	1,108,000	905,000	1,091,000	173,000
Cost				
Capital Cost ($)	1,508,000	923,000	1,276,000	3,160,000
Benefit Cost Ratio	0.74	0.98	0.86	0.05

From the results of the benefit cost analysis shown in Table 27 mitigation option 2 (culverts) has a very low benefit cost ratio and is therefore not recommended.

Mitigation Option 1a (construction of levee 2 and 3) is the most economical solution with a benefit cost ratio of 0.98. However, mitigation Option 1 (construction of all levees) still has a reasonable benefit cost ratio of 0.75. The actual benefit cost ratio will be higher once intangible flood damages are considered.

The costs shown in Table 27 do not include an allowance for maintenance. A number of discussions were had with the NCCMA about what an appropriate cost for maintenance would be for Donald as a significant portion of the proposed levees already exists. For comparison purposes a value of 1% of the construction costs was chosen. With maintenance costs of 1% included the benefit cost ratio for Option 1 (all levees) becomes 0.60, for mitigation Option 1a (levee 2 and 3) 0.81 and mitigation Option 1b (levee 1, 2 and 3) 0.7. With the maintenance cost included mitigation Option 1a and mitigation Option 1 b still have reasonable benefit cost ratio. The benefit cost ratio for mitigation option 1 (all levees) with maintenance included is becoming difficult to justify from an economic view point. The results of mitigation Option 1a and mitigation Option 1b indicate that levee 4 is heavily influencing the benefit cost ratio of mitigation Option 1 (all levees) as the construction and maintenance costs of levee 4 are outweighing the benefits (that is protecting one or two properties). If levee 4 is too be constructed, consideration should be given to lowering the level of service (in terms of ARI) provided to reduce the construction cost and enter into an agreement with the landowner in regards to maintenance. If maintenance costs for levee 4 are not included and the levee is lowered to the 100 year ARI level (with no freeboard) the benefit cost ratio for the modified Option 1 increases from 0.60 to 0.64.

9. Recommendations

The Donald Flood and Drainage Management Plan has been guided by the CRG with support from the TSC.

Structural Flood Mitigation Works

It is recommended for Donald that the following works be undertaken as a first priority:

- Construction of Levee No. 2 (refer to Figure 13 for location);
- Construction of Levee No. 3 (refer to Figure 13 for location).

It is recommended that the following works be undertaken as a second priority:

- Construction of Levee No. 1 (refer to Figure 13 for location).

It is recommended that the following works be considered:

- Construction of Levee No. 4 (refer to Figure 13 for location). With the construction of Levee 4 consideration should be given to improving the economic viability of the levee by:
  - Providing a lower level of service (in terms of ARI event); and
  - Reaching an agreement with the landowner in regards to maintenance.

Non - Structural Flood Mitigation Works

It is recommended for Donald that:

- The Buloke Shire Council uses the information from this study to complete the Municipal Flood Emergency Management Plan with the assistance of the VICSES;
- The Council undertake a detailed investigation into drainage (local non riverine flooding) issues for Donald and develop a stormwater management plan for Donald;
- Information from this investigation be used to improve the flood warning received by Donald during a flood event;
- A gauge board at the Bullocks head or at the Sunraysia Highway bridge is installed to assist in future flood warning;
- Flood awareness in the community is increased and maintained with a public campaign through the implementation of the VICSES Floodsafe program; and
- The Buloke Shire Council undertake a planning scheme amendment to incorporate flood related provisions to reflect the flood risks identified by this study

10. References

Agricultural and Resources Management Council of Australia and New Zealand, Standing Committee on Agriculture and Resource Management Report No. 73 “Floodplain Management in Australia, Best Practice Principles and Guidelines”, 2000/

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Department of Natural Resources and Environment, “Rapid Appraisal Method (RAM) for Floodplain Management”, 2000

Department of Natural Resources and Environment, “Advisory Notes for Delineating Floodways”, 1998

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Emergency Management Australia, “Disaster Loss Assessment Guidelines”, 2002

Institute of Engineers, “Australian Rainfall and Runoff, A Guide to Runoff Estimation”,

Rawlinsons, “Australian Construction Handbook”, 2012

SKM, “Avon-Richardson Floodplain Management Strategy”, 1998

SKM, “Avon Plains Lakes Water Management Plan” 2006

Victorian Salinity Program “Avon Richardson Land and Water Plan, Surface Water Management in the Avon-Richardson Catchment”, 1992

Victorian Flood Warning Consultative Committee, “Arrangement for Flood Warning Services in Victoria”, 2001

Appendices

Appendix A – Survey Flood Levels

August 1909

September 2010

January 2011

Legend

- Aug 1909 Survey Flood Level (mAHD)
- Sep 2010 Survey Flood Level (mAHD)
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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Donald Flood and Drainage Investigation

Survey Flood Levels (August 1909 and September 2010)

Job Number	31-28519
Revision	A
Date	09 Nov 2012

Appendix A

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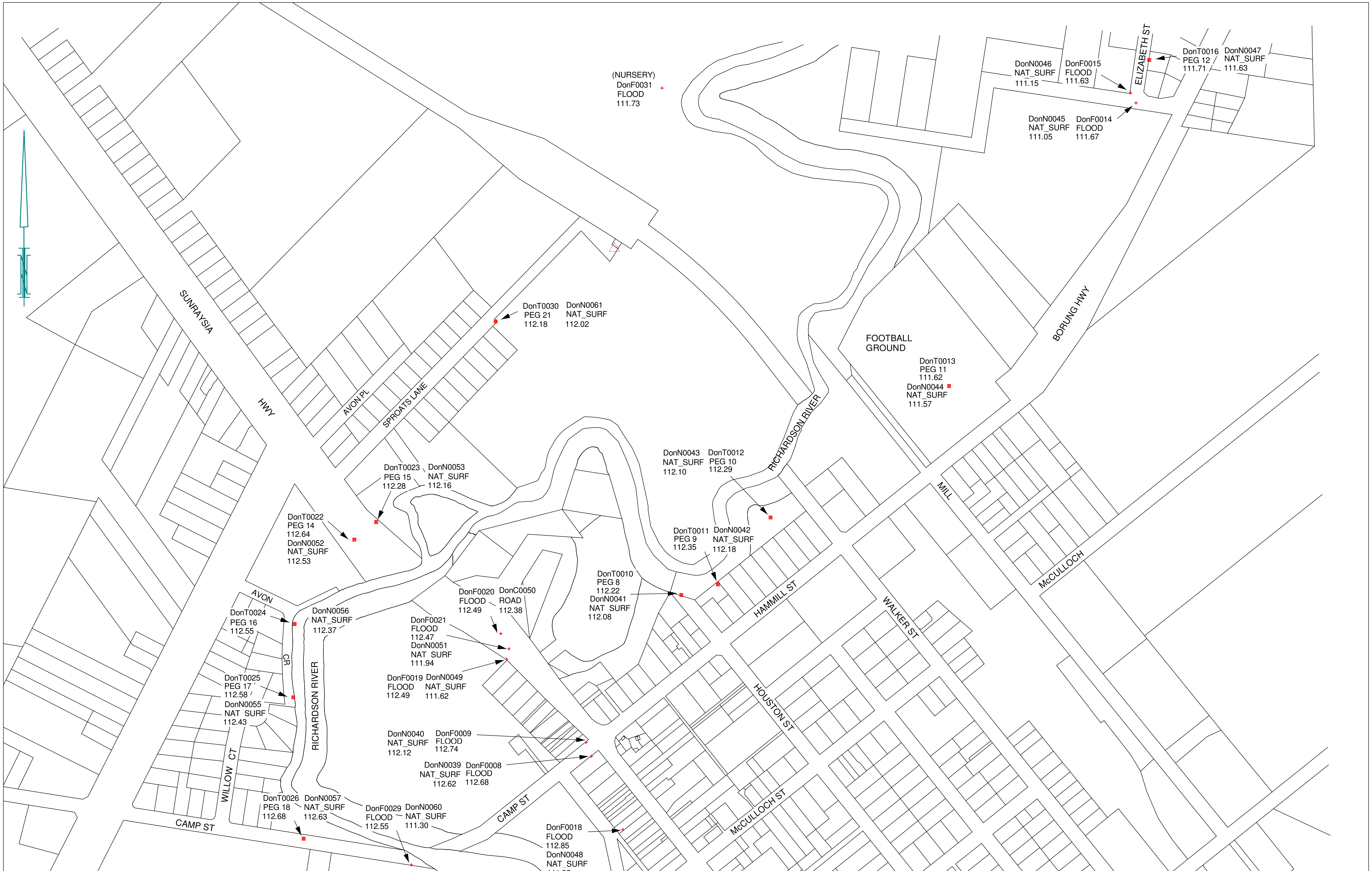
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:scowan



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REV	DATE	REVISIONS	DRN	CHK

JOB DETAILS

DESIGNED : -
DRAWN : R.J.MACLEAN
SURVEY DATE : FEBRUARY 2011
DATUM : A.H.D.
GRID INTERVAL :
LEVEL BOOK : L105
FIELD BOOK : F029
AREA : -

SCALE OF METRES

50 0 100 200

ORIGINAL DRAWING SCALE
1:5000 (A3 SHEET SIZE)

MGA
ZONE 54

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NORTH CENTRAL CATCHMENT MANAGEMENT AUTHORITY
PEG, FLOOD & NATURAL SURFACE LEVELS
DONALD

CROWN ALLOTMENT	SECTION	PARISH	FILE NUMBER	SHEET NUMBER	DRAWING No.	REVISION	SHEET SIZE
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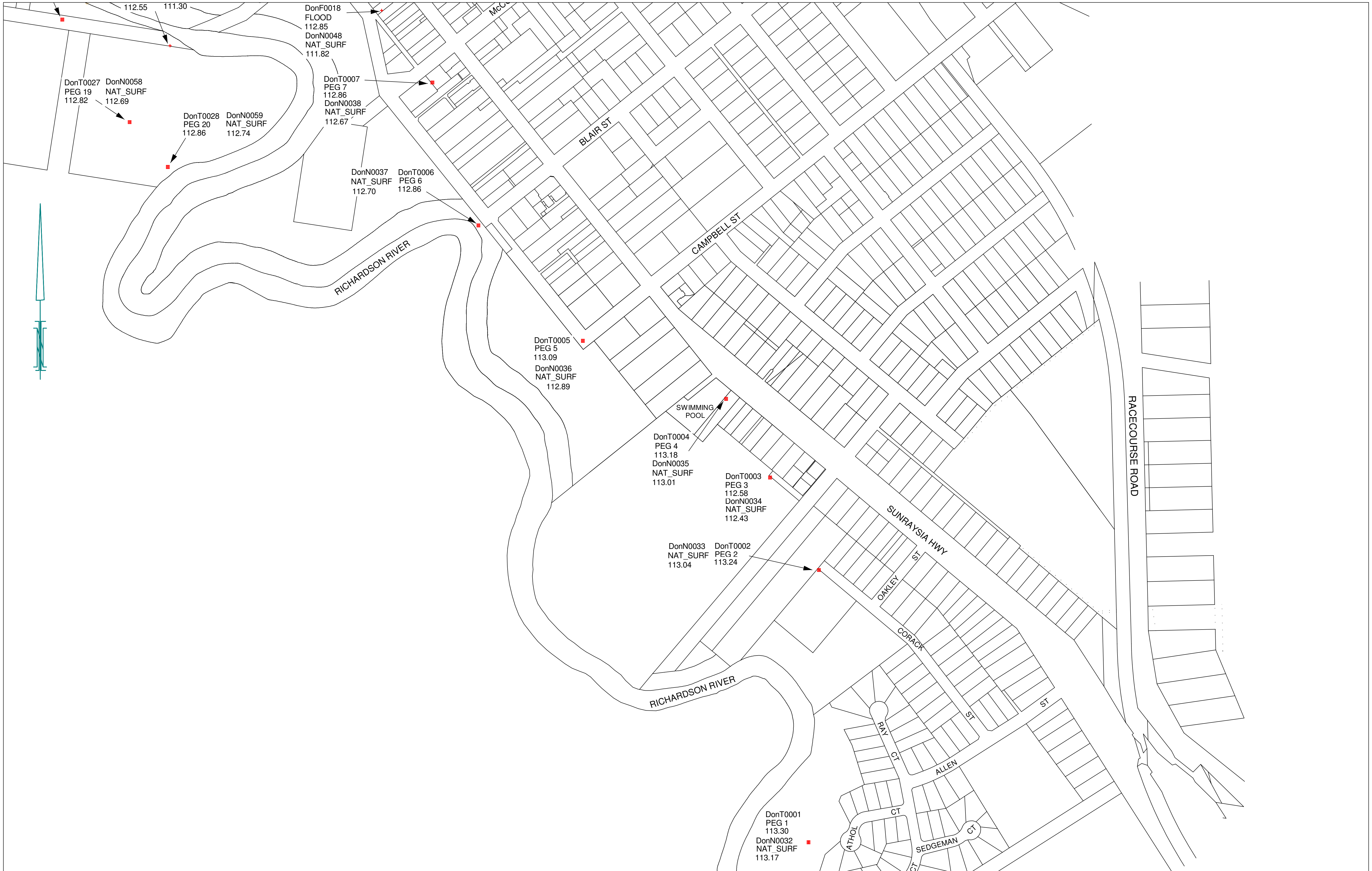

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REV	DATE	REVISIONS	DRN	CHK

JOB DETAILS

DESIGNED : -
DRAWN : R.J.MACLEAN
SURVEY DATE : FEBRUARY 2011
DATUM : A.H.D.
GRID INTERVAL :
LEVEL BOOK : L105
FIELD BOOK : F029
AREA : -

SCALE OF METRES

50 0 100 200

ORIGINAL DRAWING SCALE
1:5000 (A3 SHEET SIZE)

MGA
ZONE 54

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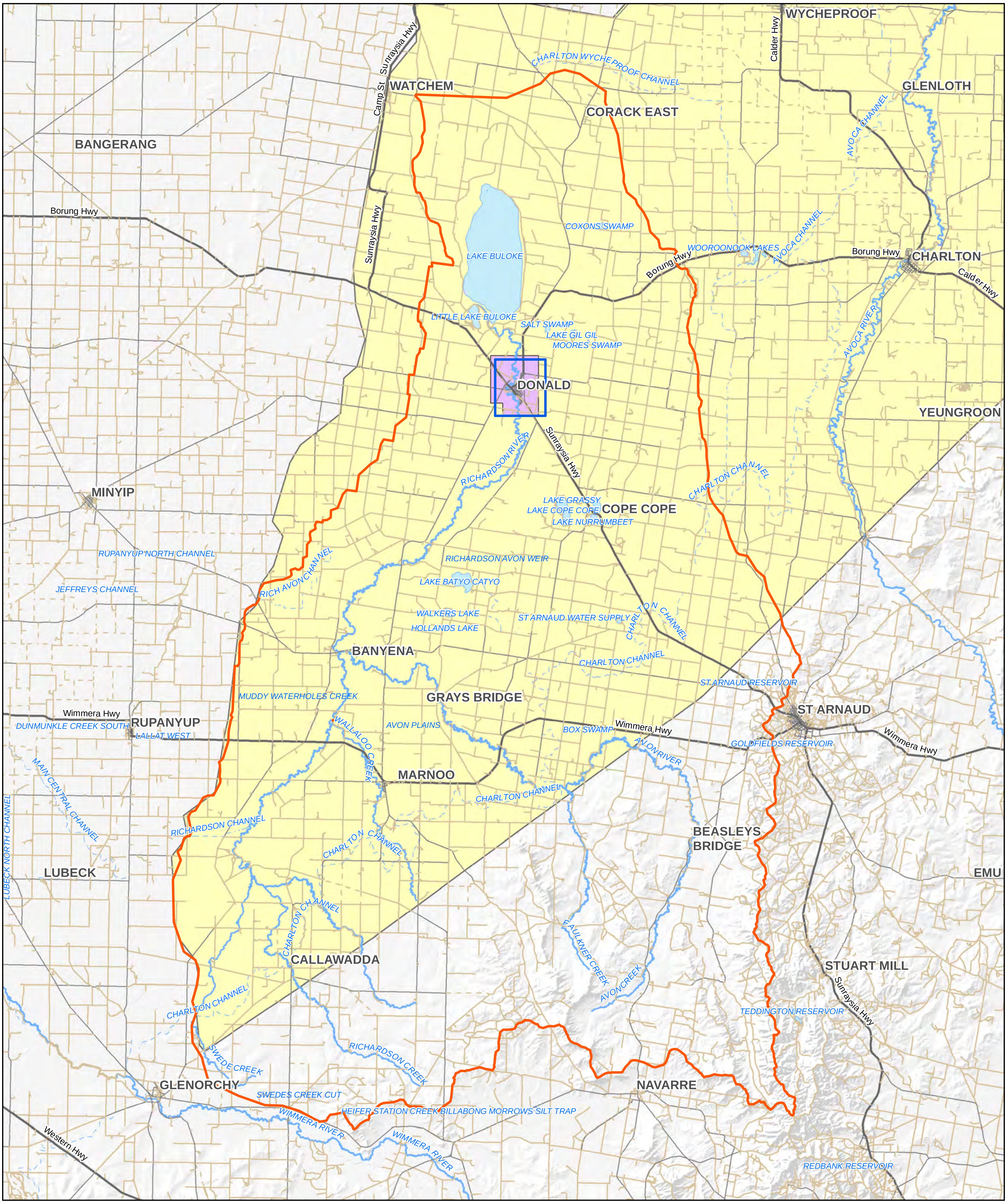
NORTH CENTRAL CATCHMENT MANAGEMENT AUTHORITY
PEG, FLOOD & NATURAL SURFACE LEVELS
DONALD

CROWN ALLOTMENT	SECTION	PARISH	FILE NUMBER	SHEET NUMBER	DRAWING No.	REVISION	SHEET SIZE
-	-	-	F6459	2 of 2	3303	0	A3

Appendix B – Area of Supplied DEM's



LEGEND

- Donald Study Area
- Avon-Richardson Catchment
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Stream
- Connector
- Channel / drain
- DSE Rivers LiDAR Extent (Supplied)
- GWMW LiDAR Extent (Supplied)

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

North Central CMA
Donald Flood and Drainage Investigation

Job Number 31-28519
Revision A
Date 16 May 2014

DEM Extents

Appendix B

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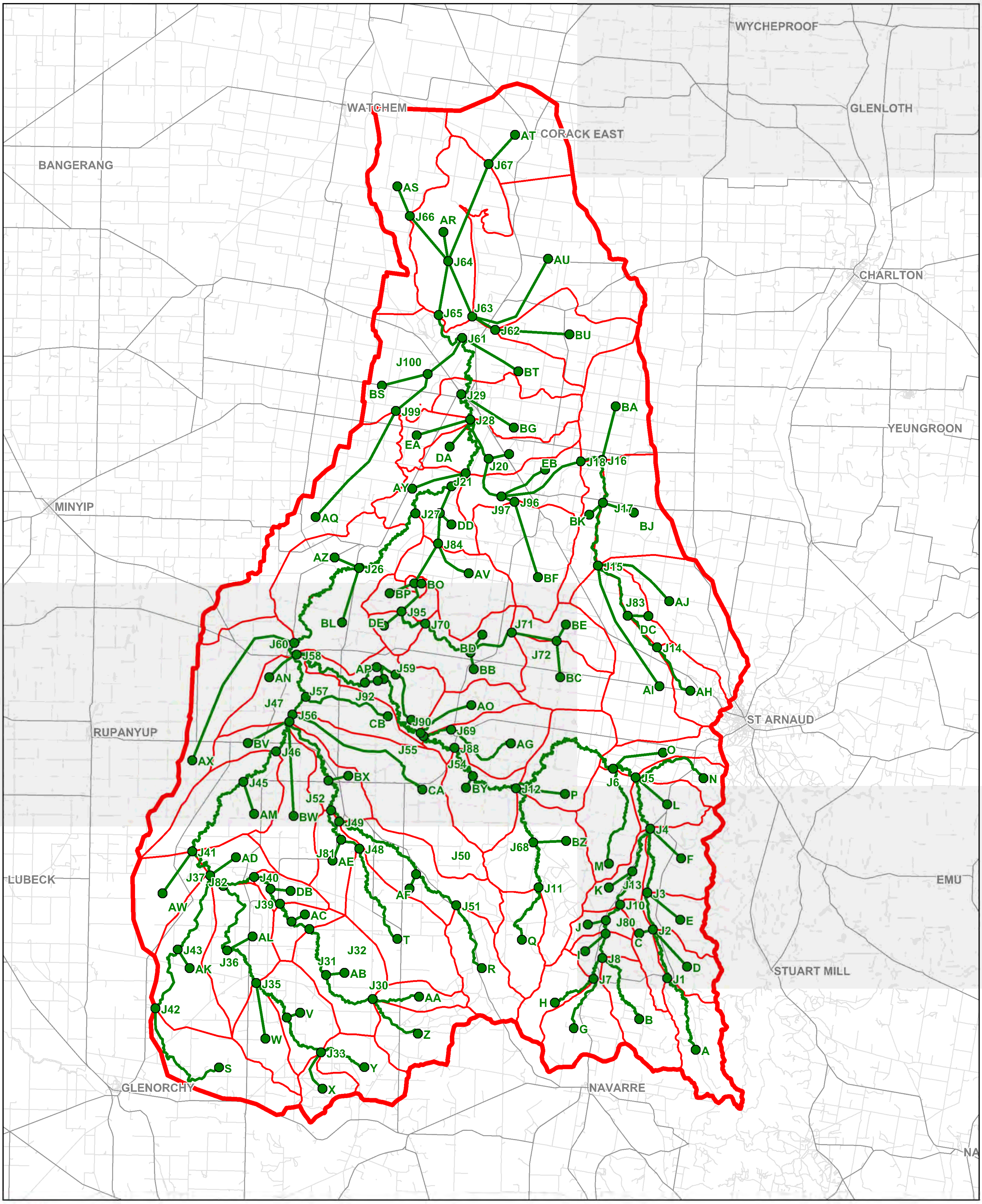
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DEPI, VicMap (2012). Created by:scowan

Appendix C – RORB Model Layout



LEGEND

RORB Catchment Boundary
RORB Subcatchment Boundary
RORB Node
RORB Reach Alignment
Major Road
Road

Paper Size A3

0 1.5 3 4.5 6 7.5 9

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 54

N

GHD

NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Donald Flood Investigation

Job Number	31-28519
Revision	A
Date	01/11/2012

RORB Model Layout

Appendix C

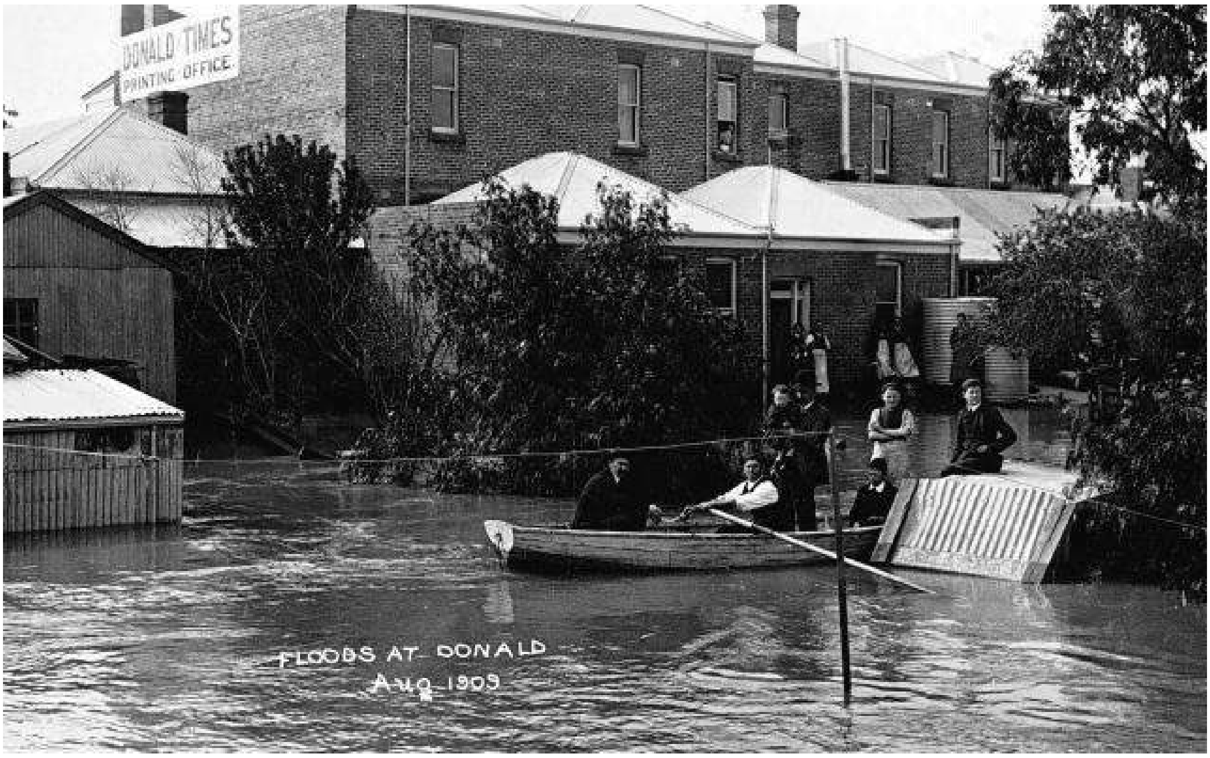
G:\31\28519\GIS\Maps\Working\Donald- Figures for Report.wor

