WENTWORTH SHIRE COUNCIL

WENTWORTH FLOOD STUDY

DECEMBER 2025

VOLUME 1 – MAIN REPORT

DRAFT REPORT FOR PUBLIC EXHIBITION

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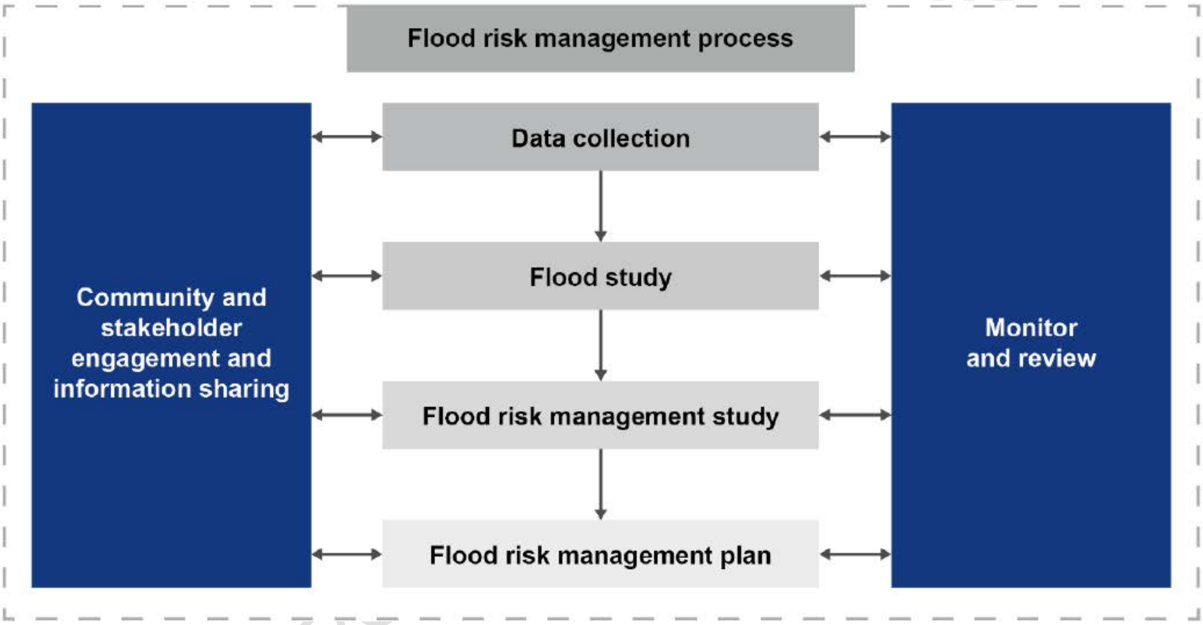
FOREWORD

The NSW State Government's Flood Prone Land Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood constraint and does not create additional flooding problems in other areas.

Under the Policy, the management of flood prone land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the flood risk management process shown below.



The *Wentworth Flood Study* is jointly funded by Wentworth Shire Council and the NSW Government, via the Department of Climate Change, Energy, the Environment and Water. The Flood Study constitutes the first and second stage of the flood risk management process for this area and has been prepared for Wentworth Shire Council to define flood behaviour under current conditions.

ACKNOWLEDGEMENT

Wentworth Shire Council has commissioned this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Climate Change, Energy, the Environment and Water.

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NOTE ON FLOOD FREQUENCY

In this report, the frequency of floods is referred to in terms of their Annual Exceedance Probability (**AEP**). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (**ARI**). The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) (%)	Average Recurrence Interval (ARI) (years)
0.2	500
0.5	200
1	100
2	50
5	20
10	10
20	5

The AEP of a flood represents the percentage chance of its being equalled or exceeded in any one year. Thus a 1% AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years; similarly, a 20 year ARI flood has a 5% chance of exceedance, and so on.

Reference is also made in the report to the Extreme Flood on the Murray and Darling rivers and the Probable Maximum Flood (**PMF**) in the urbanised parts of the study area. Both the Extreme Flood and the PMF define the upper limit of flooding that could reasonably be expected to occur and are much rarer than the 1% AEP flood which is usually adopted for planning purposes.

The PMF occurs as a result of the Probable Maximum Precipitation (**PMP**). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. While the PMP is used to estimate PMF discharges using a model which simulates the conversion of rainfall to runoff, the discharge hydrograph of the Extreme Flood was derived by applying a multiplication factor of three (3) to the corresponding 1% AEP discharge hydrograph.

NOTE ON QUOTED LEVEL OF ACCURACY

Peak flood levels have on occasion been quoted to more than one decimal place in the report in order to identify minor differences in values. For example, to demonstrate minor differences between peak heights reached by both historic and design floods and also minor differences in peak flood levels which will result from, for example, a partial blockage of hydraulic structures. It is not intended to infer a greater level of accuracy than is possible in hydrologic and hydraulic modelling.

ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
AMC	Antecedent Moisture Condition
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff (Geoscience Australia, 2019)
AWS	All Weather Station
BoM	Bureau of Meteorology
Council	Wentworth Shire Council
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EY	Exceedances per Year
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMM	Flood Risk Management Manual (NSW Government, 2023)
FRMS&P	Floodplain Risk Management Study and Plan
GDSM	Generalised Short Duration Method
GS	Gauging Station
IFD	Intensity-Frequency-Duration
LiDAR	Light Detecting and Ranging (type of aerial based survey)
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
TUFLOW	A true two-dimensional hydrodynamic computer model which has been used to define flooding patterns as part of the present investigation.

Chapter 7 of the report contains definitions of flood-related terms used in the study.

SUMMARY

S.1 Study Objective

The objective of the *Wentworth Flood Study* was to define the nature of both riverine (denoted herein as "Murray and Darling River flooding") and local catchment type flooding at the urban centres of Wentworth, Dareton, Buronga and Gol Gol (referred to herein collectively as "the four urban centres") for flood frequencies ranging between 20 and 0.2 per cent Annual Exceedance Probability (**AEP**), as well as for the Extreme Flood/Probable Maximum Flood (**PMF**).

The study focuses on the following two types of flooding which are present in different parts of the study area:

- **Murray and Darling River flooding**, which occurs when floodwater surcharges the inbank area of the Murray and Darling rivers, as well as their many anabranches. Murray and Darling River flooding is typically characterised by relatively deep and faster flowing floodwater in the main channel of the rivers but can include shallower and slower moving floodwater in overbank areas.
- **Local catchment flooding**, which is experienced at the four urban centres during periods of heavy rain. Local catchment flooding is typically characterised by relatively shallow and slow-moving floodwater.

The findings of the *Wentworth Flood Study* will be used as the basis for preparing the future *Wentworth Flood Risk Management Study and Plan* (***Wentworth FRMS&P***) which will assess options for flood mitigation and prepare a plan of works and measures for managing the existing, future and continuing flood risk in the four urban centres.

S.2 Existing Drainage and Levee Systems

While the study area principally comprises the urbanised parts of Wentworth, Dareton, Buronga and Gol Gol, it was necessary to analyse flood behaviour along a 420 km reach of the Murray River, 135 km reach of the Darling River and a 125 km reach of the Great Darling Anabranch in order to more accurately define the nature of flooding at the four urban centres.

Figure 1.1 in **Volume 2** of this report shows the location of the four urban centres, as well as the network of stream gauges that are presently in operation along the Murray and Darling river systems. **Figure 2.1** shows the layout of the two river systems in more detail, while **Figures 2.2** (3 sheets), **2.3** (2 sheets) and **2.4** (2 sheets) show the layout of the existing stormwater drainage system in the vicinity of the urban centres of Gol Gol and Buronga, Dareton and Wentworth, respectively.

The plan extent of the three levees that currently protect existing development at Wentworth from flooding on the Murray and Darling Rivers is shown on **Figure 2.4** (2 sheets), while longitudinal sections along their crest are shown on **Figure 2.5**, sheets 2 and 3. Note that for the purpose of the present study, the three levees have been denoted the Western, Eastern and Hospital levees and collectively referred to herein as the Wentworth town levees.

The Wentworth town levees were originally constructed in response to the 1956 flood and were later upgraded to provide a 1 m freeboard to the then computed 1% AEP flood level of RL 34.75 m AHD.

Figure 2.5, sheet 3 is a longitudinal section along the crest of an existing earthen levee which protects the Curlwaa Irrigation Area from flooding on the Murray River (denoted herein as the Curlwaa Levee), while **Figure 2.6** shows its plan extent. The Curlwaa Levee was originally constructed as a temporary levee prior to the arrival of the 1956 flood wave before being reconstructed in the late 1950s with the crest elevation set at the approximate height of the 1956 flood.

S.3 Historic Flooding at Wentworth

Major flooding has been experienced at Wentworth dating back to the 1870 flood of record. Other major floods to have been experienced at the four urban centres occurred in 1917, 1931, 1956 and more recently in 2022. **Annexure B10** of **Appendix B** of this report contains several photographs showing the flood behaviour that was observed in the vicinity the study area during the 1956 flood, while **Annexure B11** of **Appendix B** contains several photographs that show flood behaviour that was experienced in parts of the study area during the more recent 2022 flood. **Figure B1.1** (3 sheets) of **Appendix B** also shows the extent to which floodwater inundated parts of the floodplain near the peak of the 2022 flood.

While the 1956 flood has historically been considered to be equivalent to a design flood with an AEP of 1% in both peak flow and flood level terms, the present study found that while the peak flow in the Murray River was equivalent to about a 1% AEP flood, due to changes in floodplain topography and hydraulic roughness, the peak flood levels that were experienced at the time of the 1956 flood are now generally equivalent to a design flood with an AEP of only 2% (refer **Section 5.2.1** of this report for further discussion).

It is noted that a section of the Curlwaa Levee failed in the vicinity of Box Tree Lane during the 2022 flood, with floodwater backfilling a remnant flood runner that is located on the left (southern) bank of Tuckers Creek prior to the levee being repaired. It is also understood that the mechanism that is used to manually close the regulator that prevents floodwater from backing up Gol Gol Creek (denoted herein