8/180 Lonsdale St Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au W www.ghd.com.au

Data source: DSE, VicMap, 2012: GHD, RORB Model. Created by: scowan

Appendix D – Flood Photos

Donald 1909 – Source: NCCMA



Donald Railway Bridge 1909 – source: NCCMA

Sunraysia Highway Bridge September 2010 – Source: Ian and Alison McEwen

Ian and Alison McEwen's House September 2010 – Source: Ian and Alison McEwen

Donald Motor Lodge January 2011 – Source: Kate and Kelvin

Donald Motor Lodge January 2011 from the air – Source: Kate and Kelvin

Ian and Alison McEwen's House January 2011 – Source: Ian and Alison McEwen

Sunraysia Highway Bridge January 2011 – Source: Ian and Alison McEwen

Donald from the air January 2011 - Source: Robert Adams

Donald from the air January 2011 - Source: Robert Adams

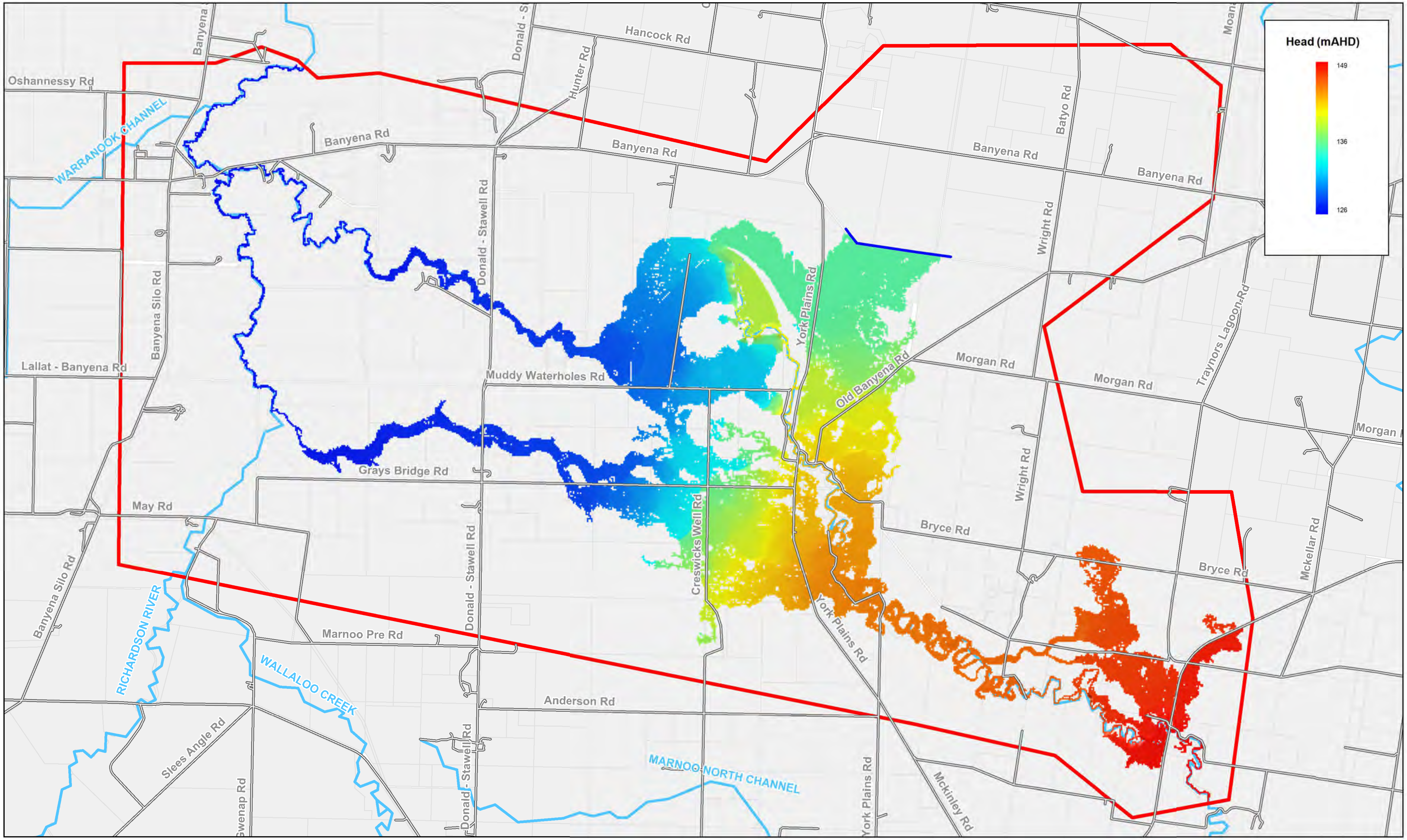
Donald from the air January 2011 - Source: Robert Adams

Donald from the air January 2011 - Source: Robert Adams

Appendix E – Hydraulic Model of Avon River Floodplain between Wimmera Highway and Banyena

Flow distribution within the Avon River floodplain between the Wimmera Highway and Banyena is complex. A hydraulic model (TUFLOW) was established for this area to gain a greater understanding of the flow regime within this area and establish flow distribution relationships to place into the RORB model.

A two dimensional grid was established to represent the surface terrain of all major overland flow paths within the Avon River floodplain between the Wimmera Highway and Banyena. Using the GWMW DEM, a 12 000 m by 17 000 m grid comprising 20 metre square cells was formed. A roughness value of 0.05 was allocated as a general representation of the land use type. The roughness value was based on the aerial photo and information gathered during the site visit. A z shape file was created to represent the main creeks within the floodplain. Recorded flows on the Avon River at the Wimmera Highway (415220) for the October 1996 were entered into the hydraulic model. The Figure below shows the extent of the hydraulic model and the maximum inundation extent.



Paper Size A3

0 500 1000 1500 2000 2500

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 54

N

LEGEND

- TUFLOW 2D Z-Shape
- Road
- Major Watercourse
- TUFLOW Code Boundary
- Property Parcel

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North Central CMA
Donald Flood Investigation

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Date	09/11/2012

Tuflow Model Used for RORB Relationships

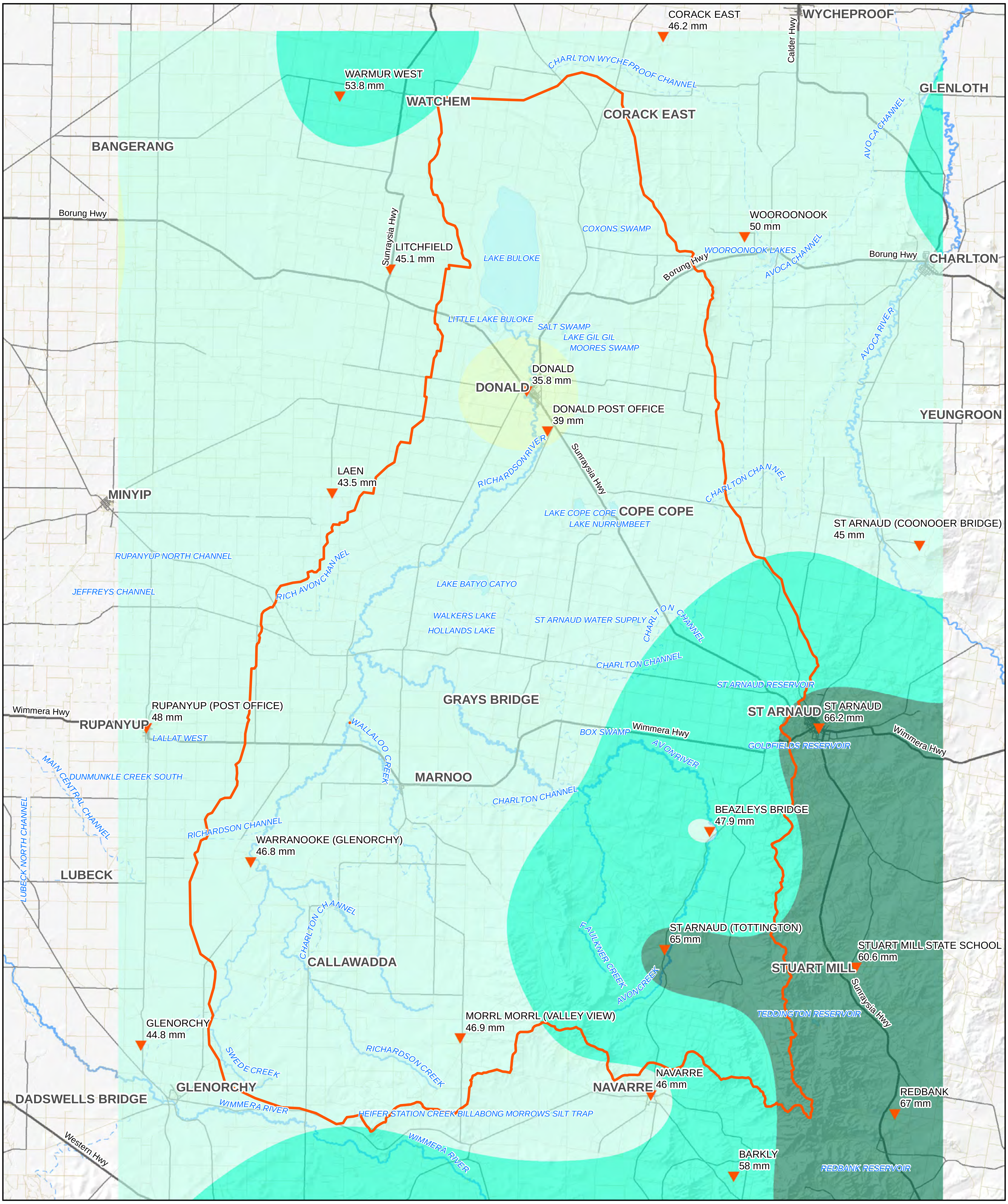
Appendix E

G:\31\28519\GIS\Maps\Working\Donald- Figures for Report.wor

Data source: DSE, VicMap, 2012: GHD, TUFLOW Model. Created by: scowan

180 Lonsdale St Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8555 E melmail@ghd.com.au W www.ghd.com.au

Appendix F – Historical Rainfall Data



LEGEND

Avon-Richardson Catchment	Lake	Stream
Highway	Flat	Connector
Sealed road (arterial & local)	River	Channel / drain
Unsealed road		Rainfall gauge
Unsealed track		

Rainfall Depth (mm)

35 - 40, 40 - 50, 50 - 60, 60 - 70

Paper Size A3
0 1.25 2.5 5 7.5 10 12.5
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

NORTH CENTRAL
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North Central CMA
Donald Flood and Drainage Investigation

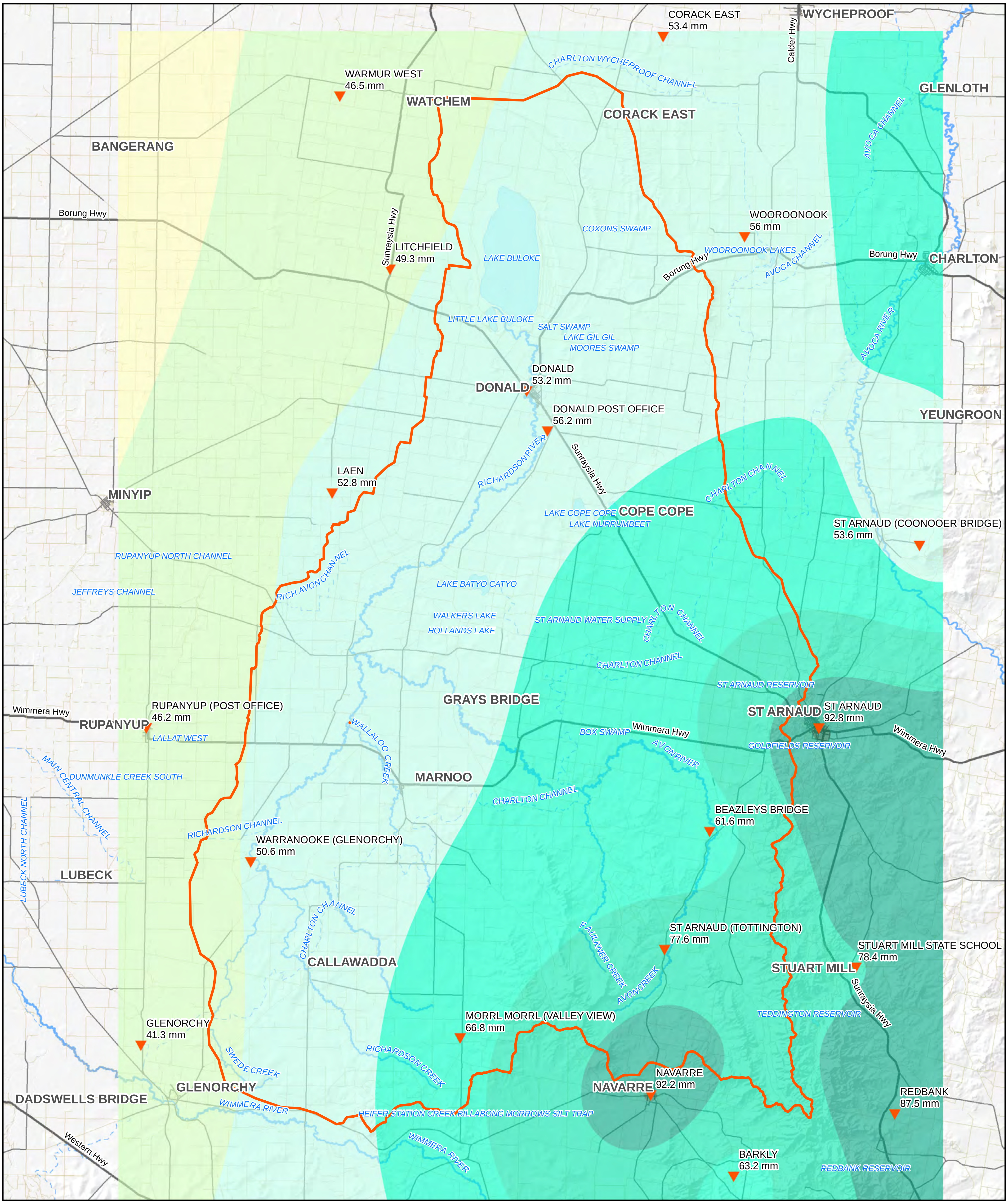
Job Number	31-28519
Revision	A
Date	16 May 2014

October 1996 Rainfall Depth

Appendix F1

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan



LEGEND

- Avon-Richardson Catchment
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Stream
- Connector
- Channel / drain
- Rainfall gauge

Rainfall Depth (mm)

30 - 40 | 40 - 50 | 50 - 60 | 60 - 70 | 70 - 80 | 80 - 90 | 90 - 100

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Donald Flood and Drainage Investigation

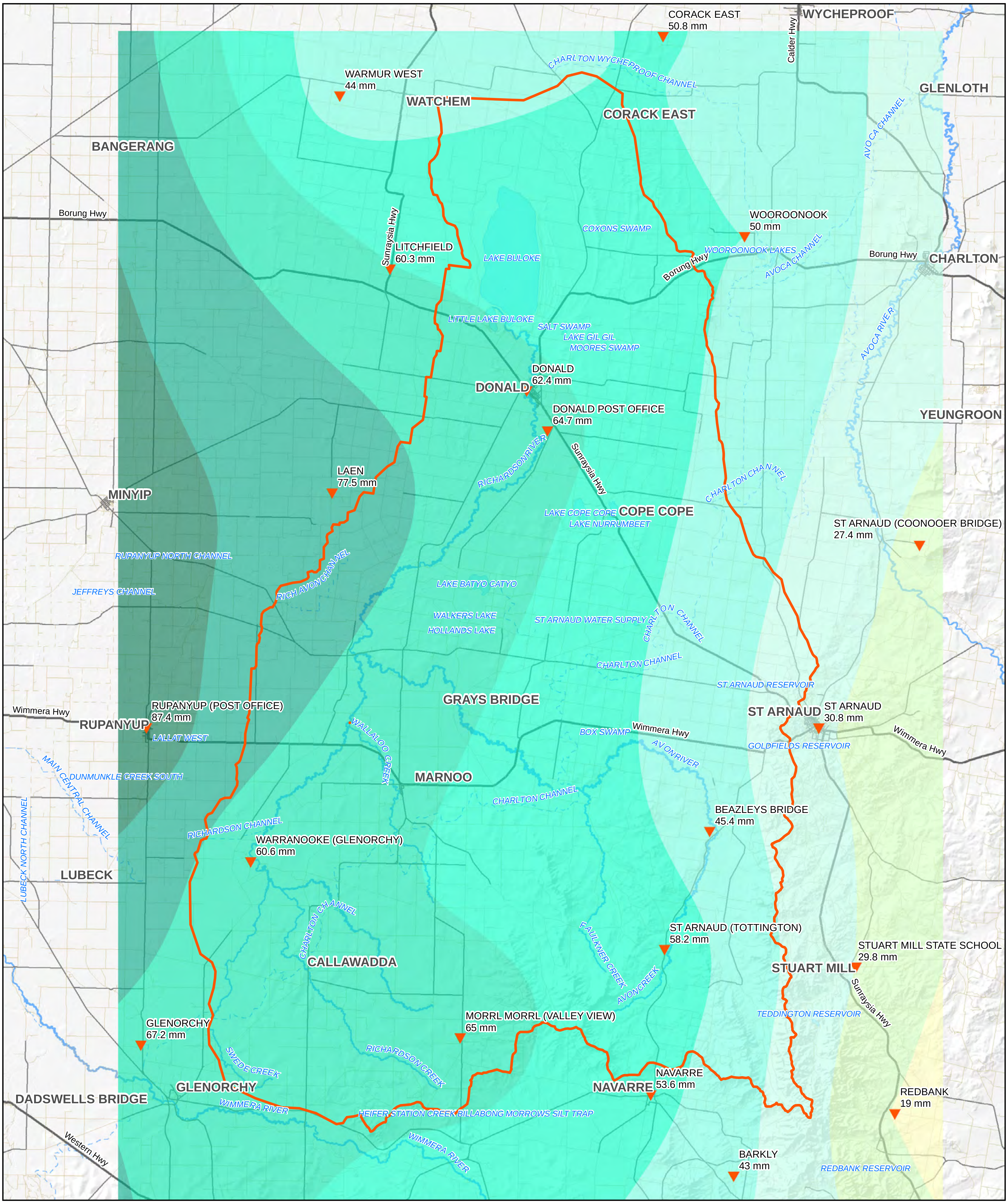
Job Number 31-28519
Revision A
Date 16 May 2014

September 2010 Rainfall Depth

Appendix F2

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan



LEGEND

Avon-Richardson Catchment	Lake	Stream
Highway	Flat	Connector
Sealed road (arterial & local)	River	Channel / drain
Unsealed road		Rainfall gauge
Unsealed track		

Rainfall Depth (mm)

16 - 20, 20 - 30, 30 - 40, 40 - 50, 50 - 60, 60 - 70, 70 - 80, 80 - 90

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

North Central CMA
Donald Flood and Drainage Investigation

Job Number	31-28519
Revision	A
Date	16 May 2014

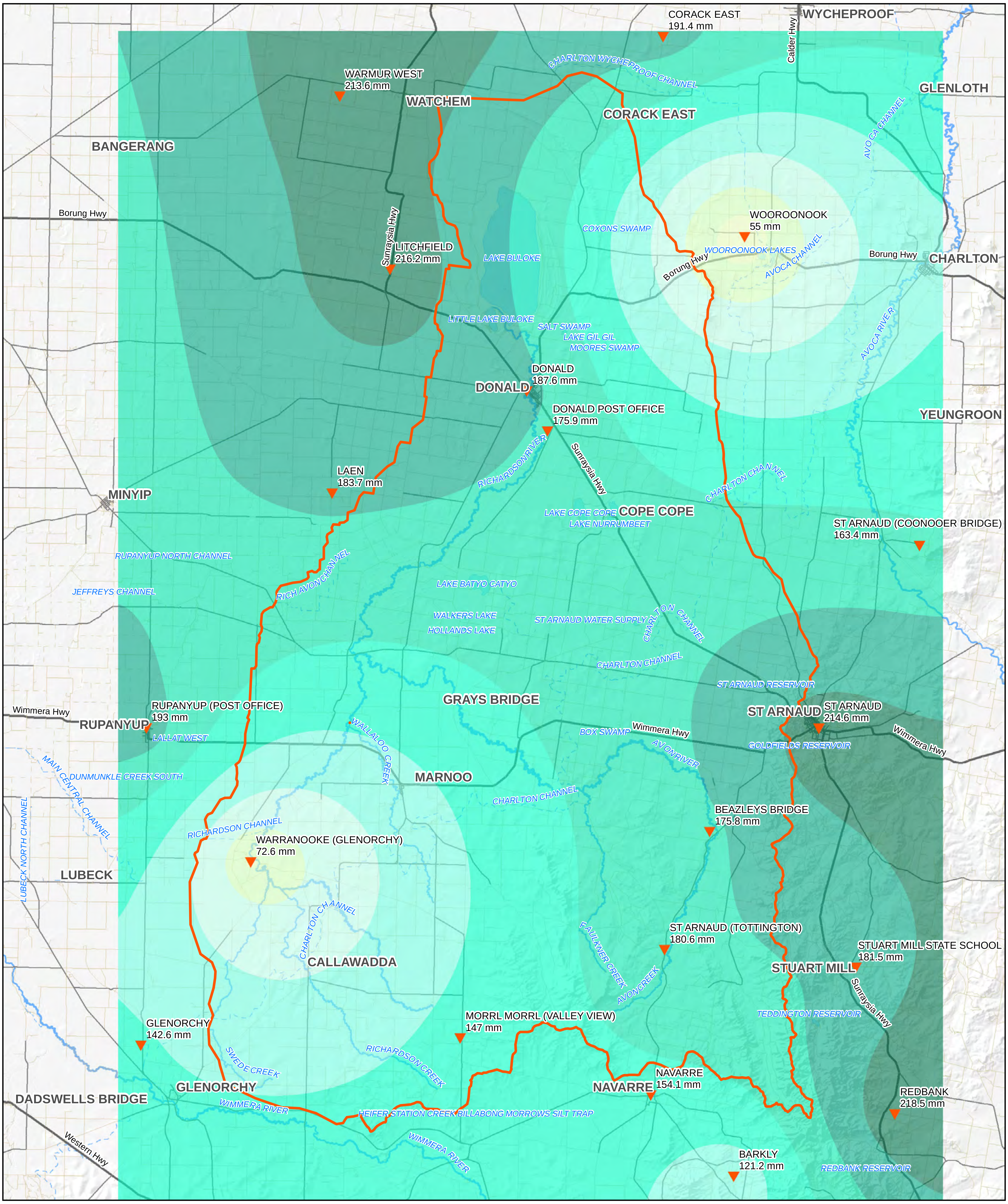
December 2010 Rainfall Depth

Appendix F3

G:\31\28519\GIS\Maps\Deliverables\3128519_015_Rainfall_Depths_A3L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan



LEGEND

Avon-Richardson Catchment	Lake	Stream
Highway	Flat	Connector
Sealed road (arterial & local)	River	Channel / drain
Unsealed road		Rainfall gauge
Unsealed track		

Rainfall Depth (mm)

55 - 60, 60 80, 80 - 100, 100 - 120, 120 - 140, 140 - 160, 160 - 180, 180 - 200, 200 - 220

Paper Size A3

0 1.25 2.5 5 7.5 10 12.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

North Central CMA
Donald Flood and Drainage Investigation

January 2011 Rainfall Depth

Job Number	31-28519
Revision	A
Date	16 May 2014

Appendix F4

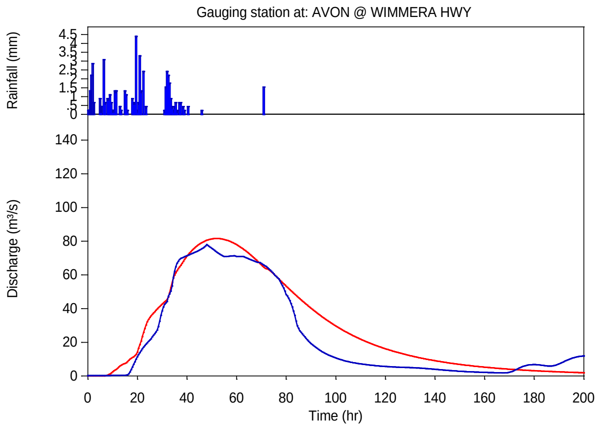
G:\31\28519\GIS\Maps\Deliverables\3128519_015_Rainfall_Depths_A3L.mxd

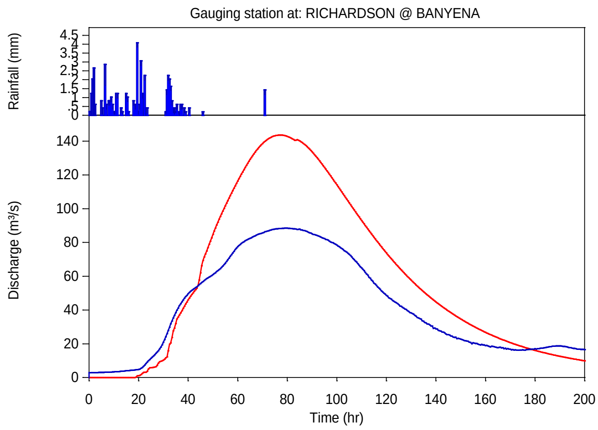
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

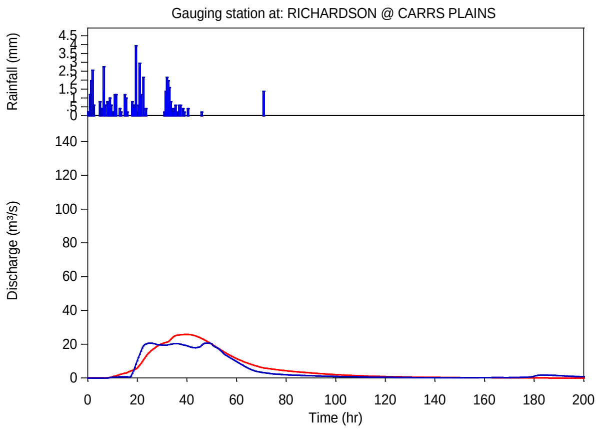
Data source: DSE, VicMap, 2012; Bureau of Meteorology, Annual Rainfall Data. Created by:scowan

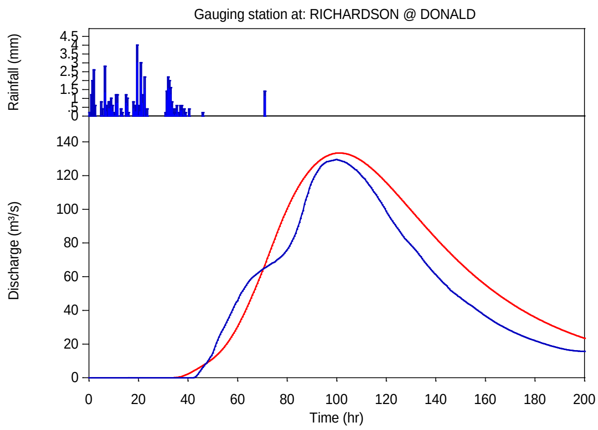
Appendix G – Calibration Results - RORB

October 1996

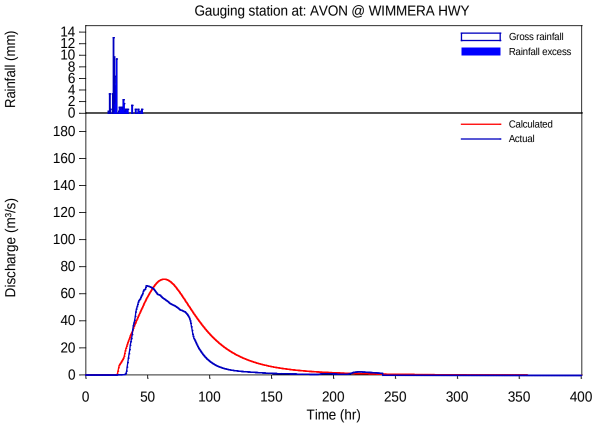


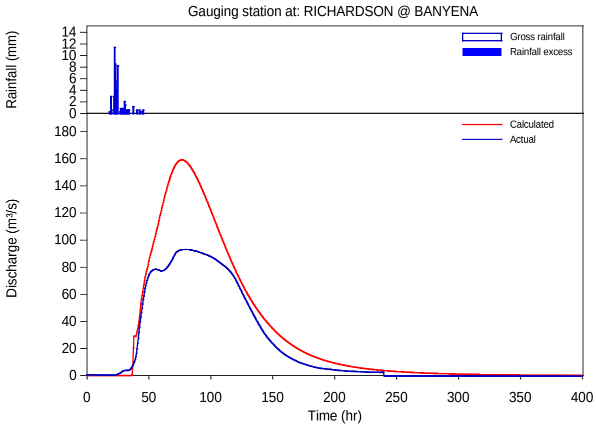


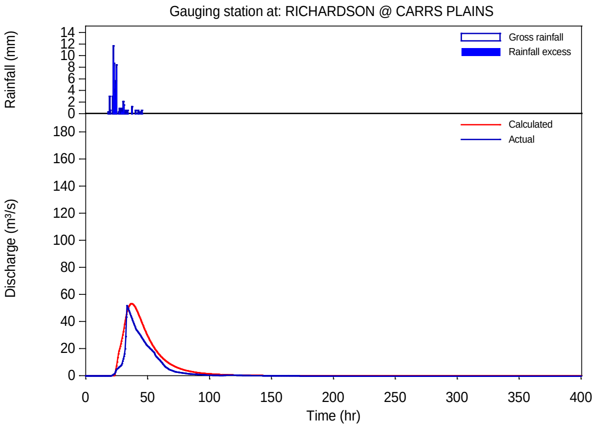


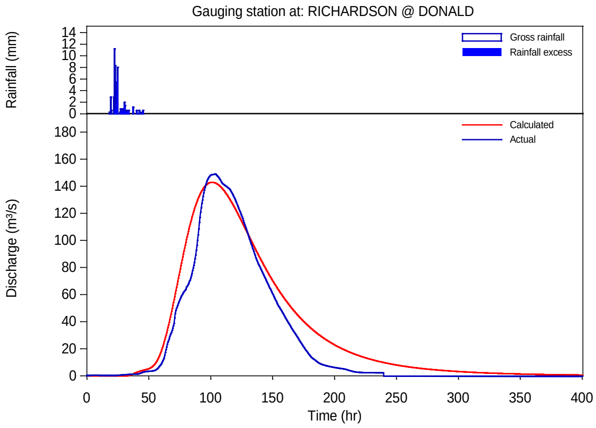


September 2010

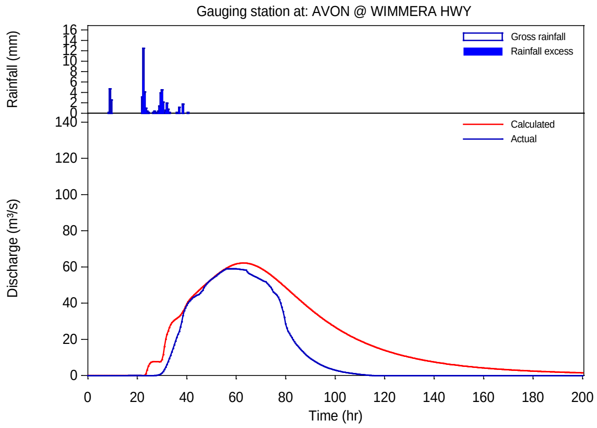


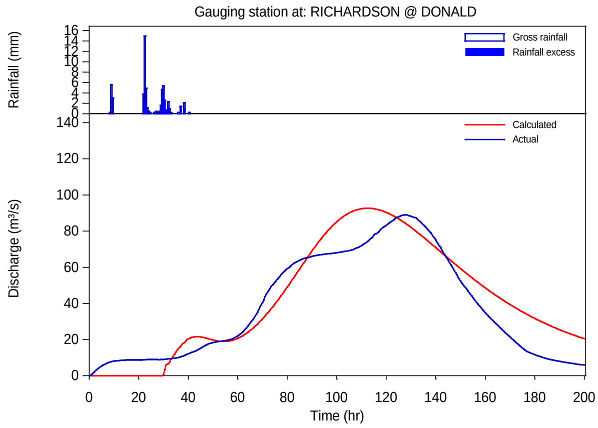


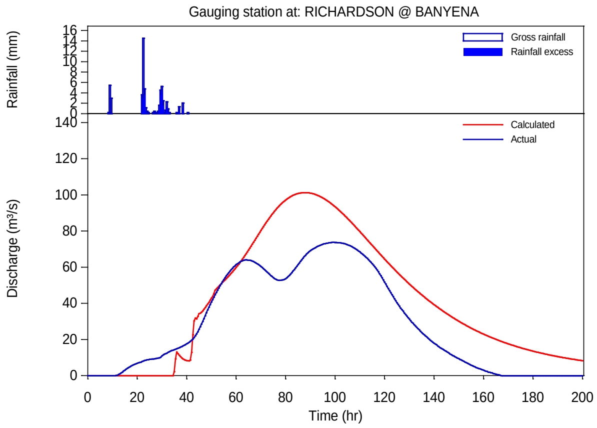




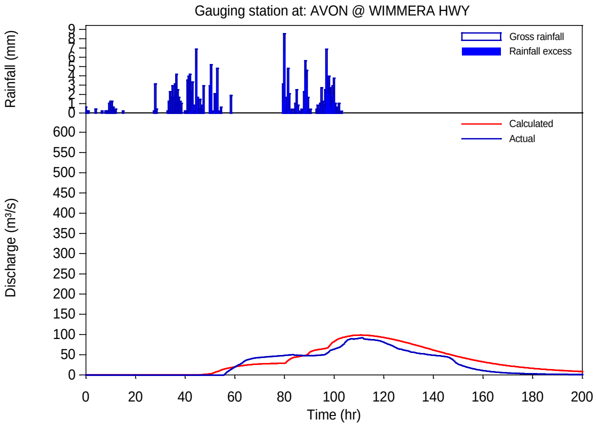
December 2010

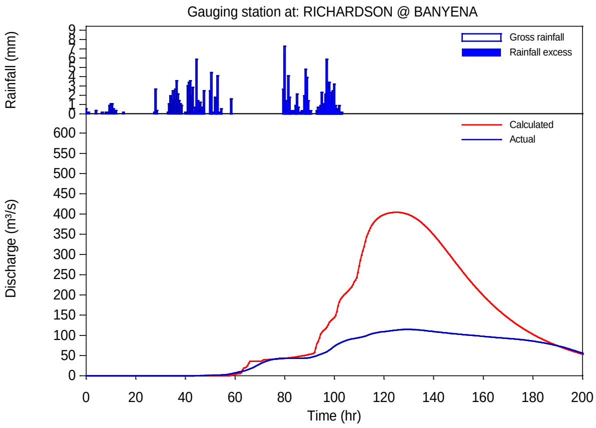


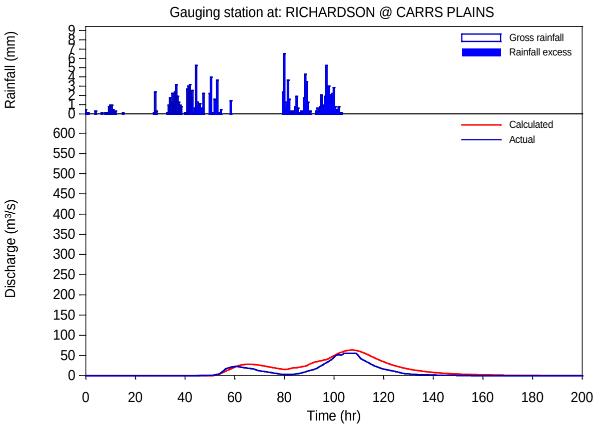


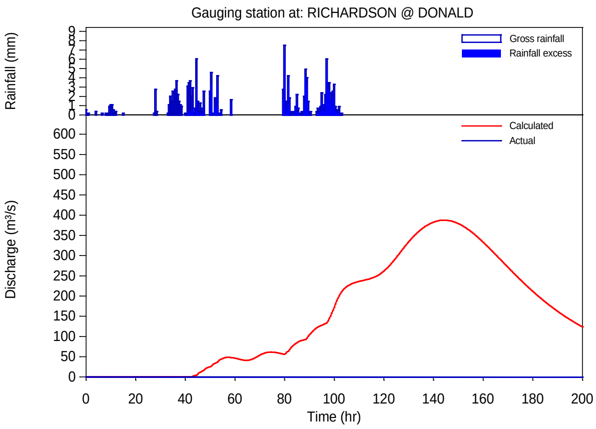


January 2011



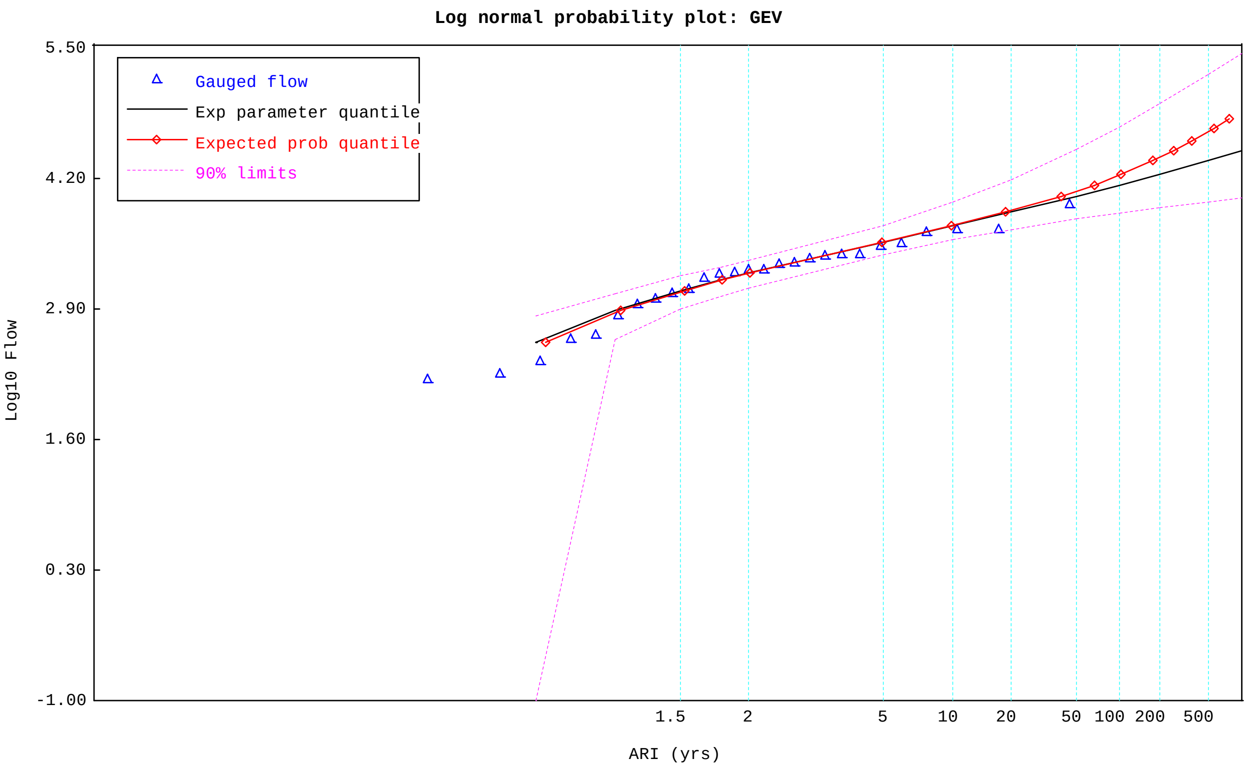






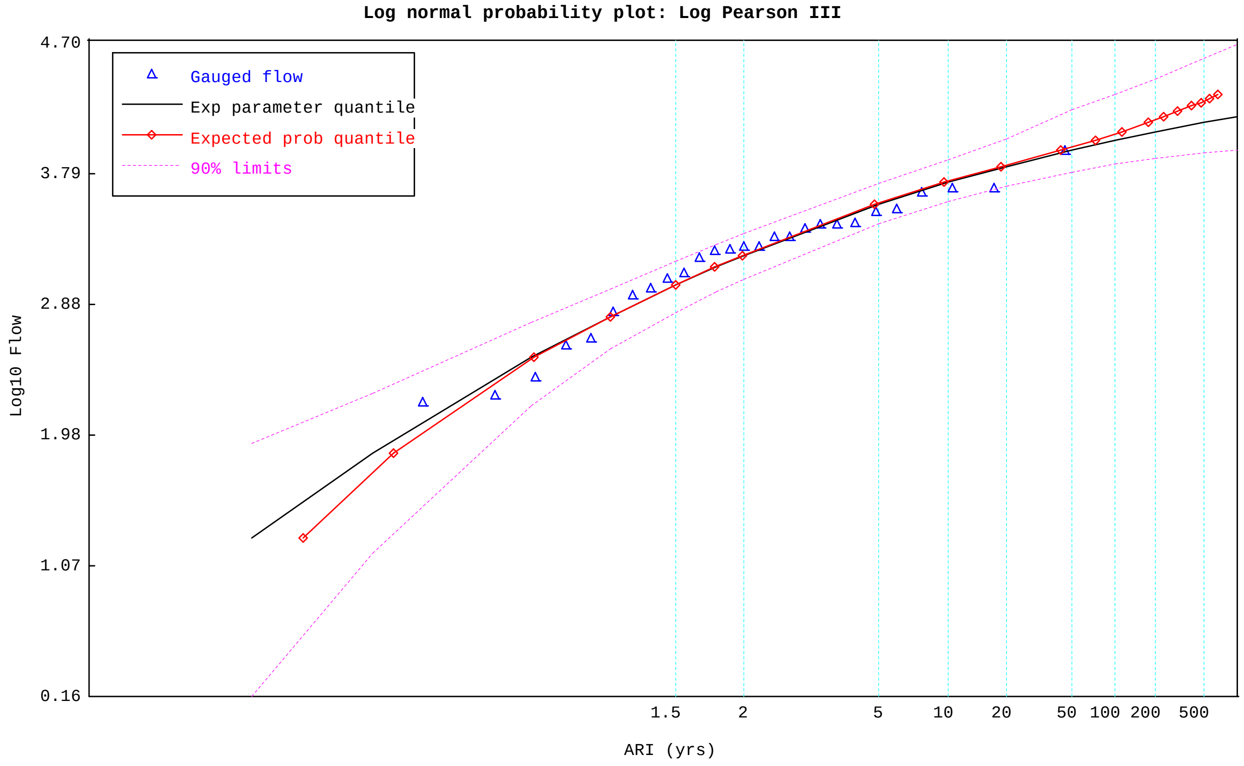
Appendix H – Flood Frequency Analysis

Carrs



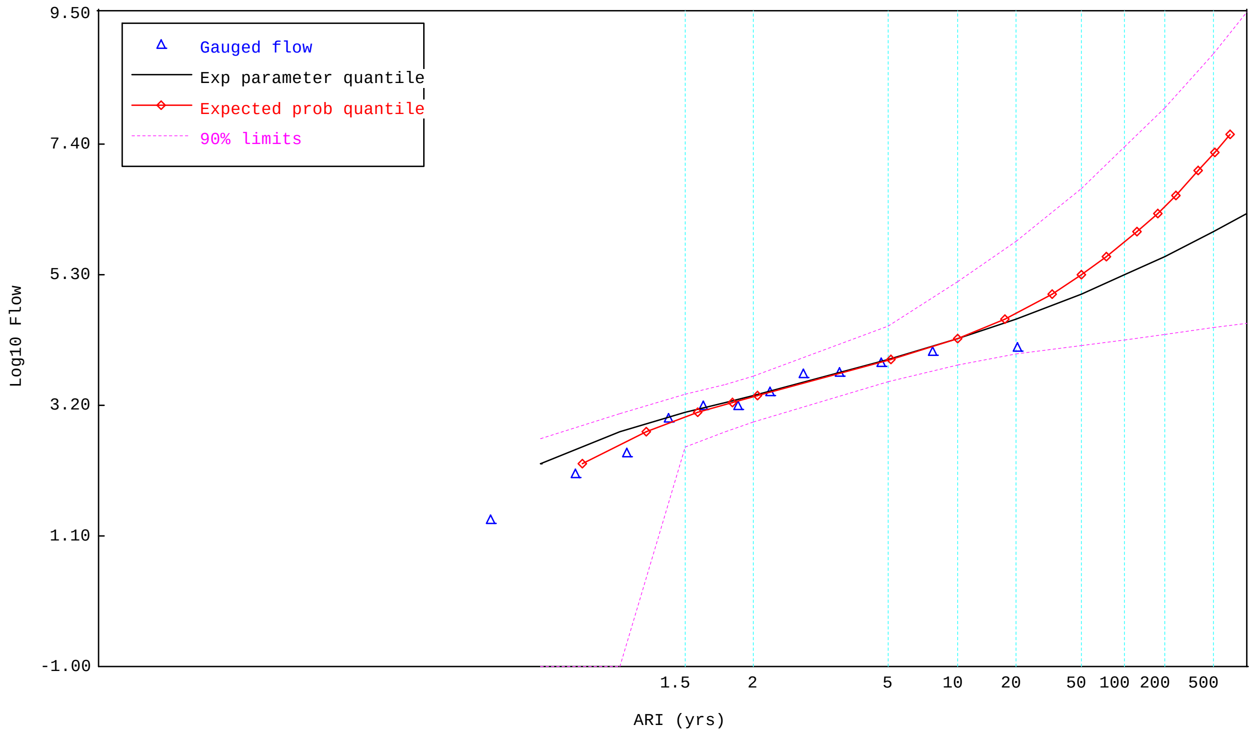
Log normal probability plot: GEV
Gauged flow
Exp parameter quantile
Expected prob quantile
90% limits
5.50
4.20
2.90
1.60
0.30
-1.00
Log10 Flow
1.5
2
5
10
20
50
100
200
500
ARI (yrs)

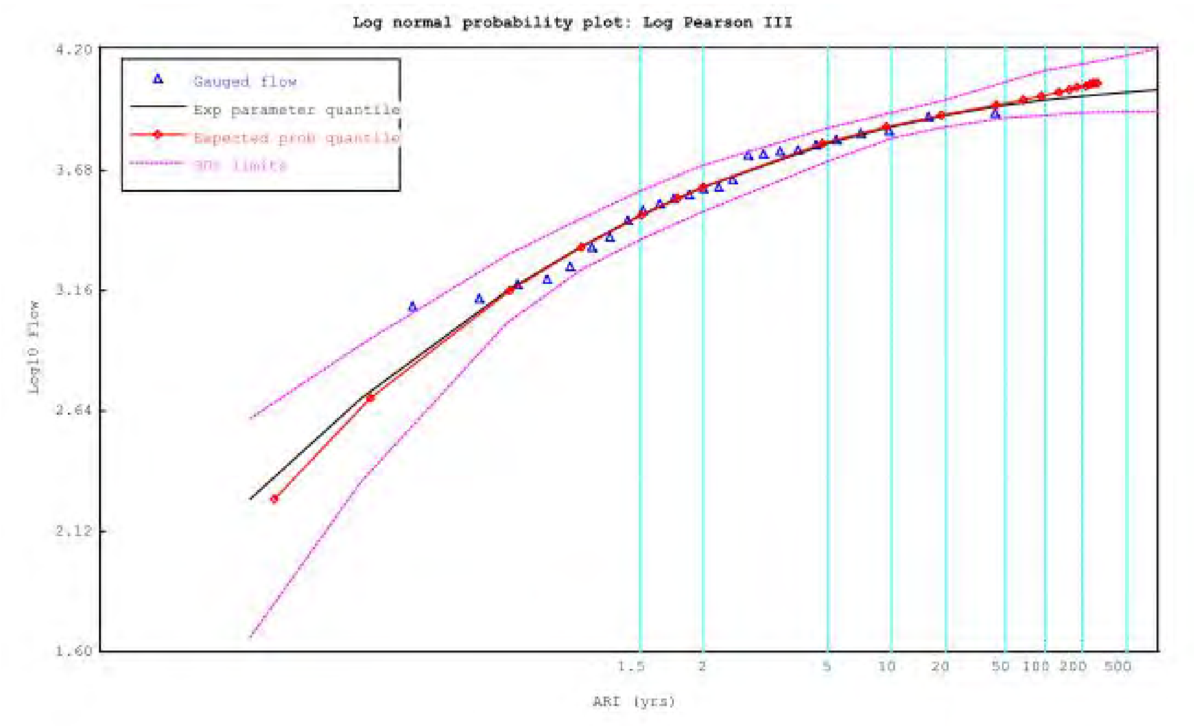
Carrs


Log normal probability plot: Log Pearson III
Gauged flow
Exp parameter quantile
Expected prob quantile
90% limits
4.70
3.79
2.88
1.98
1.07
0.16
Log10 Flow
1.5
2
5
10
20
50
100
200
500
ARI (yrs)

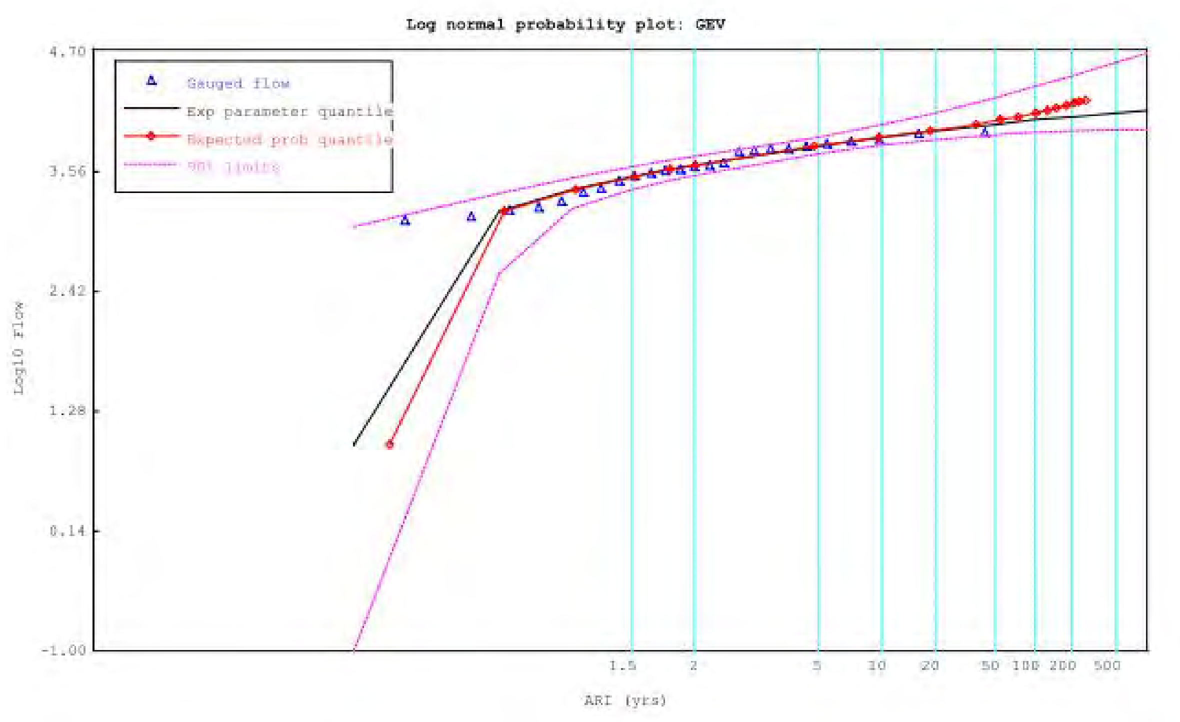
Donald

Log normal probability plot: GEV

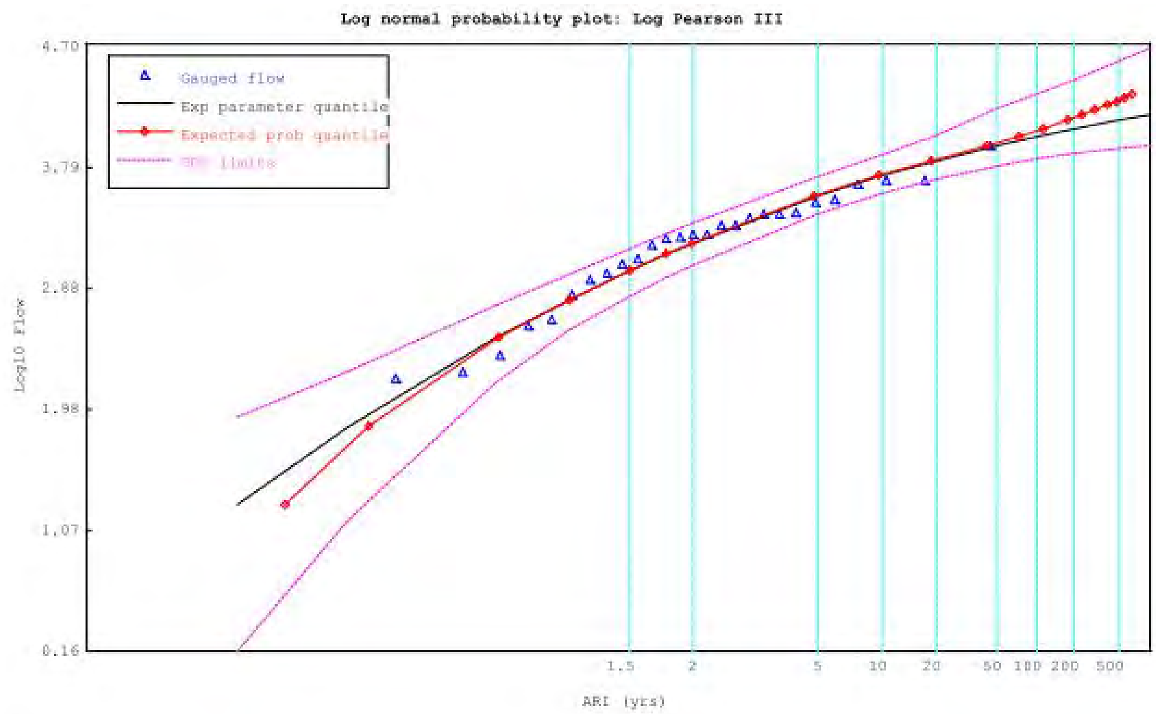




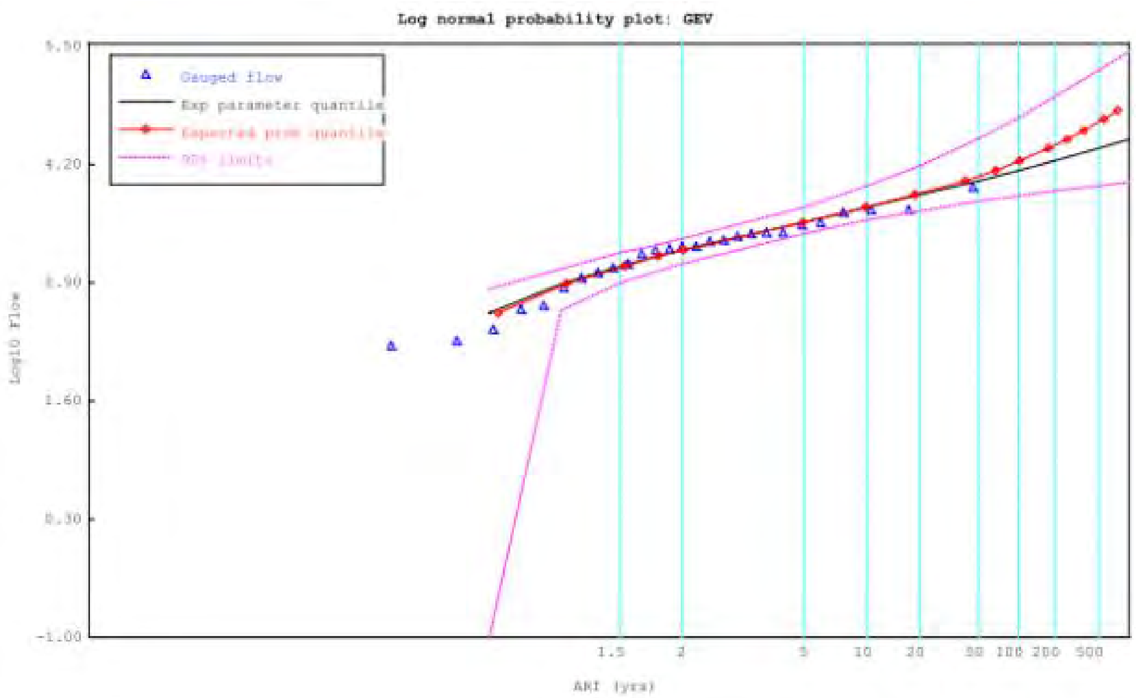
Avon River @ Wimmera Highway - LPIII



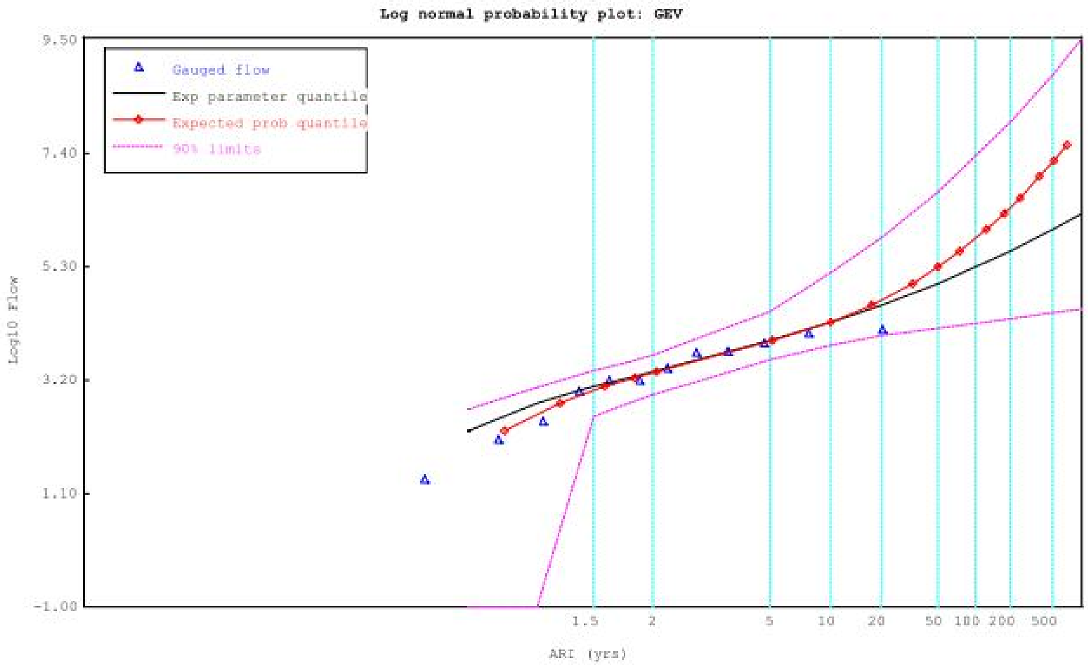
Avon @ Wimmera Highway - GEV



Richardson River @ Carrs Plains – LPIII



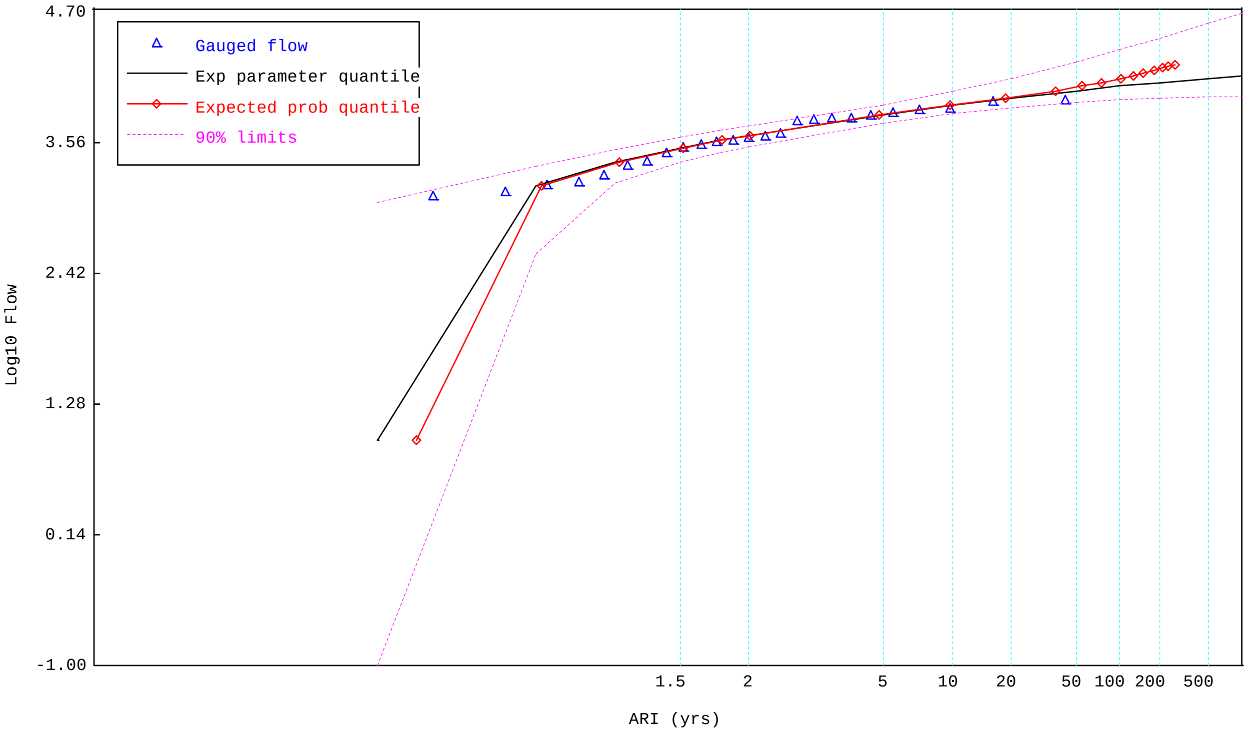
Richardson River @ Carrs Plains – GEV



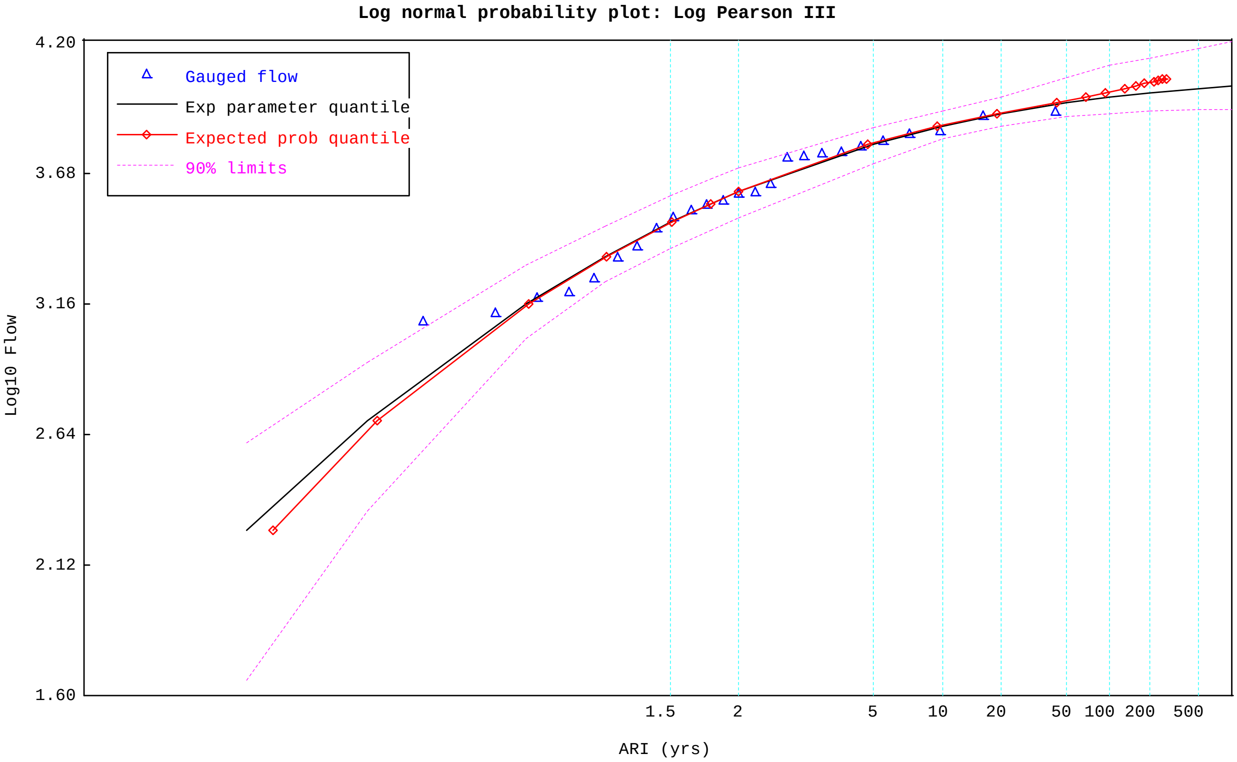
Richardson River @ Donald - GEV

Wimmear

Log normal probability plot: GEV

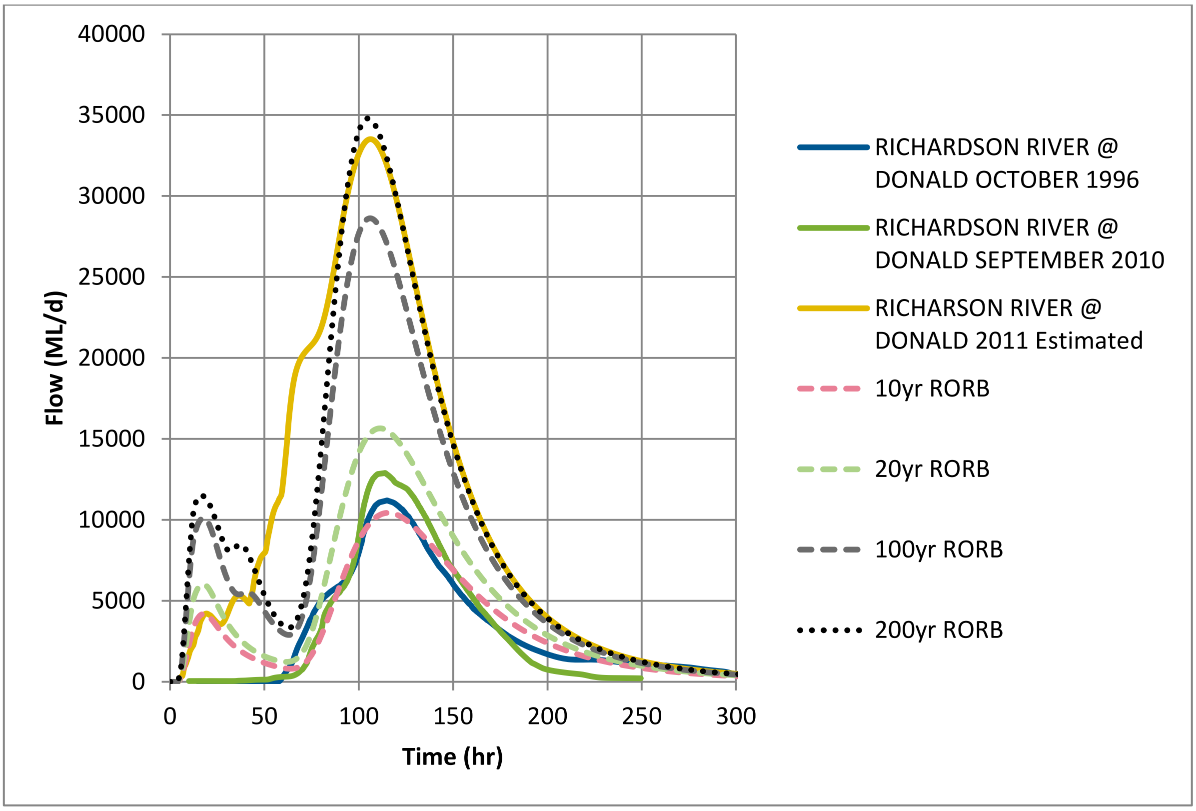


Wimmear



Log normal probability plot: Log Pearson III
Gauged flow
Exp parameter quantile
Expected prob quantile
90% limits
Log10 Flow
4.20
3.68
3.16
2.64
2.12
1.60
1.5
2
5
10
20
50
100
200
500
ARI (yrs)

Appendix I – Design Hydrographs versus Historical Hydrographs at 415257 (Richardson River @ Donald)

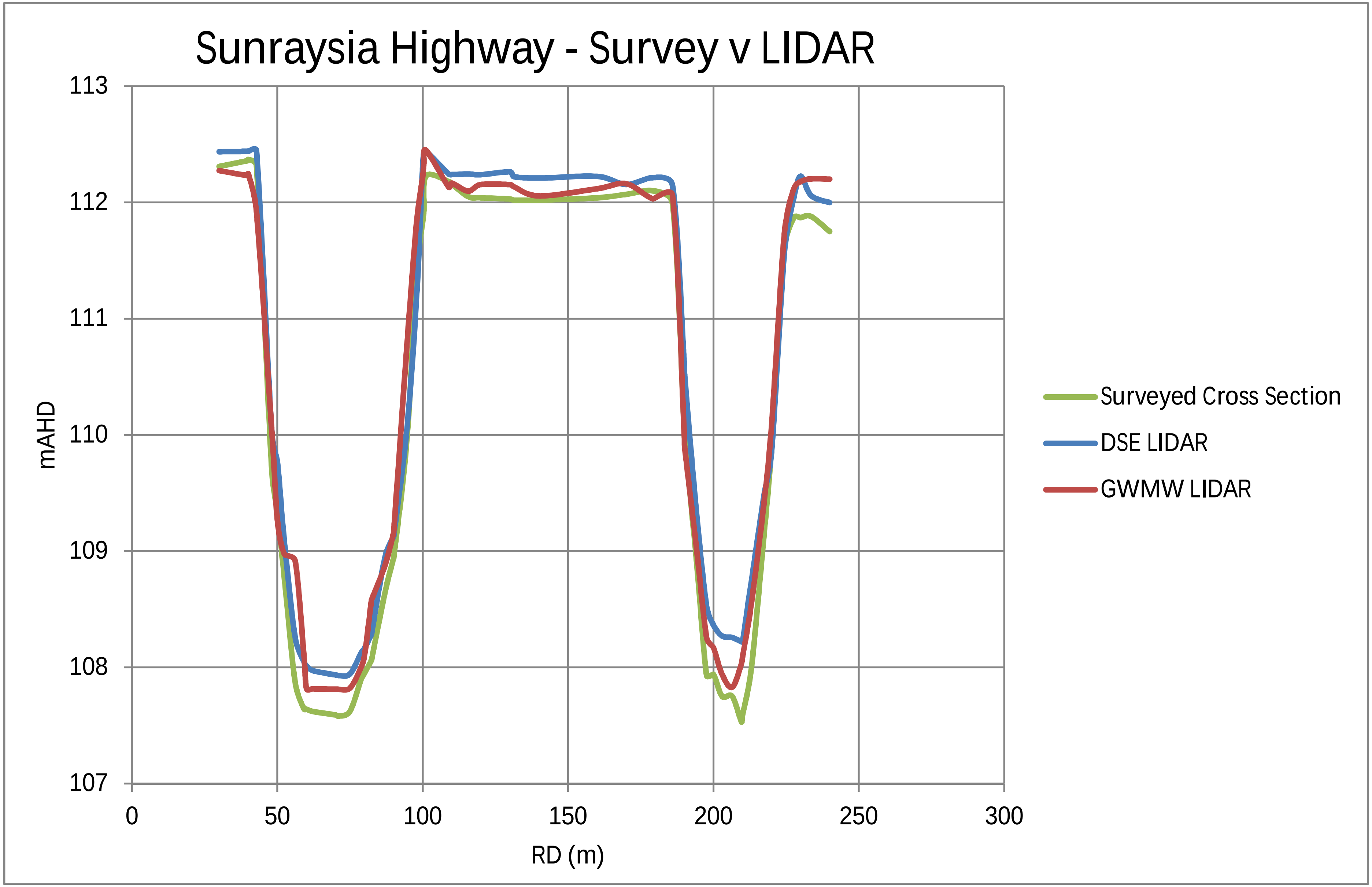


40000
35000
30000
25000
20000
15000
10000
5000
0
Flow (ML/d)
0
50
100
150
200
250
300
Time (hr)
RICHARDSON RIVER @ DONALD OCTOBER 1996
RICHARDSON RIVER @ DONALD SEPTEMBER 2010
RICHARSON RIVER @ DONALD 2011 Estimated
10yr RORB
20yr RORB
100yr RORB
200yr RORB

Appendix J – Survey compared to DEM's

Survey Level (mAHD) - Price Merrett	Easting	Northing	Comment	Level from DSE LIDAR (mAHD)	Difference	Level from GWMW LIDAR (mAHD)	Difference
112.76	677866.84	5972893.9	Byrne street	112.87	0.11	112.765	0.00
111.84	677838.01	5972929	Byrne street	112.01	0.17	111.903	0.06
111.46	677787.53	5972992.3	Byrne street	111.62	0.16	111.437	-0.02
111.43	677757.25	5973030.5	Byrne street	111.59	0.16	111.447	0.02
111.64	677744.78	5973050.7	Byrne street	111.81	0.17	111.633	-0.01
111.56	677738.31	5973069.3	Byrne street	111.75	0.19	111.575	0.02
111.13	677721.93	5973136.7	Byrne street	111.29	0.16	111.104	-0.03
110.93	677698.64	5973181	Byrne street	111.12	0.19	110.862	-0.07
110.94	677672.97	5973212.2	Byrne street	111.08	0.14	110.911	-0.03
111.16	677655.33	5973234.1	Byrne street	111.35	0.19	111.136	-0.02
111.24	677650.47	5973240.1	Int Camp & Byrne street	111.43	0.19	111.236	0.00
110.94	677629.29	5973224.2	Camp st	111.16	0.22	110.906	-0.03
114.55	677937.22	5972806.4	Byrne street	114.67	0.12	114.498	-0.05
114.33	677916.06	5972833	Byrne street	114.46	0.13	114.285	-0.05
113.97	677896.43	5972857.3	Byrne street	114.07	0.10	113.929	-0.04
112.11	677849.1	5972876.2	NS at toe of Byrne St Bank	112.3	0.19	112.111	0.00
111.84	677833.93	5972884.6	NS at toe of Byrne St Bank	112	0.16	111.905	0.06
111.93	677824.17	5972891.9	NS at toe of Byrne St Bank	112.07	0.14	111.9	-0.03
111.78	677739.47	5973047.1	NS at toe of Byrne St Bank	111.97	0.19	111.833	0.05
111.57	677733.1	5973067.3	NS at toe of Byrne St Bank	111.73	0.16	111.623	0.05
111.2	677726.51	5973093.5	NS at toe of Byrne St Bank	111.36	0.16	111.19	-0.01
111.02	677721.9	5973112.1	NS at toe of Byrne St Bank	111.17	0.15	111.055	0.04
110.99	677710.8	5973135.5	NS at toe of Byrne St Bank	111.2	0.21	111.023	0.03
110.74	677684.25	5973168.9	NS at toe of Byrne St Bank	110.98	0.24	110.739	0.00
110.94	677645.73	5973222.4	NS at toe of Byrne St Bank	111.16	0.22	110.901	-0.04
110.78	677632.21	5973220.5	NS at toe of Byrne St Bank	110.99	0.21	110.844	0.06
110.85	677658.62	5973205.9	NS at toe of Byrne St Bank	111.05	0.20	110.787	-0.06
113.7	677929	5972798.2	NS at toe of Byrne St Bank	113.89	0.19	113.65	-0.05
113.84	677921.14	5972814.3	NS at toe of Byrne St Bank	114.07	0.23	113.979	0.14
114.12	677912.54	5972829.2	NS at toe of Byrne St Bank	114.24	0.12	114.07	-0.05
113.72	677892.95	5972852.6	NS at toe of Byrne St Bank	113.84	0.12	113.633	-0.09
113.4	677885.48	5972858.5	NS at toe of Byrne St Bank	113.56	0.16	113.437	0.04
112.77	677873.08	5972868.1	NS at toe of Byrne St Bank	112.97	0.20	112.736	-0.03
111.4	677832.07	5972921.8	NS at toe of Byrne St Bank	111.62	0.22	111.541	0.14
111.27	677818.07	5972939.2	NS at toe of Byrne St Bank	111.47	0.20	111.397	0.13
111	677782	5972986.1	NS at toe of Byrne St Bank	111.18	0.18	111.071	0.07
110.72	677763.6	5973009	NS at toe of Byrne St Bank	110.99	0.27	110.984	0.26
111.24	677752.47	5973024.9	NS at toe of Byrne St Bank	111.45	0.21	111.385	0.15
112.31	677648.74	5973315	Natural Surface at house	112.79	0.48	112.441	0.13
112.36	677618.79	5973343.6	Natural Surface at house	112.6	0.24	112.416	0.06
112.26	677604.16	5973356.1	Natural Surface at house	112.47	0.21	112.289	0.03
112.05	677592.8	5973372.3	Natural Surface at house	112.23	0.18	112.085	0.03
110.95	677603.45	5973493.1	Natural Surface at house	111.44	0.49	111.247	0.30
113.58	677192.29	5973177	Natural Surface at house	113.68	0.10	113.636	0.06
113.4	677210.92	5973173.5	Natural Surface at house	113.6	0.20	113.553	0.15
113.28	677233.05	5973170.4	Natural Surface at house	113.49	0.21	113.372	0.09
113.25	677255.57	5973168.1	Natural Surface at house	113.4	0.15	113.17	-0.08
113.27	677812.24	5973477.4	Natural Surface at house	113.28	0.01	113.184	-0.09
113.41	677869.79	5973495.5	Natural Surface at house	113.48	0.07	113.556	0.15
113.42	677383.68	5973632.7	Natural Surface at house	113.5	0.08	113.441	0.02
113.52	677367.76	5973659.7	Natural Surface at house	113.69	0.17	113.527	0.01
112.92	677416	5973714.2	Natural Surface at house	113.06	0.14	112.913	-0.01
111.97	677524.54	5973665.4	Natural Surface at house	112.41	0.44	112.204	0.23
112.73	677445.01	5973746.2	Natural Surface at house	112.83	0.10	112.609	-0.12
112.65	677459.52	5973758.1	Natural Surface at house	112.83	0.18	112.604	-0.05
112.58	677474.03	5973772.2	Natural Surface at house	112.73	0.15	112.495	-0.08
112.6	677485.15	5973790.3	Natural Surface at house	112.67	0.07	112.502	-0.10
112.48	677502.22	5973804.3	Natural Surface at house	112.59	0.11	112.311	-0.17
				Average Difference	0.18	Average Difference	0.02

Survey Level (mAHD) - Price Merrett	Easting	Northing	Comment	Level from DSE LIDAR (mAHD)	Difference	Level from GWMW LIDAR (mAHD)	Difference
113.17	678348	5971976	Natural Surface at Peg 1	113.26	0.09	113.183	0.013
113.04	678362.9	5972364	Natural Surface at Peg 2	113.22	0.18	113.187	0.147
113.01	678230.7	5972607	Natural Surface at Peg 4	113.23	0.22	113.128	0.118
112.7	677878.3	5972854	Natural Surface at Peg 6	113.06	0.36	112.873	0.173
112.67	677812.8	5973057	Natural Surface at Peg 7	112.93	0.26	112.803	0.133
112.62	677695.8	5973264	Natural Surface at Chinese Restaurant	112.41	-0.21	112.267	-0.353
112.12	677688.2	5973284	Natural Surface at F0009	112.32	0.2	112.26	0.14
112.08	677823.8	5973494	Natural Surface at Peg 8	112.38	0.3	112.359	0.279
112.18	677875.7	5973509	Natural Surface at Peg 9	112.34	0.16	112.248	0.068
112.1	677950.7	5973604	Natural Surface at Peg 10	112.5	0.4	112.449	0.349
111.57	678204.8	5973791	Natural Surface at Peg 11	111.83	0.26	111.885	0.315
111.05	678470.8	5974194	Natural Surface at F0014	111.29	0.24	111.227	0.177
111.15	678463.3	5974209	Natural Surface at F0015	111.37	0.22	111.199	0.049
111.63	678489.7	5974256	Natural Surface at Peg 12	112.1	0.47	112.063	0.433
111.82	677740.7	5973160	Natural Surface at F0018	111.82	0	111.709	-0.111
111.62	677575.1	5973402	Natural Surface at F0019	111.86	0.24	111.577	-0.043
111.94	677578.5	5973417	Natural Surface at Bridge Armco	112.43	0.49	112.212	0.272
112.53	677358.4	5973573	Natural Surface at Peg 14	112.66	0.13	112.484	-0.046
112.16	677389.5	5973598	Natural Surface at Peg 15	112.23	0.07	112.031	-0.129
112.43	677271.5	5973348	Natural Surface at Peg 17	112.77	0.34	112.369	-0.061
112.37	677273.5	5973452	Natural Surface at Peg 16	112.75	0.38	112.504	0.134
112.63	677286.2	5973147	Natural Surface at Peg 18	112.81	0.18	112.673	0.043
112.69	677382	5973001	Natural Surface at Peg 19	113.38	0.69	112.921	0.231
112.74	677436.3	5972937	Natural Surface at Peg 20	113.06	0.32	112.93	0.19
111.3	677439.4	5973110	Natural Surface at F0029	111.63	0.33	111.44	0.14
112.02	677559.5	5973883	Natural Surface at Peg 21	112.19	0.17	111.934	-0.086
				Average Difference	0.25	Average Difference	0.10



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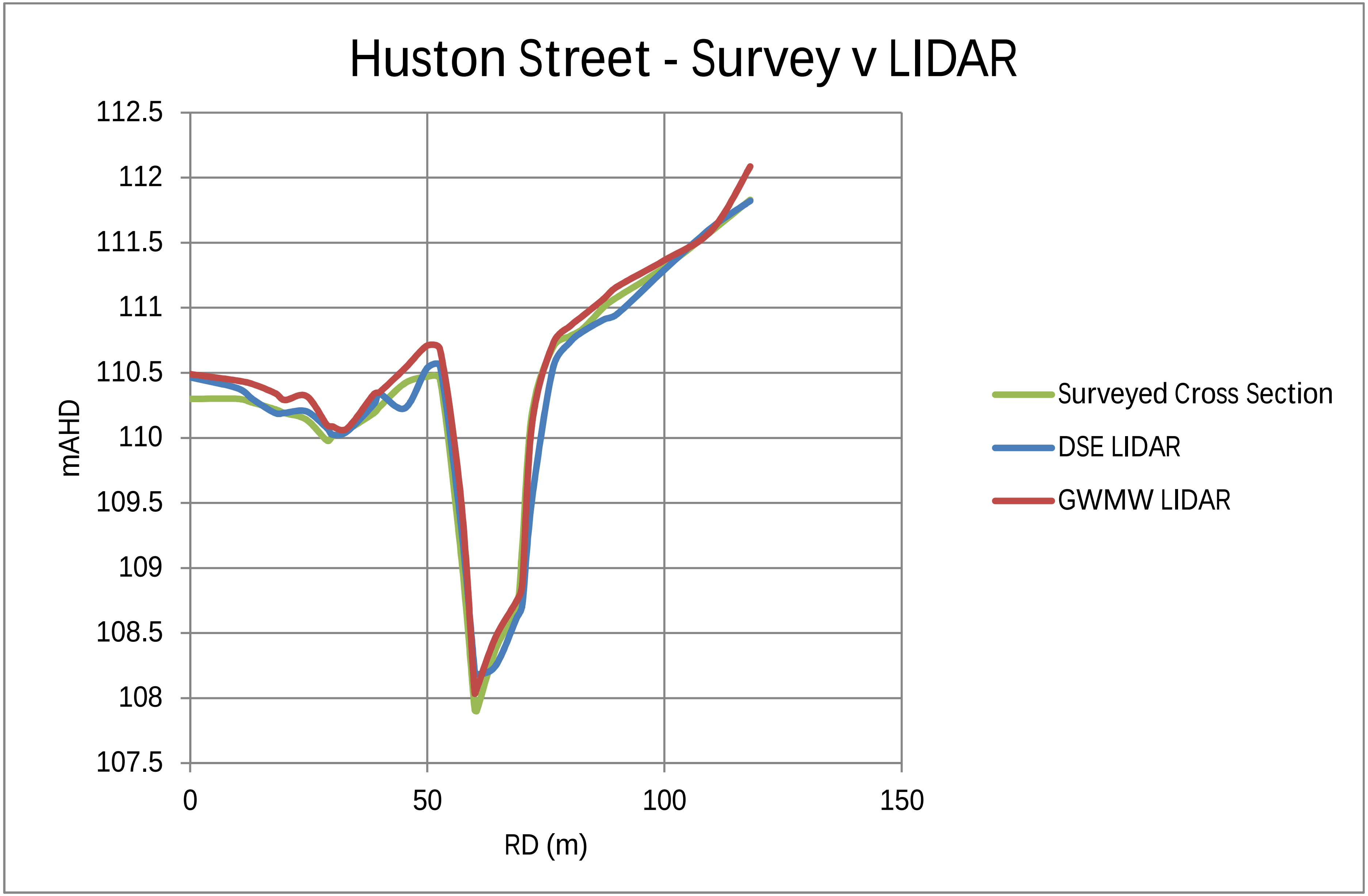

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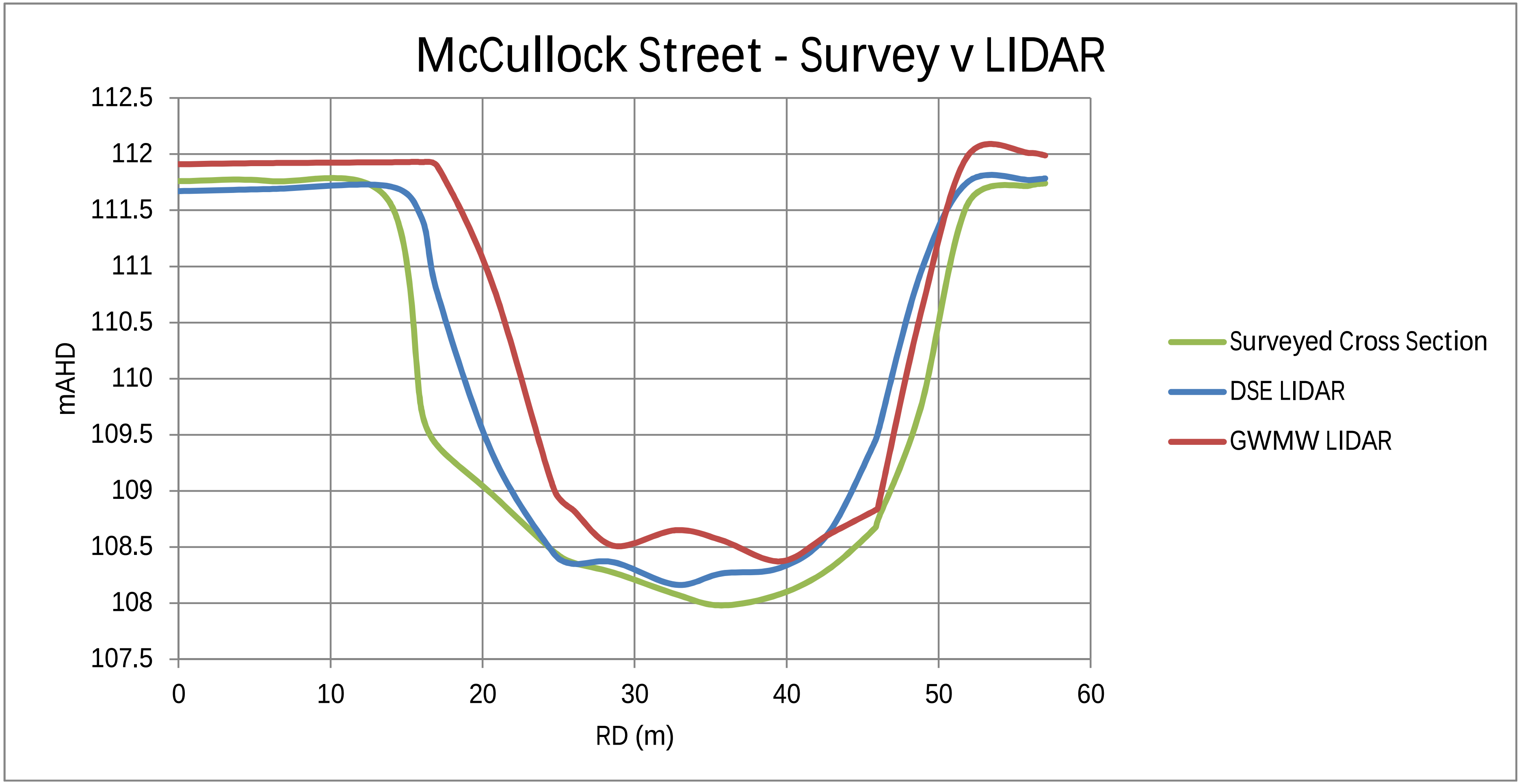

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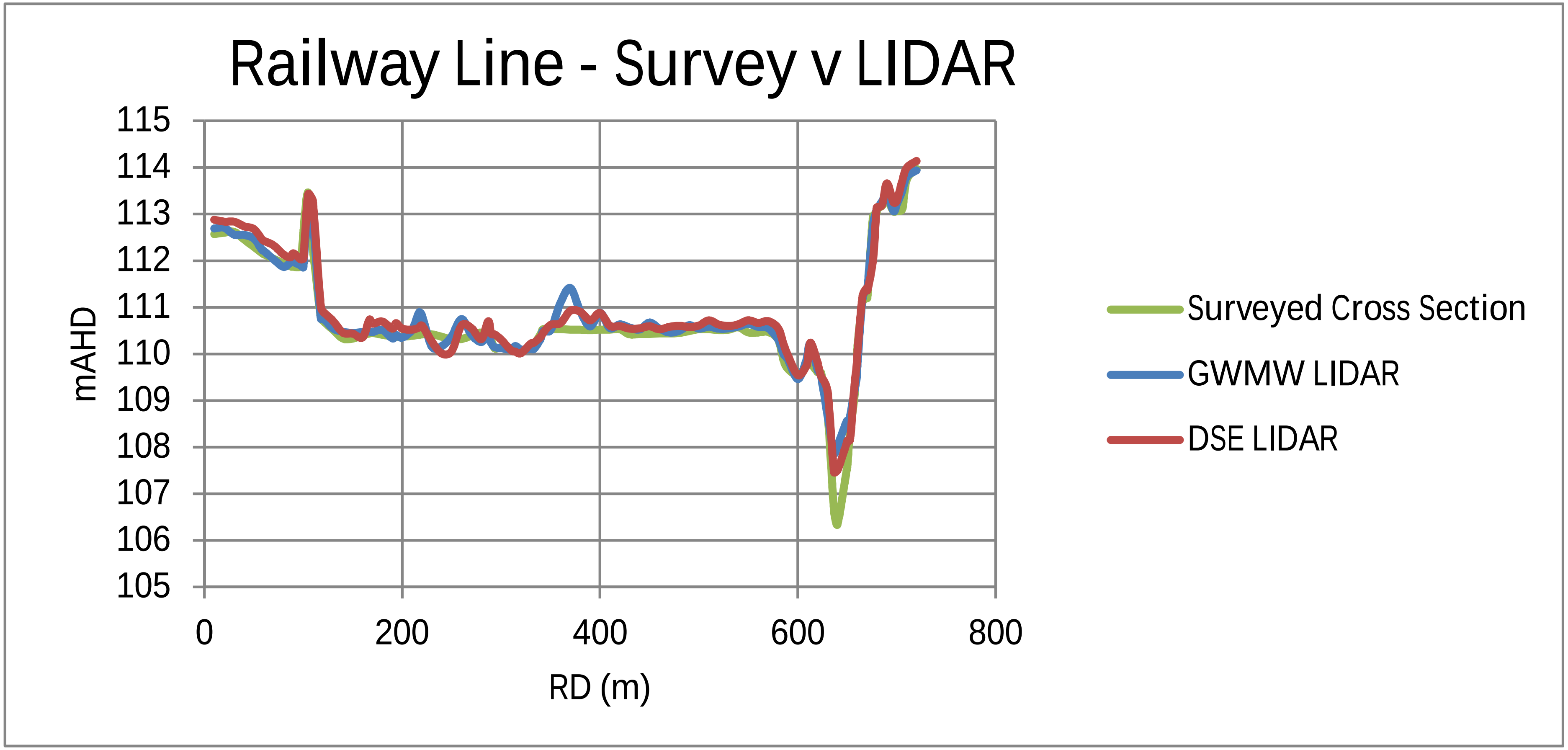
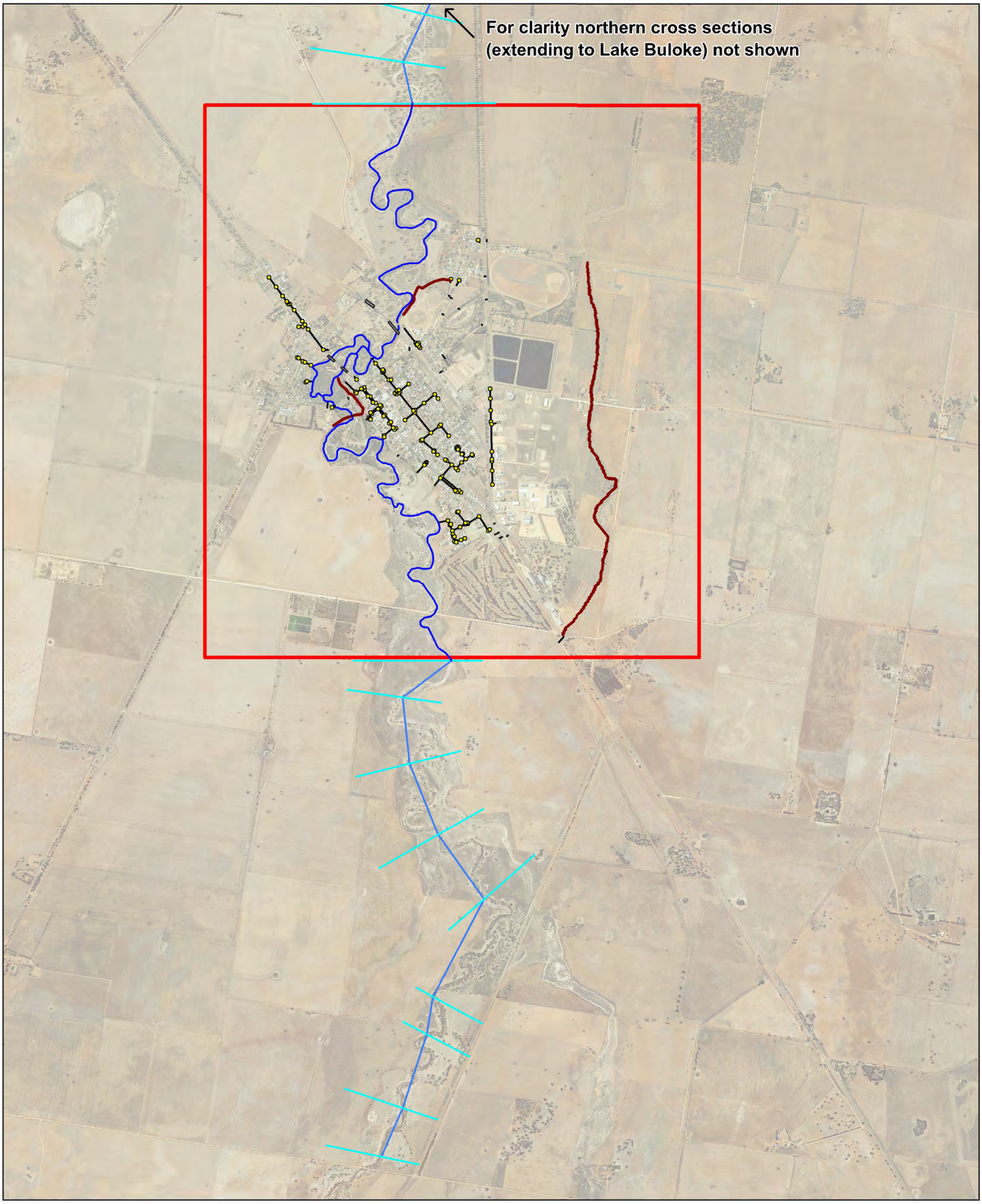


G:\31\28519\GIS\Data\Elevation\Railway GWM.xlsm

Appendix K – TUFLOW Model Layout



LEGEND

- 2D Z-Shape (Levee)
- 2D Z-Shape (River)
- 1D Network Channel
- 1D Network Cross Section
- 1D Network Pipe
- Pipe Boundary Condition
- 2D Layered Flow Constriction
- TUFLOW Boundary

Paper Size A3

0 300 600 900 1200 1500

Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 54

N

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Donald Flood Investigation

Job Number	31-28519
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Date	01/11/2012

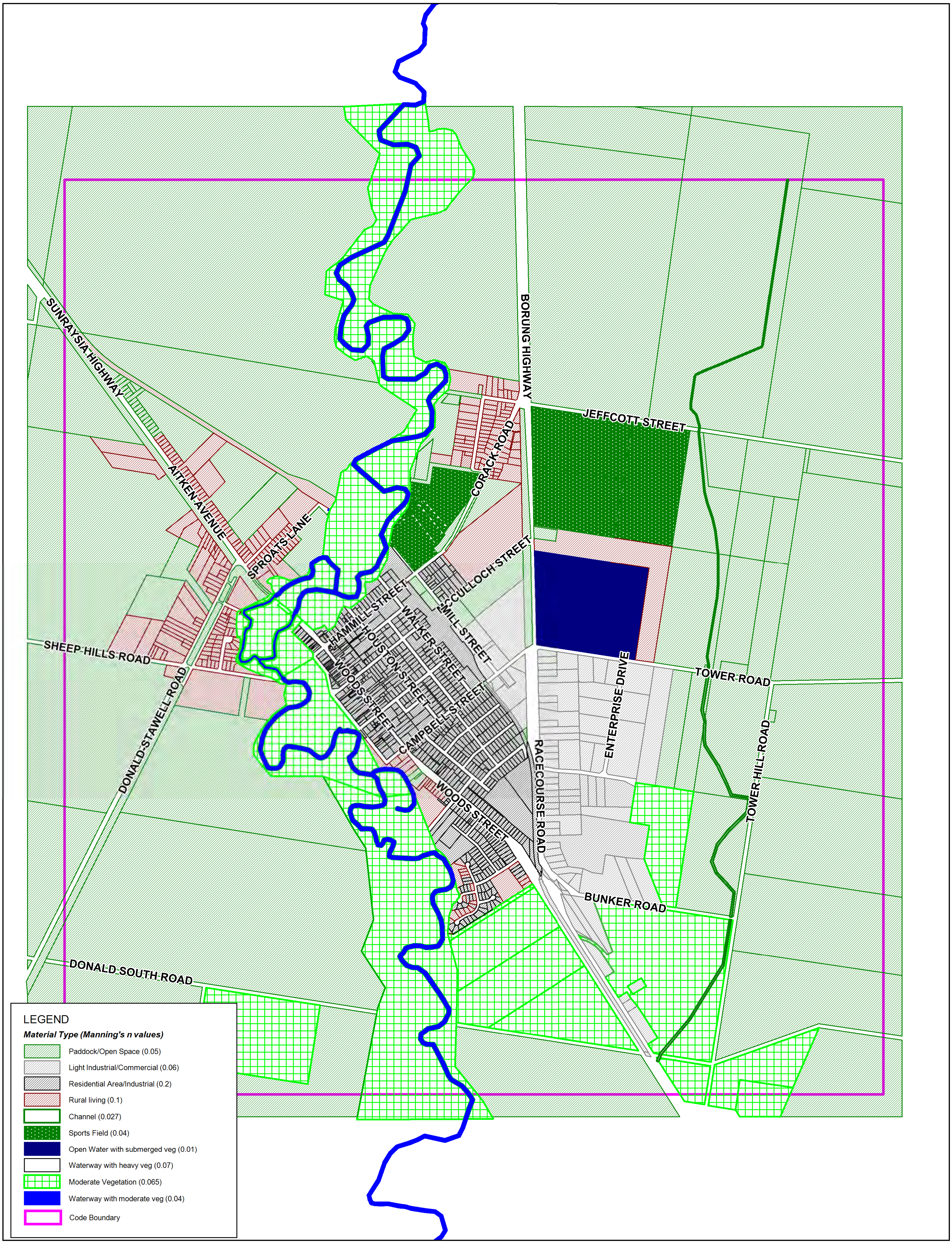
TUFLOW Model Layout

Appendix K1

G:\31\28519\GIS\Maps\Working\Donald- Figures for Report.wor

8/180 Lonsdale St Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au W www.ghd.com.au

Data source: DSE, VicMap, 2012: GHD, TUFLOW Model. Created by: scowan



Paper Size A3

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Metres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 54

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Date | 01/11/2012

TUFLOW Materials Layer

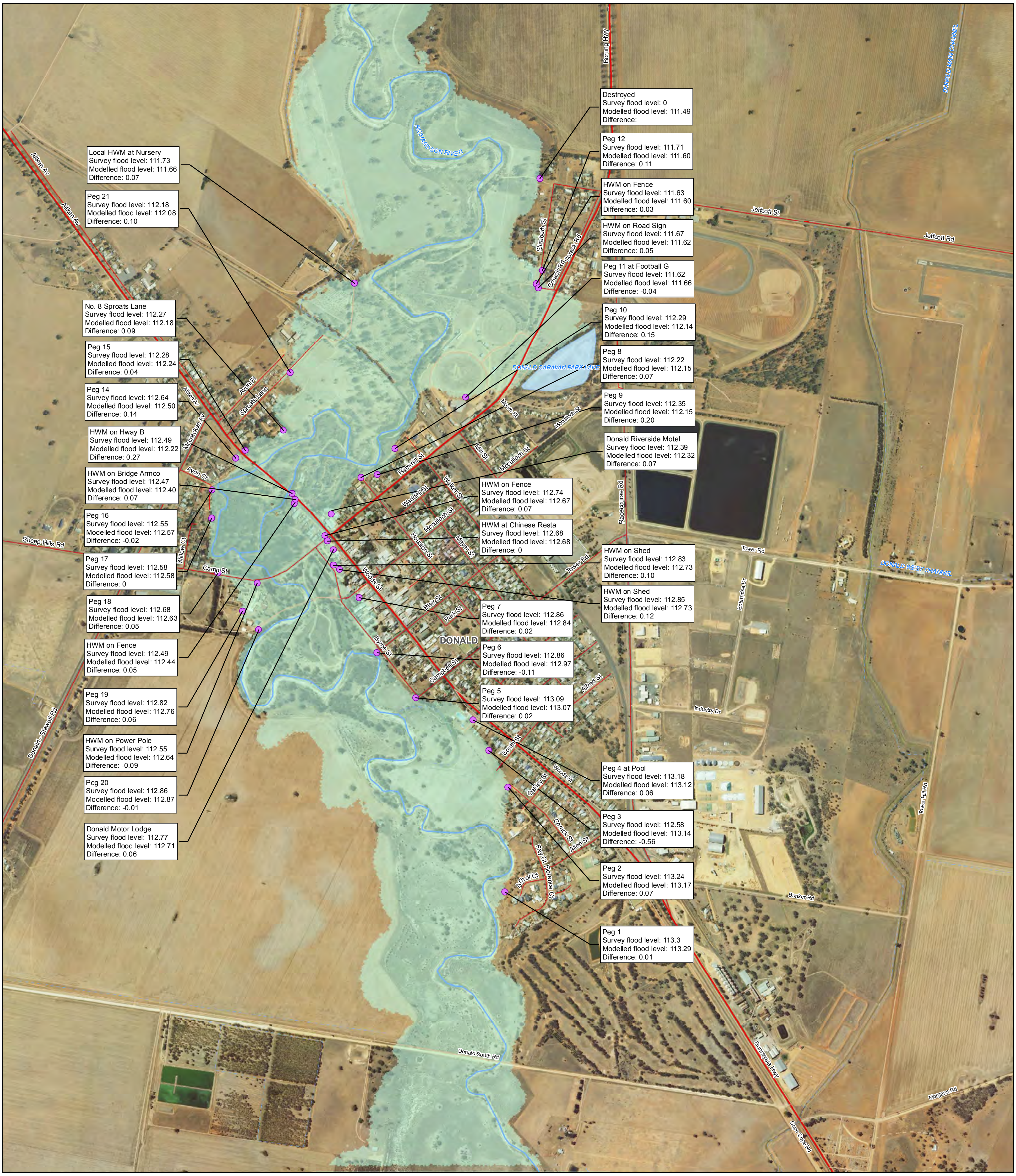
Appendix K2

G:\31\28519\GIS\Maps\Working\Donald- Figures for Report.wor

8/180 Lonsdale St Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au W www.ghd.com.au

Data source: DSE, VicMap, 2012: GHD, TUFLOW Model. Created by: scowan

Appendix L – TUFLOW Calibration Results



Legend

- Survey Flood Level (mAHD)
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain
- January 2011 Modelled Flood Extent

Paper Size A2

0 90 180 360 540 720

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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January 2011 Flood Event
(River Flood Only)

Job Number	31-28519
Revision	A
Date	16 May 2014

Appendix L1

G:\31\28519\GIS\Maps\Deliverables\3128519_006_Donald_Township_Jan2011_Event_A2P.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Legend

- Survey Flood Level (mAHD)
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain
- September 2010 Modelled Flood Extent
- Parks

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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September 2010 Flood Event
(River Flood Only)

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Appendix L2

G:\31\28519\GIS\Maps\Deliverables\3128519_005_Donald_Township_Sep2010_Event_A2P.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

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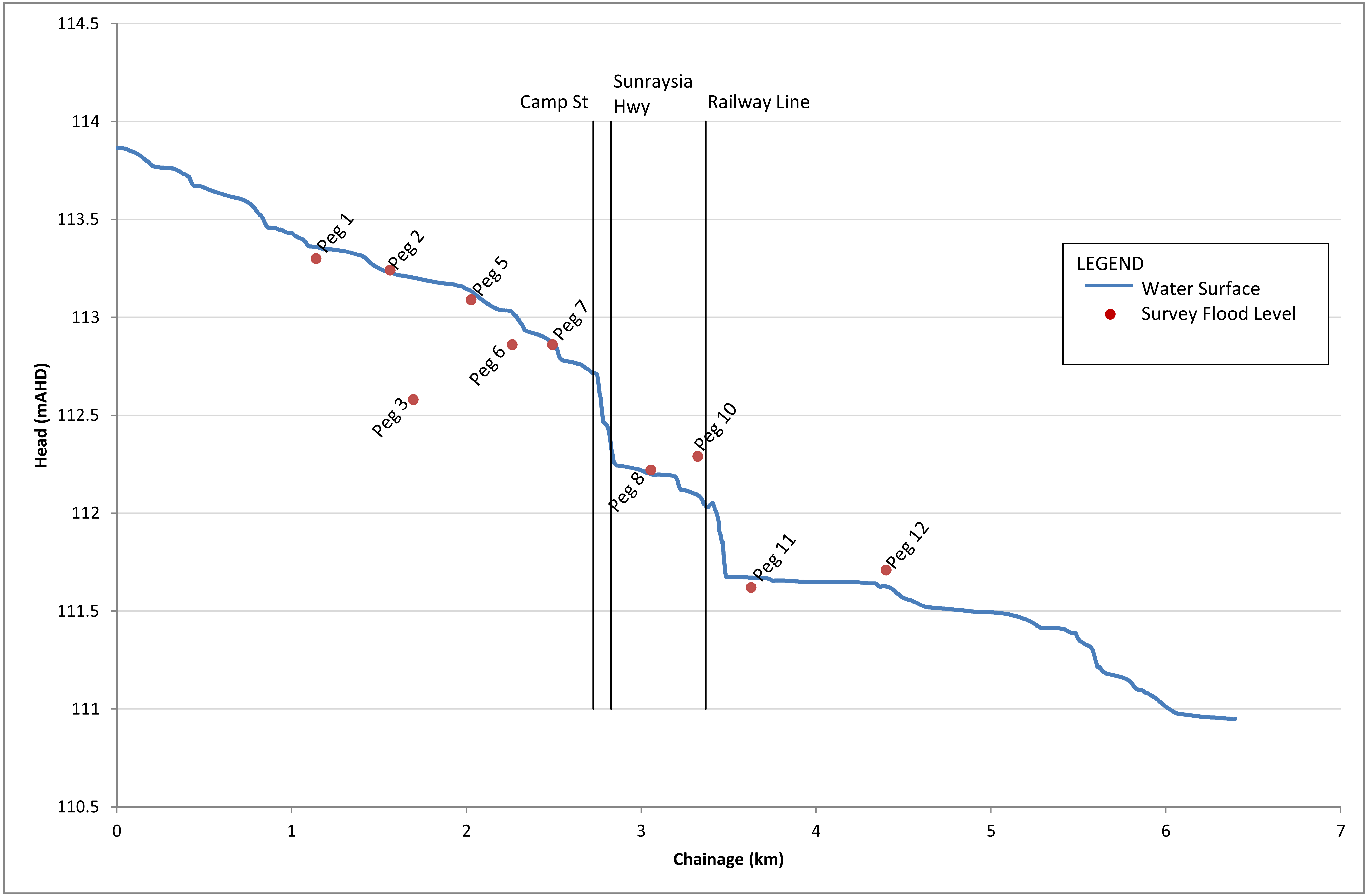
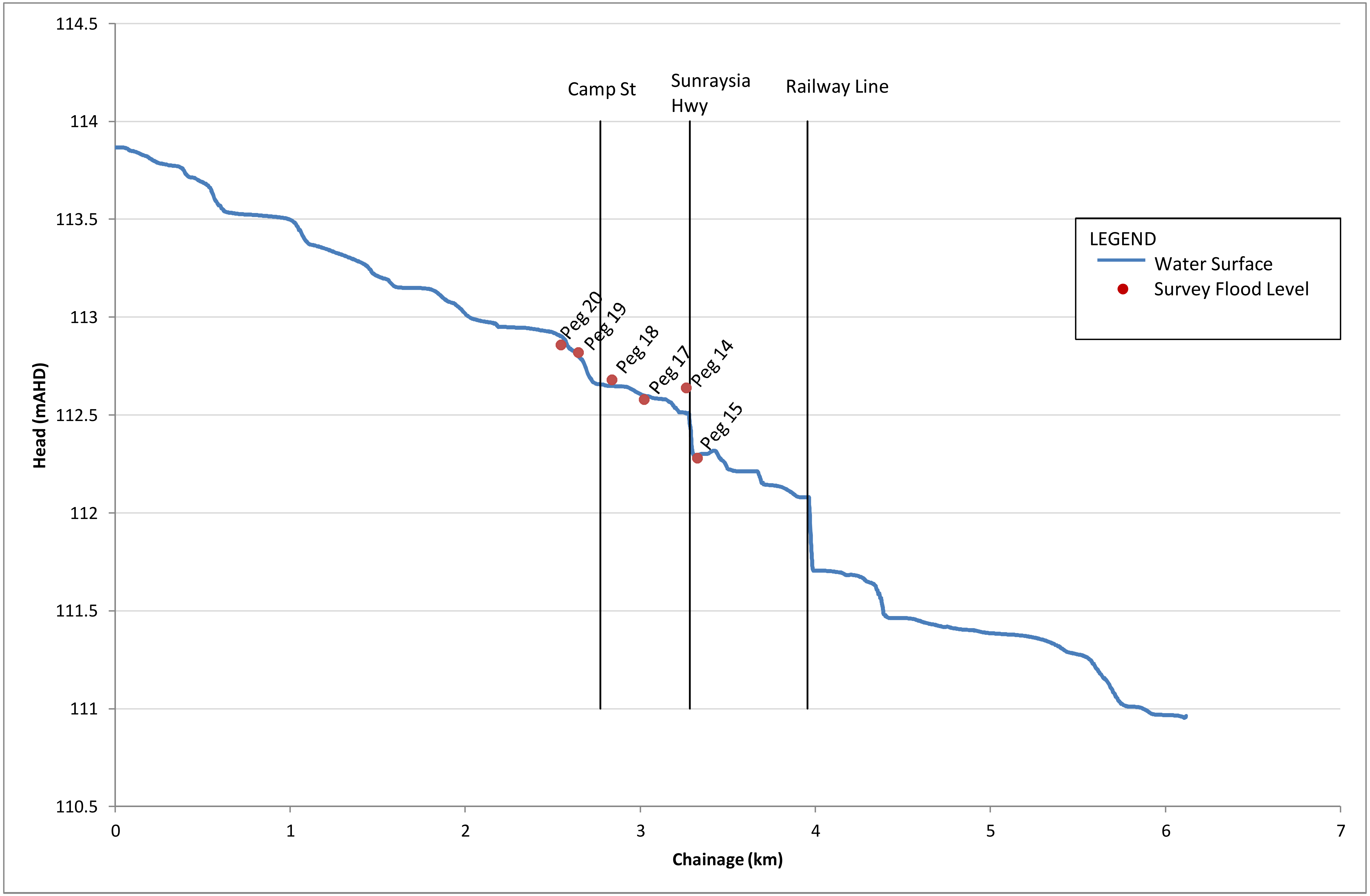
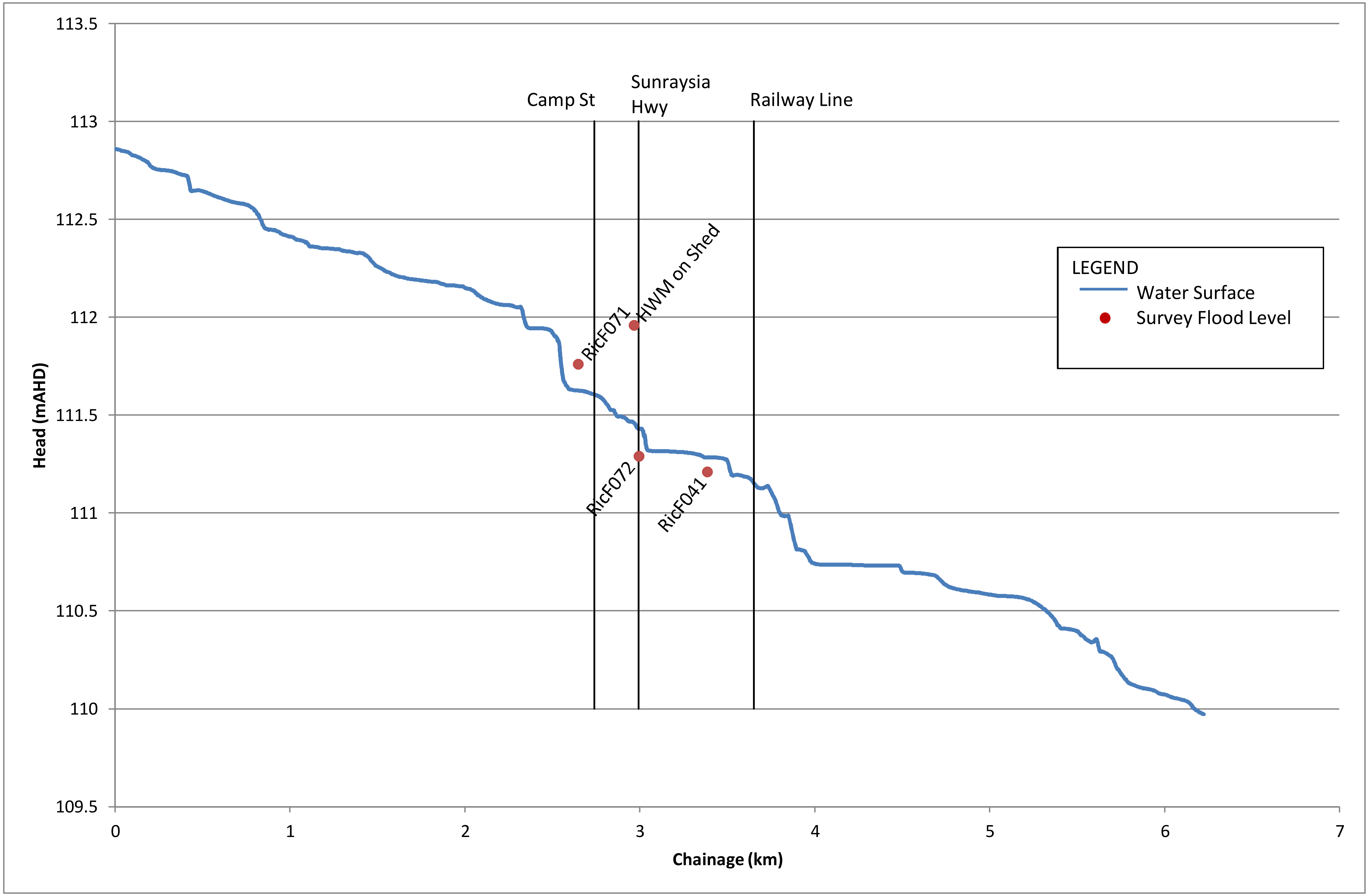
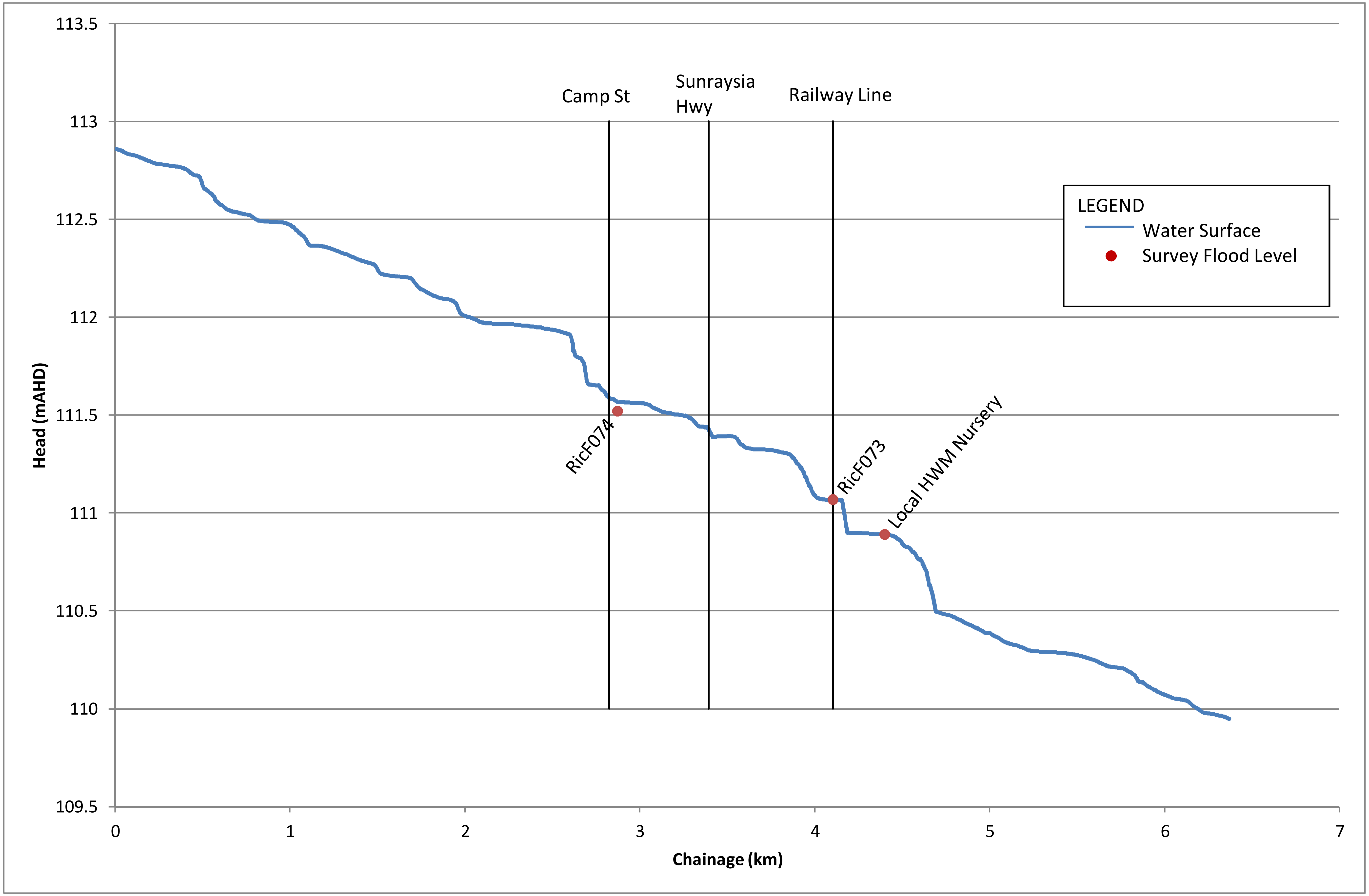


G:\31\28519\GIS\Data\InlandWaters\Long Section Water Surface Profiles\Long Section Water Surface Profiles.xlsxLong Section Water Surface Profiles.xlsx





113.5
113
112.5
112
111.5
111
110.5
110
109.5
Head (mAHD)
0
1
2
3
4
5
6
7
Chainage (km)
Camp St
Sunraysia Hwy
Railway Line
RicF071
HWM on Shed
RicF072
RicF041
LEGEND
Water Surface
Survey Flood Level


113.5
113
112.5
112
111.5
111
110.5
110
109.5
Head (mAHD)
0
1
2
3
4
5
6
7
Chainage (km)
Camp St
Sunraysia Hwy
Railway Line
RicF074
RicF073
Local HWM Nursery
LEGEND
Water Surface
Survey Flood Level

Appendix M – Sketch of Levee

LEVEE LOCATION PLAN


EXISTING CONDITIONS - VIEW 1 LOOKING WEST ALONG BYRNE ST


LEVEE 2 - VIEW 1 LOOKING WEST ON BYRNE ST

EXISTING CONDITIONS - VIEW 2 LOOKING WEST ON CAMP ST

LEVEE 2 - VIEW 2 LOOKING WEST ALONG CAMP ST

NOTE: The images are an artists' impression of the proposed levee and are for indicative purpose only.

NORTH CENTRAL CMA

Donald Flood and Drainage Investigation

NORTH CENTRAL Catchment Management Authority
Connecting Rivers, Landscapes, People

date: FEB 2013
job no: 31-28519
drawing: SK001

GHD

Levee Options

Appendix N – Afflux Plots with Levees in Place

Legend

- Levee Alignment
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain

Afflux (mm)

<-100 | -100-0 | 0-100 | >100

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Afflux-Levee Option
100 yr Flood Event

Job Number | 31-28519
Revision | A
Date | 16 May 2014

Appendix N1

G:\31\28519\GIS\Maps\Deliverables\3128519_007_Donald_Township_Afflux_100yr_Levee.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Legend

- Proposed Levee
- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain

Afflux (mm)

<-100 | -100-0 | 0-100 | 100-150

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Afflux-Levee Option
January 2011 Flood Event

Job Number	31-28519
Revision	A
Date	16 May 2014

Appendix N2

G:\31\28519\GIS\Maps\Deliverables\3128519_007_Donald_Township_Afflux_Jan2011_Levee.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Appendix O – Afflux Plots with Culverts in Place

Legend

- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain

Afflux (mm)

<-100 | -100-0 | 0-100 | >100

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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Date | 16 May 2014

Afflux-Culvert Option
100 yr Flood Event

Appendix O1

G:\31\28519\GIS\Maps\Deliverables\3128519_007_Donald_Township_Afflux_100yr_Culvert.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Legend

Highway	Lake
Sealed road (arterial & local)	Flat
Unsealed road	River
Unsealed track	Channel / drain

Afflux (mm)

<-100 | -100-0 | 0-100 | >100

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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Afflux-Culvert Option
January 2011 Flood Event

Appendix O2

G:\31\28519\GIS\Maps\Deliverables\3128519_007_Donald_Township_Afflux_Jan2011_Culvert.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Legend

- Highway
- Sealed road (arterial & local)
- Unsealed road
- Unsealed track
- Lake
- Flat
- River
- Channel / drain

Afflux (mm)

<-100 | -100-0 | 0-100 | >100

Paper Size A2

0 95 190 380 570 760

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

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Revision A
Date 16 May 2014

Afflux-Culvert Option
Sep 2010 Flood Event

Appendix O3

G:\31\28519\GIS\Maps\Deliverables\3128519_007_Donald_Township_Afflux_Sep2011_Culvert.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEPI, VicMap (2012); NCCMA, Areal Imagery (2009); GHD, Inundation Mapping (2012). Created by:scowan

Appendix P – Flood Damage Assessment

RAPID APPRAISAL METHOD CPI 1.32

Study Area Donald

Estimated Damages For Each Flood
Direct Damages to Buildings

	Low	Medium	High
	Offices, Sporting Pavilions, Churches	Libraries, Clothing Business, Caravan Parks	Electronic, Printing
Cubic Meters of large (>1,000m^2) non-residential buildings within flood extents		2266	
No. of other buildings (i.e. residential and small-medium size non-residential properties) with flood extents	27		
Warning Time Ratio (see Table 2)	0.7		
Total Direct Damages to Buildings	*$678,949*		

Direct Damages to Agricultural Enterprises

	HA inundation less than a week	HA inundation greater than a week
Dryland Pastures		
Irrigation Pastures		
Dryland Broadacre Crops		
Irrigated Broadacre Crops		
Vegetables		
Grapes		
Flood Sensitive Orchard		
Tobacco		
Hops		
Other Horticulture		

Note fill in distribution of Flood in Table 3.7 and 3.8

No. of Livestock Lost	
Dairy	
Beef	
Sheep for Wool Production	
Sheep for Lamb Production	

Clean Up Cost	HA
Pastures and broadacre crops in floodway areas	
Pastures and broadacre crops on low velocity flood events	
Horticultural enterprises	

Total Direct Damages to Agricultural Enterprises *$0.00*

Direct Damages to Regional Infrastructure

	Kilometres of Road Inundated	
Major Sealed Roads	1.2	
Minor Sealed Roads	0.4	
Unsealed Roads	0.5	
	Cost ($)	
Other	60000	Pool
Other	133467	Sheds

Total Direct Damages to Regional Infrastructure *$305,465*

Indirect Damages
Percentage of Total Direct Costs 30%

Total Indirect Damages *$295,324*

Total Damages $1,279,738

Type	Floor Leve	Flood Lev	Flood Lev	200yr	100yr	50yr	20yr	10yr	5yr	Area	Comment
Commercia	111.8	112.72	111.64	112.68	112.43	112.15	111.82	111.44	0	925.562	Donald Motor Lodge
Commercia	112.4	112.7	0	112.67	112.42	112.14	0	0	0	314.448	Chinese Resturant
Commercia	112.09	112.49	0	112.47	112.11	0	0	0	0	1026.16	Holden
Commercia	113.35	112.84	0	112.82	0	0	0	0	0	273.416	Harris Clothing
Commercia	112.67	112.72	0	112.69	112.44	112.16	111.83	0	0	216.359	Cafe
Commercia	112.86	112.73	0	112.7	112.44	112.16	0	0	0	281.031	Donald Motor Cycles
Commercia	112.63	112.72	0	112.69	112.44	112.16	111.83	0	0	190.94	
Commercia	112.37	112.39	0	112.25	111.93	111.71	111.45	111.2	0	259.672	Riverside Motel - Reception
Commercia	111.66	112.18	111.34	112.15	111.93	111.71	111.45	111.19	110.89	415.205	Riverside Motel Rooms
Commercia	112.16	112.53	0	112.51	112.26	111.98	111.65	0	0	530.294	Furniture
Commerica	110.83	112.73	111.67	112.7	112.44	112.16	111.83	111.46	111.14	95.7463	Shed as part of Donald Motor cycle
House	112.16	112.67	0	112.65	112.4	112.12	111.78	0	0	128.267	
House	112.21	112.64	0	112.63	112.39	112.11	111.77	0	0	90.2773	
House	112.33	112.63	0	112.62	112.37	112.09	111.75	111.41	111.02	135.625	
House	112.37	112.58	0	112.57	112.33	0	0	0	0	187.405	
House	112.91	112.57	0	112.57	112.33	0	0	0	0	193.839	
House	111.88	112.45	0	112.43	112.18	111.93	0	0	0	137.158	
House	111.47	112.21	111.39	112.18	111.97	111.75	111.5	111.28	0	416.72	
House	111.24	111.58	0	111.52	111.3	111.07	110.8	110.56	0	534.859	
House	113	112.16	0	112.13	111.92	111.71	0	0	0	177.526	In google
House	112.46	112.25	0	112.22	112.01	111.79	111.52	111.26	0	329.728	
House	113.74	112.62	0	112.59	112.33	0	0	0	0	385.186	
Unit	112.8	112.81	0	112.79	112.57	112.3	0	0	0	248.038	Goodwin
Units	112.46	112.63	0	112.6	112.34	112.06	0	0	0	222.567	3No Goodwin
Units	112.46	112.65	0	112.61	112.38	0	0	0	0	227.649	3No. Goodwin
Units	112.46	112.66	0	112.63	112.39	0	0	0	0	211.174	3 No Goodwin
Units	112.46	112.63	0	112.6	0	0	0	0	0	232.196	3No Goodwin Village
Units	112.46	112.68	0	112.65	0	0	0	0	0	260.366	Goodwin
Units	112.46	112.7	0	112.68	112.51	0	0	0	0	169.254	Goodwin
Units	112.46	112.78	0	112.75	112.53	112.29	0	0	0	2471.21	Goodwin Village Complex
Shed	112.26	113.13	112.22	113.1	112.87	112.63	112.34	112.05	0	45.8822	
Shed	112.2	113.13	112.2	113.1	112.87	112.63	112.34	112.05	0	47.192	
Shed	111.95	113.12	112.2	113.09	112.86	112.61	112.32	112.03	111.74	84.8137	Swimming Pool
Shed	112.06	113.12	112.21	113.09	112.86	112.62	112.33	112.04	0	129.811	Swimming Pool
Shed	111.77	112.87	111.97	112.84	112.61	112.36	112.09	111.81	0	242.173	Rooms? - BP
Shed	111.67	112.87	111.97	112.84	112.6	112.36	112.08	111.81	0	79.8797	Davey Plumbing
Shed	111.99	112.86	111.96	112.83	112.6	112.36	112.08	111.8	111.55	484.699	Davey Plumbing
Shed	111.61	112.85	119.96	112.82	112.59	112.35	112.08	111.8	111.55	9.9413	
Shed	111.85	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	12.5719	
Shed	111.78	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	7.7288	
Shed	112.07	112.85	111.96	112.82	112.59	112.34	112.08	0	0	7.06455	
Shed	112.68	112.86	0	112.83	112.59	0	0	0	0	42.686	
Shed	112.97	112.82	0	112.79	112.55	112.31	0	0	0	215.422	Scouts
Shed	112.09	112.73	0	112.7	112.45	112.17	111.83	111.46	0	21.8442	
Shed	111.18	111.57	0	111.5	111.29	111.06	110.8	0	0	233.911	
Shed	111.55	111.56	0	111.5	111.29	0	0	0	0	135.145	
Shed	111.44	111.55	0	111.49	111.28	0	0	0	0	137.942	
Shed	111.92	112.16	0	112.13	111.92	0	0	0	0	28.1277	
Sheds	112.09	112.26	0	112.26	111.93	0	0	0	0	351.974	?
Swimming	0	113.12	112.21	113.09	112.86	112.62	112.33	112.03	0	454.971	
Tourist Bui	112.5	112.49	0	112.49	0	0	0	0	0	92.7323	Old Police Camp
Toilet Block	111.64	0	0	112.46	112.2	111.93	0	0	0		Apex Park
Sports Ova	110.87	0	0	111.61	111.43	111.23	110.99	110.82	0		
Sports Ova	110.37	0	0	111.59	111.4	111.18	110.89	110.6	0		
Sports Ova	110.39	0	0	111.59	111.39	111.18	110.88	110.6	0		

RAPID APPRAISAL METHOD CPI 1.32

Study Area Donald

Estimated Damages For Each Flood
Direct Damages to Buildings

	Low	Medium	High
	Offices, Sporting Pavilions, Churches	Libraries, Clothing Business, Caravan Parks	Electronic, Printing
Cubic Meters of large (>1,000m^2) non-residential buildings within flood extents		2266	
No. of other buildings (i.e. residential and small-medium size non-residential properties) with flood extents	22		
Warning Time Ratio (see Table 2)	0.7		
Total Direct Damages to Buildings	*$584,239*		

Direct Damages to Agricultural Enterprises

	HA inundation less than a week	HA inundation greater than a week
Dryland Pastures		
Irrigation Pastures		
Dryland Broadacre Crops		
Irrigated Broadacre Crops		
Vegetables		
Grapes		
Flood Sensitive Orchard		
Tobacco		
Hops		
Other Horticulture		

Note fill in distribution of Flood in Table 3.7 and 3.8

No. of Livestock Lost	
Dairy	
Beef	
Sheep for Wool Production	
Sheep for Lamb Production	

Clean Up Cost	HA
Pastures and broadacre crops in floodway areas	
Pastures and broadacre crops on low velocity flood events	
Horticultural enterprises	

Total Direct Damages to Agricultural Enterprises *$0.00*

Direct Damages to Regional Infrastructure

	Kilometres of Road Inundated	
Major Sealed Roads	0.9	
Minor Sealed Roads	0.4	
Unsealed Roads	0.4	
	Cost ($)	
Other	60000	Pool
Other	102063	Sheds

Total Direct Damages to Regional Infrastructure *$250,644*

Indirect Damages

Percentage of Total Direct Costs 30%

Total Indirect Damages *$250,465*

Total Damages $1,085,348

Type	Floor Lev	Flood Lev	Flood Lev	200yr	100yr	50yr	20yr	10yr	5yr	Area	Comment
Commercial	111.8	112.72	111.64	112.68	112.43	112.15	111.82	111.44	0	925.562	Donald Motor Lodge
Commercial	112.4	112.7	0	112.67	112.42	112.14	0	0	0	314.448	Chinese Resturant
Commercial	112.09	112.49	0	112.47	112.11	0	0	0	0	1026.16	Holden
Commercial	113.35	112.84	0	112.82	0	0	0	0	0	273.416	Harris Clothing
Commercial	112.67	112.72	0	112.69	112.44	112.16	111.83	0	0	216.359	Cafe
Commercial	112.86	112.73	0	112.7	112.44	112.16	0	0	0	281.031	Donald Motor Cycles
Commercial	112.63	112.72	0	112.69	112.44	112.16	111.83	0	0	190.94	
Commercial	112.37	112.39	0	112.25	111.93	111.71	111.45	111.2	0	259.672	Riverside Motel - Reception
Commercial	111.66	112.18	111.34	112.15	111.93	111.71	111.45	111.19	110.89	415.205	Riverside Motel Rooms
Commercial	112.16	112.53	0	112.51	112.26	111.98	111.65	0	0	530.294	Furniture
Commerical	110.83	112.73	111.67	112.7	112.44	112.16	111.83	111.46	111.14	95.7463	Shed as part of Donald Motor cycle
House	112.16	112.67	0	112.65	112.4	112.12	111.78	0	0	128.267	
House	112.21	112.64	0	112.63	112.39	112.11	111.77	0	0	90.2773	
House	112.33	112.63	0	112.62	112.37	112.09	111.75	111.41	111.02	135.625	
House	112.37	112.58	0	112.57	112.33	0	0	0	0	187.405	
House	112.91	112.57	0	112.57	112.33	0	0	0	0	193.839	
House	111.88	112.45	0	112.43	112.18	111.93	0	0	0	137.158	
House	111.47	112.21	111.39	112.18	111.97	111.75	111.5	111.28	0	416.72	
House	111.24	111.58	0	111.52	111.3	111.07	110.8	110.56	0	534.859	
House	113	112.16	0	112.13	111.92	111.71	0	0	0	177.526	In google
House	112.46	112.25	0	112.22	112.01	111.79	111.52	111.26	0	329.728	
House	113.74	112.62	0	112.59	112.33	0	0	0	0	385.186	
Unit	112.8	112.81	0	112.79	112.57	112.3	0	0	0	248.038	Goodwin
Units	112.46	112.63	0	112.6	112.34	112.06	0	0	0	222.567	3No Goodwin
Units	112.46	112.65	0	112.61	112.38	0	0	0	0	227.649	3No. Goodwin
Units	112.46	112.66	0	112.63	112.39	0	0	0	0	211.174	3 No Goodwin
Units	112.46	112.63	0	112.6	0	0	0	0	0	232.196	3No Goodwin Village
Units	112.46	112.68	0	112.65	0	0	0	0	0	260.366	Goodwin
Units	112.46	112.7	0	112.68	112.51	0	0	0	0	169.254	Goodwin
Units	112.46	112.78	0	112.75	112.53	112.29	0	0	0	2471.21	Goodwin Village Complex
Shed	112.26	113.13	112.22	113.1	112.87	112.63	112.34	112.05	0	45.8822	
Shed	112.2	113.13	112.2	113.1	112.87	112.63	112.34	112.05	0	47.192	
Shed	111.95	113.12	112.2	113.09	112.86	112.61	112.32	112.03	111.74	84.8137	Swimming Pool
Shed	112.06	113.12	112.21	113.09	112.86	112.62	112.33	112.04	0	129.811	Swimming Pool
Shed	111.77	112.87	111.97	112.84	112.61	112.36	112.09	111.81	0	242.173	Rooms? - BP
Shed	111.67	112.87	111.97	112.84	112.6	112.36	112.08	111.81	0	79.8797	Davey Plumbing
Shed	111.99	112.86	111.96	112.83	112.6	112.36	112.08	111.8	111.55	484.699	Davey Plumbing
Shed	111.61	112.85	119.96	112.82	112.59	112.35	112.08	111.8	111.55	9.9413	
Shed	111.85	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	12.5719	
Shed	111.78	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	7.7288	
Shed	112.07	112.85	111.96	112.82	112.59	112.34	112.08	0	0	7.06455	
Shed	112.68	112.86	0	112.83	112.59	0	0	0	0	42.686	
Shed	112.97	112.82	0	112.79	112.55	112.31	0	0	0	215.422	Scouts
Shed	112.09	112.73	0	112.7	112.45	112.17	111.83	111.46	0	21.8442	
Shed	111.18	111.57	0	111.5	111.29	111.06	110.8	0	0	233.911	
Shed	111.55	111.56	0	111.5	111.29	0	0	0	0	135.145	
Shed	111.44	111.55	0	111.49	111.28	0	0	0	0	137.942	
Shed	111.92	112.16	0	112.13	111.92	0	0	0	0	28.1277	
Sheds	112.09	112.26	0	112.26	111.93	0	0	0	0	351.974	?
Swimming Poo	0	113.12	112.21	113.09	112.86	112.62	112.33	112.03	0	454.971	
Tourist Buildin	112.5	112.49	0	112.49	0	0	0	0	0	92.7323	Old Police Camp
Toilet Block	111.64	0	0	112.46	112.2	111.93	0	0	0		Apex Park
Sports Oval	110.87	0	0	111.61	111.43	111.23	110.99	110.82	0		
Sports Oval	110.37	0	0	111.59	111.4	111.18	110.89	110.6	0		
Sports Oval	110.39	0	0	111.59	111.39	111.18	110.88	110.6	0		

RAPID APPRAISAL METHOD CPI 1.32

Study Area Donald

Estimated Damages For Each Flood
Direct Damages to Buildings

	Low	Medium	High
	Offices, Sporting Pavilions, Churches	Libraries, Clothing Business, Caravan Parks	Electronic, Printing
Cubic Meters of large (>1,000m^2) non-residential buildings within flood extents		926	

No. of other buildings (i.e. residential and small-medium size non-residential properties) with flood extents: 14

Warning Time Ratio (see Table 2): 0.7

Total Direct Damages to Buildings *$333,606*

Direct Damages to Agricultural Enterprises

	HA inundation less than a week	HA inundation greater than a week
Dryland Pastures		
Irrigation Pastures		
Dryland Broadacre Crops		
Irrigated Broadacre Crops		
Vegetables		
Grapes		
Flood Sensitive Orchard		
Tobacco		
Hops		
Other Horticulture		

Note fill in distribution of Flood in Table 3.7 and 3.8

No. of Livestock Lost	
Dairy	
Beef	
Sheep for Wool Production	
Sheep for Lamb Production	

Clean Up Cost	HA
Pastures and broadacre crops in floodway areas	
Pastures and broadacre crops on low velocity flood events	
Horticultural enterprises	

Total Direct Damages to Agricultural Enterprises *$0.00*

Direct Damages to Regional Infrastructure

	Kilometres of Road Inundated
Major Sealed Roads	0.7
Minor Sealed Roads	0.4
Unsealed Roads	0.4

	Cost ($)	
Other	60000	Pool
Other	94212	Sheds

Total Direct Damages to Regional Infrastructure *$223,583*

Indirect Damages

Percentage of Total Direct Costs: 30%

Total Indirect Damages *$167,157*

Total Damages *$724,345*

Type	Floor Leve	Flood Lev	Flood Lev	200yr	100yr	50yr	20yr	10yr	5yr	Area	Comment
Commercia	111.8	112.72	111.64	112.68	112.43	112.15	111.82	111.44	0	925.562	Donald Motor Lodge
Commercia	112.4	112.7	0	112.67	112.42	112.14	0	0	0	314.448	Chinese Resturant
Commercia	112.09	112.49	0	112.47	112.11	0	0	0	0	1026.16	Holden
Commercia	113.35	112.84	0	112.82	0	0	0	0	0	273.416	Harris Clothing
Commercia	112.67	112.72	0	112.69	112.44	112.16	111.83	0	0	216.359	Cafe
Commercia	112.86	112.73	0	112.7	112.44	112.16	0	0	0	281.031	Donald Motor Cycles
Commercia	112.63	112.72	0	112.69	112.44	112.16	111.83	0	0	190.94	
Commercia	112.37	112.39	0	112.25	111.93	111.71	111.45	111.2	0	259.672	Riverside Motel - Reception
Commercia	111.66	112.18	111.34	112.15	111.93	111.71	111.45	111.19	110.89	415.205	Riverside Motel Rooms
Commercia	112.16	112.53	0	112.51	112.26	111.98	111.65	0	0	530.294	Furniture
Commerica	110.83	112.73	111.67	112.7	112.44	112.16	111.83	111.46	111.14	95.7463	Shed as part of Donald Motor cycle
House	112.16	112.67	0	112.65	112.4	112.12	111.78	0	0	128.267	
House	112.21	112.64	0	112.63	112.39	112.11	111.77	0	0	90.2773	
House	112.33	112.63	0	112.62	112.37	112.09	111.75	111.41	111.02	135.625	
House	112.37	112.58	0	112.57	112.33	0	0	0	0	187.405	
House	112.91	112.57	0	112.57	112.33	0	0	0	0	193.839	
House	111.88	112.45	0	112.43	112.18	111.93	0	0	0	137.158	
House	111.47	112.21	111.39	112.18	111.97	111.75	111.5	111.28	0	416.72	
House	111.24	111.58	0	111.52	111.3	111.07	110.8	110.56	0	534.859	
House	113	112.16	0	112.13	111.92	111.71	0	0	0	177.526	In google
House	112.46	112.25	0	112.22	112.01	111.79	111.52	111.26	0	329.728	
House	113.74	112.62	0	112.59	112.33	0	0	0	0	385.186	
Unit	112.8	112.81	0	112.79	112.57	112.3	0	0	0	248.038	Goodwin
Units	112.46	112.63	0	112.6	112.34	112.06	0	0	0	222.567	3No Goodwin
Units	112.46	112.65	0	112.61	112.38	0	0	0	0	227.649	3No. Goodwin
Units	112.46	112.66	0	112.63	112.39	0	0	0	0	211.174	3 No Goodwin
Units	112.46	112.63	0	112.6	0	0	0	0	0	232.196	3No Goodwin Village
Units	112.46	112.68	0	112.65	0	0	0	0	0	260.366	Goodwin
Units	112.46	112.7	0	112.68	112.51	0	0	0	0	169.254	Goodwin
Units	112.46	112.78	0	112.75	112.53	112.29	0	0	0	2471.21	Goodwin Village Complex
Shed	112.26	113.13	112.22	113.1	112.87	112.63	112.34	112.05	0	45.8822	
Shed	112.2	113.13	112.2	113.1	112.87	112.63	112.34	112.05	0	47.192	
Shed	111.95	113.12	112.2	113.09	112.86	112.61	112.32	112.03	111.74	84.8137	Swimming Pool
Shed	112.06	113.12	112.21	113.09	112.86	112.62	112.33	112.04	0	129.811	Swimming Pool
Shed	111.77	112.87	111.97	112.84	112.61	112.36	112.09	111.81	0	242.173	Rooms? - BP
Shed	111.67	112.87	111.97	112.84	112.6	112.36	112.08	111.81	0	79.8797	Davey Plumbing
Shed	111.99	112.86	111.96	112.83	112.6	112.36	112.08	111.8	111.55	484.699	Davey Plumbing
Shed	111.61	112.85	119.96	112.82	112.59	112.35	112.08	111.8	111.55	9.9413	
Shed	111.85	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	12.5719	
Shed	111.78	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	7.7288	
Shed	112.07	112.85	111.96	112.82	112.59	112.34	112.08	0	0	7.06455	
Shed	112.68	112.86	0	112.83	112.59	0	0	0	0	42.686	
Shed	112.97	112.82	0	112.79	112.55	112.31	0	0	0	215.422	Scouts
Shed	112.09	112.73	0	112.7	112.45	112.17	111.83	111.46	0	21.8442	
Shed	111.18	111.57	0	111.5	111.29	111.06	110.8	0	0	233.911	
Shed	111.55	111.56	0	111.5	111.29	0	0	0	0	135.145	
Shed	111.44	111.55	0	111.49	111.28	0	0	0	0	137.942	
Shed	111.92	112.16	0	112.13	111.92	0	0	0	0	28.1277	
Sheds	112.09	112.26	0	112.26	111.93	0	0	0	0	351.974	?
Swimming	0	113.12	112.21	113.09	112.86	112.62	112.33	112.03	0	454.971	
Tourist Buil	112.5	112.49	0	112.49	0	0	0	0	0	92.7323	Old Police Camp
Toilet Block	111.64	0	0	112.46	112.2	111.93	0	0	0		Apex Park
Sports Ova	110.87	0	0	111.61	111.43	111.23	110.99	110.82	0		
Sports Ova	110.37	0	0	111.59	111.4	111.18	110.89	110.6	0		
Sports Ova	110.39	0	0	111.59	111.39	111.18	110.88	110.6	0		

RAPID APPRAISAL METHOD CPI 1.32

Study Area Donald

Estimated Damages For Each Flood
Direct Damages to Buildings

	Low	Medium	High
	Offices, Sporting Pavilions, Churches	Libraries, Clothing Business, Caravan Parks	Electronic, Printing
Cubic Meters of large (>1,000m^2) non-residential buildings within flood extents		926	
No. of other buildings (i.e. residential and small-medium size non-residential properties) with flood extents	6		
Warning Time Ratio (see Table 2)	0.7		
Total Direct Damages to Buildings	*$182,070*		

Direct Damages to Agricultural Enterprises

	HA inundation less than a week	HA inundation greater than a week
Dryland Pastures		
Irrigation Pastures		
Dryland Broadacre Crops		
Irrigated Broadacre Crops		
Vegetables		
Grapes		
Flood Sensitive Orchard		
Tobacco		
Hops		
Other Horticulture		
Note fill in distribution of Flood in Table 3.7 and 3.8		

No. of Livestock Lost	
Dairy	
Beef	
Sheep for Wool Production	
Sheep for Lamb Production	

Clean Up Cost	HA
Pastures and broadacre crops in floodway areas	
Pastures and broadacre crops on low velocity flood events	
Horticultural enterprises	
Total Direct Damages to Agricultural Enterprises	*$0.00*

Direct Damages to Regional Infrastructure

	Kilometres of Road Inundated	
Major Sealed Roads	0.6	
Minor Sealed Roads	0.4	
Unsealed Roads	0.4	
	Cost ($)	
Other	60000	Pool
Other	86361	Sheds
Total Direct Damages to Regional Infrastructure	*$205,863*	

Indirect Damages

Percentage of Total Direct Costs	30%
Total Indirect Damages	*$116,380*
Total Damages	$504,312

Type	Floor Leve	Flood Lev	Flood Lev	200yr	100yr	50yr	20yr	10yr	5yr	Area	Comment
Commercia	111.8	112.72	111.64	112.68	112.43	112.15	111.82	111.44	0	925.562	Donald Motor Lodge
Commercia	112.4	112.7	0	112.67	112.42	112.14	0	0	0	314.448	Chinese Resturant
Commercia	112.09	112.49	0	112.47	112.11	0	0	0	0	1026.16	Holden
Commercia	113.35	112.84	0	112.82	0	0	0	0	0	273.416	Harris Clothing
Commercia	112.67	112.72	0	112.69	112.44	112.16	111.83	0	0	216.359	Cafe
Commercia	112.86	112.73	0	112.7	112.44	112.16	0	0	0	281.031	Donald Motor Cycles
Commercia	112.63	112.72	0	112.69	112.44	112.16	111.83	0	0	190.94	
Commercia	112.37	112.39	0	112.25	111.93	111.71	111.45	111.2	0	259.672	Riverside Motel - Reception
Commercia	111.66	112.18	111.34	112.15	111.93	111.71	111.45	111.19	110.89	415.205	Riverside Motel Rooms
Commercia	112.16	112.53	0	112.51	112.26	111.98	111.65	0	0	530.294	Furniture
Commerica	110.83	112.73	111.67	112.7	112.44	112.16	111.83	111.46	111.14	95.7463	Shed as part of Donald Motor cycle
House	112.16	112.67	0	112.65	112.4	112.12	111.78	0	0	128.267	
House	112.21	112.64	0	112.63	112.39	112.11	111.77	0	0	90.2773	
House	112.33	112.63	0	112.62	112.37	112.09	111.75	111.41	111.02	135.625	
House	112.37	112.58	0	112.57	112.33	0	0	0	0	187.405	
House	112.91	112.57	0	112.57	112.33	0	0	0	0	193.839	
House	111.88	112.45	0	112.43	112.18	111.93	0	0	0	137.158	
House	111.47	112.21	111.39	112.18	111.97	111.75	111.5	111.28	0	416.72	
House	111.24	111.58	0	111.52	111.3	111.07	110.8	110.56	0	534.859	
House	113	112.16	0	112.13	111.92	111.71	0	0	0	177.526	In google
House	112.46	112.25	0	112.22	112.01	111.79	111.52	111.26	0	329.728	
House	113.74	112.62	0	112.59	112.33	0	0	0	0	385.186	
Unit	112.8	112.81	0	112.79	112.57	112.3	0	0	0	248.038	Goodwin
Units	112.46	112.63	0	112.6	112.34	112.06	0	0	0	222.567	3No Goodwin
Units	112.46	112.65	0	112.61	112.38	0	0	0	0	227.649	3No. Goodwin
Units	112.46	112.66	0	112.63	112.39	0	0	0	0	211.174	3 No Goodwin
Units	112.46	112.63	0	112.6	0	0	0	0	0	232.196	3No Goodwin Village
Units	112.46	112.68	0	112.65	0	0	0	0	0	260.366	Goodwin
Units	112.46	112.7	0	112.68	112.51	0	0	0	0	169.254	Goodwin
Units	112.46	112.78	0	112.75	112.53	112.29	0	0	0	2471.21	Goodwin Village Complex
Shed	112.26	113.13	112.22	113.1	112.87	112.63	112.34	112.05	0	45.8822	
Shed	112.2	113.13	112.2	113.1	112.87	112.63	112.34	112.05	0	47.192	
Shed	111.95	113.12	112.2	113.09	112.86	112.61	112.32	112.03	111.74	84.8137	Swimming Pool
Shed	112.06	113.12	112.21	113.09	112.86	112.62	112.33	112.04	0	129.811	Swimming Pool
Shed	111.77	112.87	111.97	112.84	112.61	112.36	112.09	111.81	0	242.173	Rooms? - BP
Shed	111.67	112.87	111.97	112.84	112.6	112.36	112.08	111.81	0	79.8797	Davey Plumbing
Shed	111.99	112.86	111.96	112.83	112.6	112.36	112.08	111.8	111.55	484.699	Davey Plumbing
Shed	111.61	112.85	119.96	112.82	112.59	112.35	112.08	111.8	111.55	9.9413	
Shed	111.85	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	12.5719	
Shed	111.78	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	7.7288	
Shed	112.07	112.85	111.96	112.82	112.59	112.34	112.08	0	0	7.06455	
Shed	112.68	112.86	0	112.83	112.59	0	0	0	0	42.686	
Shed	112.97	112.82	0	112.79	112.55	112.31	0	0	0	215.422	Scouts
Shed	112.09	112.73	0	112.7	112.45	112.17	111.83	111.46	0	21.8442	
Shed	111.18	111.57	0	111.5	111.29	111.06	110.8	0	0	233.911	
Shed	111.55	111.56	0	111.5	111.29	0	0	0	0	135.145	
Shed	111.44	111.55	0	111.49	111.28	0	0	0	0	137.942	
Shed	111.92	112.16	0	112.13	111.92	0	0	0	0	28.1277	
Sheds	112.09	112.26	0	112.26	111.93	0	0	0	0	351.974	?
Swimming	0	113.12	112.21	113.09	112.86	112.62	112.33	112.03	0	454.971	
Tourist Buil	112.5	112.49	0	112.49	0	0	0	0	0	92.7323	Old Police Camp
Toilet Block	111.64	0	0	112.46	112.2	111.93	0	0	0		Apex Park
Sports Ova	110.87	0	0	111.61	111.43	111.23	110.99	110.82	0		
Sports Ova	110.37	0	0	111.59	111.4	111.18	110.89	110.6	0		
Sports Ova	110.39	0	0	111.59	111.39	111.18	110.88	110.6	0		

RAPID APPRAISAL METHOD CPI 1.32

Study Area Donald

Estimated Damages For Each Flood
Direct Damages to Buildings

	Low	Medium	High
	Offices, Sporting Pavilions, Churches	Clothing Business, Caravan Parks	Electronic, Printing
Cubic Meters of large (>1,000m^2) non-residential buildings within flood extents		0	
No. of other buildings (i.e. residential and small-medium size non-residential properties) with flood extents	4		
Warning Time Ratio (see Table 2)	0.7		
Total Direct Damages to Buildings	*$75,768*		

Direct Damages to Agricultural Enterprises

	HA inundation less than a week	HA inundation greater than a week
Dryland Pastures		
Irrigation Pastures		
Dryland Broadacre Crops		
Irrigated Broadacre Crops		
Vegetables		
Grapes		
Flood Sensitive Orchard		
Tobacco		
Hops		
Other Horticulture		
Note fill in distribution of Flood in Table 3.7 and 3.8		

No. of Livestock Lost	
Dairy	
Beef	
Sheep for Wool Production	
Sheep for Lamb Production	

Clean Up Cost	HA
Pastures and broadacre crops in floodway areas	
Pastures and broadacre crops on low velocity flood events	
Horticultural enterprises	
Total Direct Damages to Agricultural Enterprises	*$0.00*

Direct Damages to Regional Infrastructure

	Kilometres of Road Inundated	
Major Sealed Roads	0.3	
Minor Sealed Roads	0.4	
Unsealed Roads	0.4	
	Cost ($)	
Other	40000	Pool
Other	39255	Sheds
Total Direct Damages to Regional Infrastructure	*$116,308*	

Indirect Damages

Percentage of Total Direct Costs	30%
Total Indirect Damages	*$57,623*
Total Damages	*$249,698*

Type	Floor Leve	Flood Lev	Flood Lev	200yr	100yr	50yr	20yr	10yr	5yr	Area	Comment
Commercia	111.8	112.72	111.64	112.68	112.43	112.15	111.82	111.44	0	925.562	Donald Motor Lodge
Commercia	112.4	112.7	0	112.67	112.42	112.14	0	0	0	314.448	Chinese Resturant
Commercia	112.09	112.49	0	112.47	112.11	0	0	0	0	1026.16	Holden
Commercia	113.35	112.84	0	112.82	0	0	0	0	0	273.416	Harris Clothing
Commercia	112.67	112.72	0	112.69	112.44	112.16	111.83	0	0	216.359	Cafe
Commercia	112.86	112.73	0	112.7	112.44	112.16	0	0	0	281.031	Donald Motor Cycles
Commercia	112.63	112.72	0	112.69	112.44	112.16	111.83	0	0	190.94	
Commercia	112.37	112.39	0	112.25	111.93	111.71	111.45	111.2	0	259.672	Riverside Motel - Reception
Commercia	111.66	112.18	111.34	112.15	111.93	111.71	111.45	111.19	110.89	415.205	Riverside Motel Rooms
Commercia	112.16	112.53	0	112.51	112.26	111.98	111.65	0	0	530.294	Furniture
Commerica	110.83	112.73	111.67	112.7	112.44	112.16	111.83	111.46	111.14	95.7463	Shed as part of Donald Motor cycle
House	112.16	112.67	0	112.65	112.4	112.12	111.78	0	0	128.267	
House	112.21	112.64	0	112.63	112.39	112.11	111.77	0	0	90.2773	
House	112.33	112.63	0	112.62	112.37	112.09	111.75	111.41	111.02	135.625	
House	112.37	112.58	0	112.57	112.33	0	0	0	0	187.405	
House	112.91	112.57	0	112.57	112.33	0	0	0	0	193.839	
House	111.88	112.45	0	112.43	112.18	111.93	0	0	0	137.158	
House	111.47	112.21	111.39	112.18	111.97	111.75	111.5	111.28	0	416.72	
House	111.24	111.58	0	111.52	111.3	111.07	110.8	110.56	0	534.859	
House	113	112.16	0	112.13	111.92	111.71	0	0	0	177.526	In google
House	112.46	112.25	0	112.22	112.01	111.79	111.52	111.26	0	329.728	
House	113.74	112.62	0	112.59	112.33	0	0	0	0	385.186	
Unit	112.8	112.81	0	112.79	112.57	112.3	0	0	0	248.038	Goodwin
Units	112.46	112.63	0	112.6	112.34	112.06	0	0	0	222.567	3No Goodwin
Units	112.46	112.65	0	112.61	112.38	0	0	0	0	227.649	3No. Goodwin
Units	112.46	112.66	0	112.63	112.39	0	0	0	0	211.174	3 No Goodwin
Units	112.46	112.63	0	112.6	0	0	0	0	0	232.196	3No Goodwin Village
Units	112.46	112.68	0	112.65	0	0	0	0	0	260.366	Goodwin
Units	112.46	112.7	0	112.68	112.51	0	0	0	0	169.254	Goodwin
Units	112.46	112.78	0	112.75	112.53	112.29	0	0	0	2471.21	Goodwin Village Complex
Shed	112.26	113.13	112.22	113.1	112.87	112.63	112.34	112.05	0	45.8822	
Shed	112.2	113.13	112.2	113.1	112.87	112.63	112.34	112.05	0	47.192	
Shed	111.95	113.12	112.2	113.09	112.86	112.61	112.32	112.03	111.74	84.8137	Swimming Pool
Shed	112.06	113.12	112.21	113.09	112.86	112.62	112.33	112.04	0	129.811	Swimming Pool
Shed	111.77	112.87	111.97	112.84	112.61	112.36	112.09	111.81	0	242.173	Rooms? - BP
Shed	111.67	112.87	111.97	112.84	112.6	112.36	112.08	111.81	0	79.8797	Davey Plumbing
Shed	111.99	112.86	111.96	112.83	112.6	112.36	112.08	111.8	111.55	484.699	Davey Plumbing
Shed	111.61	112.85	119.96	112.82	112.59	112.35	112.08	111.8	111.55	9.9413	
Shed	111.85	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	12.5719	
Shed	111.78	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	7.7288	
Shed	112.07	112.85	111.96	112.82	112.59	112.34	112.08	0	0	7.06455	
Shed	112.68	112.86	0	112.83	112.59	0	0	0	0	42.686	
Shed	112.97	112.82	0	112.79	112.55	112.31	0	0	0	215.422	Scouts
Shed	112.09	112.73	0	112.7	112.45	112.17	111.83	111.46	0	21.8442	
Shed	111.18	111.57	0	111.5	111.29	111.06	110.8	0	0	233.911	
Shed	111.55	111.56	0	111.5	111.29	0	0	0	0	135.145	
Shed	111.44	111.55	0	111.49	111.28	0	0	0	0	137.942	
Shed	111.92	112.16	0	112.13	111.92	0	0	0	0	28.1277	
Sheds	112.09	112.26	0	112.26	111.93	0	0	0	0	351.974	?
Swimming	0	113.12	112.21	113.09	112.86	112.62	112.33	112.03	0	454.971	
Tourist Buil	112.5	112.49	0	112.49	0	0	0	0	0	92.7323	Old Police Camp
Toilet Block	111.64	0	0	112.46	112.2	111.93	0	0	0		Apex Park
Sports Ova	110.87	0	0	111.61	111.43	111.23	110.99	110.82	0		
Sports Ova	110.37	0	0	111.59	111.4	111.18	110.89	110.6	0		
Sports Ova	110.39	0	0	111.59	111.39	111.18	110.88	110.6	0		

RAPID APPRAISAL METHOD CPI 1.32

Study Area Donald

Estimated Damages For Each Flood
Direct Damages to Buildings

	Low	Medium	High
	Offices, Sporting Pavilions, Churches	Libraries, Clothing Business, Caravan Parks	Electronic, Printing
Cubic Meters of large (>1,000m^2) non-residential buildings within flood extents		0	
No. of other buildings (i.e. residential and small-medium size non-residential properties) with flood extents	1		
Warning Time Ratio (see Table 2)	0.7		
Total Direct Damages to Buildings	*$18,942*		

Direct Damages to Agricultural Enterprises

	HA inundation less than a week	HA inundation greater than a week
Dryland Pastures		
Irrigation Pastures		
Dryland Broadacre Crops		
Irrigated Broadacre Crops		
Vegetables		
Grapes		
Flood Sensitive Orchard		
Tobacco		
Hops		
Other Horticulture		
Note fill in distribution of Flood in Table 3.7 and 3.8		

No. of Livestock Lost	
Dairy	
Beef	
Sheep for Wool Production	
Sheep for Lamb Production	

Clean Up Cost	HA
Pastures and broadacre crops in floodway areas	
Pastures and broadacre crops on low velocity flood events	
Horticultural enterprises	
Total Direct Damages to Agricultural Enterprises	*$0.00*

Direct Damages to Regional Infrastructure

	Kilometres of Road Inundated
Major Sealed Roads	0.2
Minor Sealed Roads	0.3
Unsealed Roads	0.4

	Cost ($)	
Other		Pool
Other	0	Sheds
Total Direct Damages to Regional Infrastructure	*$28,701*	

Indirect Damages

Percentage of Total Direct Costs	30%
Total Indirect Damages	*$14,293*
Total Damages	*$61,937*

Type	Floor Leve	Flood Lev	Flood Lev	200yr	100yr	50yr	20yr	10yr	5yr	Area	Comment
Commercia	111.8	112.72	111.64	112.68	112.43	112.15	111.82	111.44	0	925.562	Donald Motor Lodge
Commercia	112.4	112.7	0	112.67	112.42	112.14	0	0	0	314.448	Chinese Resturant
Commercia	112.09	112.49	0	112.47	112.11	0	0	0	0	1026.16	Holden
Commercia	113.35	112.84	0	112.82	0	0	0	0	0	273.416	Harris Clothing
Commercia	112.67	112.72	0	112.69	112.44	112.16	111.83	0	0	216.359	Cafe
Commercia	112.86	112.73	0	112.7	112.44	112.16	0	0	0	281.031	Donald Motor Cycles
Commercia	112.63	112.72	0	112.69	112.44	112.16	111.83	0	0	190.94	
Commercia	112.37	112.39	0	112.25	111.93	111.71	111.45	111.2	0	259.672	Riverside Motel - Reception
Commercia	111.66	112.18	111.34	112.15	111.93	111.71	111.45	111.19	110.89	415.205	Riverside Motel Rooms
Commercia	112.16	112.53	0	112.51	112.26	111.98	111.65	0	0	530.294	Furniture
Commerica	110.83	112.73	111.67	112.7	112.44	112.16	111.83	111.46	111.14	95.7463	Shed as part of Donald Motor cycle
House	112.16	112.67	0	112.65	112.4	112.12	111.78	0	0	128.267	
House	112.21	112.64	0	112.63	112.39	112.11	111.77	0	0	90.2773	
House	112.33	112.63	0	112.62	112.37	112.09	111.75	111.41	111.02	135.625	
House	112.37	112.58	0	112.57	112.33	0	0	0	0	187.405	
House	112.91	112.57	0	112.57	112.33	0	0	0	0	193.839	
House	111.88	112.45	0	112.43	112.18	111.93	0	0	0	137.158	
House	111.47	112.21	111.39	112.18	111.97	111.75	111.5	111.28	0	416.72	
House	111.24	111.58	0	111.52	111.3	111.07	110.8	110.56	0	534.859	
House	113	112.16	0	112.13	111.92	111.71	0	0	0	177.526	In google
House	112.46	112.25	0	112.22	112.01	111.79	111.52	111.26	0	329.728	
House	113.74	112.62	0	112.59	112.33	0	0	0	0	385.186	
Unit	112.8	112.81	0	112.79	112.57	112.3	0	0	0	248.038	Goodwin
Units	112.46	112.63	0	112.6	112.34	112.06	0	0	0	222.567	3No Goodwin
Units	112.46	112.65	0	112.61	112.38	0	0	0	0	227.649	3No. Goodwin
Units	112.46	112.66	0	112.63	112.39	0	0	0	0	211.174	3 No Goodwin
Units	112.46	112.63	0	112.6	0	0	0	0	0	232.196	3No Goodwin Village
Units	112.46	112.68	0	112.65	0	0	0	0	0	260.366	Goodwin
Units	112.46	112.7	0	112.68	112.51	0	0	0	0	169.254	Goodwin
Units	112.46	112.78	0	112.75	112.53	112.29	0	0	0	2471.21	Goodwin Village Complex
Shed	112.26	113.13	112.22	113.1	112.87	112.63	112.34	112.05	0	45.8822	
Shed	112.2	113.13	112.2	113.1	112.87	112.63	112.34	112.05	0	47.192	
Shed	111.95	113.12	112.2	113.09	112.86	112.61	112.32	112.03	111.74	84.8137	Swimming Pool
Shed	112.06	113.12	112.21	113.09	112.86	112.62	112.33	112.04	0	129.811	Swimming Pool
Shed	111.77	112.87	111.97	112.84	112.61	112.36	112.09	111.81	0	242.173	Rooms? - BP
Shed	111.67	112.87	111.97	112.84	112.6	112.36	112.08	111.81	0	79.8797	Davey Plumbing
Shed	111.99	112.86	111.96	112.83	112.6	112.36	112.08	111.8	111.55	484.699	Davey Plumbing
Shed	111.61	112.85	119.96	112.82	112.59	112.35	112.08	111.8	111.55	9.9413	
Shed	111.85	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	12.5719	
Shed	111.78	112.85	111.96	112.82	112.59	112.35	112.08	111.8	0	7.7288	
Shed	112.07	112.85	111.96	112.82	112.59	112.34	112.08	0	0	7.06455	
Shed	112.68	112.86	0	112.83	112.59	0	0	0	0	42.686	
Shed	112.97	112.82	0	112.79	112.55	112.31	0	0	0	215.422	Scouts
Shed	112.09	112.73	0	112.7	112.45	112.17	111.83	111.46	0	21.8442	
Shed	111.18	111.57	0	111.5	111.29	111.06	110.8	0	0	233.911	
Shed	111.55	111.56	0	111.5	111.29	0	0	0	0	135.145	
Shed	111.44	111.55	0	111.49	111.28	0	0	0	0	137.942	
Shed	111.92	112.16	0	112.13	111.92	0	0	0	0	28.1277	
Sheds	112.09	112.26	0	112.26	111.93	0	0	0	0	351.974	?
Swimming	0	113.12	112.21	113.09	112.86	112.62	112.33	112.03	0	454.971	
Tourist Buil	112.5	112.49	0	112.49	0	0	0	0	0	92.7323	Old Police Camp
Toilet Block	111.64	0	0	112.46	112.2	111.93	0	0	0		Apex Park
Sports Ova	110.87	0	0	111.61	111.43	111.23	110.99	110.82	0		
Sports Ova	110.37	0	0	111.59	111.4	111.18	110.89	110.6	0		
Sports Ova	110.39	0	0	111.59	111.39	111.18	110.88	110.6	0		

Appendix Q – Cost Estimates

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180 Lonsdale Street Melbourne Vic 3000

NCCMA - Donald Flood and Drainage Management Plan

Concept Design - Levee 1

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 24,693
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	3803	m^2	$ 6	$ 21,715.86
2.2	Cut - for levee key	725	m^3	$ 22	$ 15,579
2.3	Fill - compacted clay	4370	m^3	$ 43	$ 186,439
2.4	Supply and Place unsealed pavement	90	m^3	$ 127	$ 11,453
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 95	$ 1,890
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 376	$ 752
3.3	Floodgate	1	No	$ 400	$ 400
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	1771	m^2	$ 5	$ 8,704
	Subtotals items 2-4				$ 246,933
	Item 1				$ 24,693
	Subtotals items 1-4				$ 271,626
	Contingency (items 1-4)			30%	$ 81,488
	Total				**$ 353,000**

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NCCMA - Donald Flood and Drainage Management Plan

Concept Design - Levee 2

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 51,008
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	8650	m^2	$ 1	$ 8,650
2.2	Cut - for levee key	1644	m^3	$ 22	$ 35,347
2.3	Fill - compacted clay	8857	m^3	$ 43	$ 377,886
2.4	Supply and Place unsealed pavement	215	m^3	$ 127	$ 27,272
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	60	m	$ 95	$ 5,670
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	6	No	$ 376	$ 2,256
3.3	Floodgate	3	No	$ 400	$ 1,200
3.4	Retaining Wall- Blockwork, plain faced hollow concrete block 400x200x200 thick, including core filling and bar reinforcement	170	m^2	$ 188	$ 31,897
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	4049	m^2	$ 5	$ 19,905
	Subtotals items 2-4				$ 510,082
	Item 1				$ 51,008
	Subtotals items 1-4				$ 561,090
	Contingency (items 1-4)			30%	$ 168,327
	Total				**$ 729,000**

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NCCMA - Donald Flood and Drainage Management Plan

Concept Design - Levee 3

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 13,534
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	2749	m^2	$ 9	$ 23,755
2.2	Cut - for levee key	506	m^3	$ 22	$ 10,879
2.3	Fill - compacted clay	1826	m^3	$ 43	$ 77,912
2.4	Supply and Place unsealed pavement	110	m^3	$ 127	$ 13,933
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 95	$ 1,890
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 376	$ 752
3.3	Floodgate	1	No	$ 400	$ 400
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	1184	m^2	$ 5	$ 5,818
	Subtotals items 2-4				$ 135,340
	Item 1				$ 13,534
	Subtotals items 1-4				$ 148,874
	Contingency (items 1-4)			30%	$ 44,662
	Total				**$ 194,000**

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NCCMA - Donald Flood and Drainage Management Plan

Concept Design - Levee 4

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, trafic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10%	$ 16,227
				Subtotal	
2	**Earthworks**				
2.1	Site prep including clearing and grubbing and strip and stockpile topsoil	2913	m^2	$ 8	$ 23,786
2.2	Cut - for levee key	547	m^3	$ 22	$ 11,754
2.3	Fill - compacted clay	2483	m^3	$ 43	$ 105,922
2.4	Supply and Place unsealed pavement	90	m^3	$ 127	$ 11,393
3	**Structures**				
3.1	300 mm precast concrete pipe Class 2 laid on ground including minimal excavation	20	m	$ 95	$ 1,890
3.2	Precast concrete headwall laid on ground and including additional excavation for toe	2	No	$ 376	$ 752
3.3	Floodgate	1	No	$ 400	$ 400
4	**Miscellaneous**				
4.1	Topsoiling and site rehabilitation	1296	m^2	$ 5	$ 6,373
	Subtotals items 2-4				$ 162,270
	Item 1				$ 16,227
	Subtotals items 1-4				$ 178,497
	Contingency (items 1-4)			30%	$ 53,549
	Total				**$ 232,000**

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NCCMA - Donald Flood and Drainage Management Plan

Concept Design - Culvert Option

Item	Description	Quantity	Unit	Rate	Amount
	Site access factor	1			
1	**Preliminaries and Site Establishment**				
1.1	Including Mobilisation/demobilisation, survey, environmental management,safety management, Cultural heritage management, quality management, quality management, traffic management, project co-ordination and admin, borow pit management, Miscellaneous items	1	Item	10% Subtotal	$ 220,980
2	**Roadworks**				
2.1	Excavate existing pavement and remove from site	412	m^3	$ 20	$ 8,240
2.2	Supply, deliver, place and compact a pavement consisting of:				
2.2.1	100mm layer of Class 2 crushed rock	760	m^2	$ 23	$ 17,100
2.2.2	200 layer of Class 3 3% cement treated crushed rock	760	m^2	$ 29	$ 21,660
2.2.3	Laneway pavement	231	m^2	$ 98	$ 22,523
3	**Structures**				
3.1	1500 x 1200 Box Culvert Installed	1060	m	$ 2,000	$ 2,120,000
3.2	Supply and installation of twin cell concrete endwalls (1500mm x 1200mm outlet)	2	Item	$ 10,140	$ 20,280
	Subtotals items 2-3				$ 2,209,803
	Item 1				$ 220,980
	Subtotals items 1-3				$ 2,430,783
	Contingency and Engineering (items 1-3)			30%	$ 729,235
	Total				**$ 3,160,000**

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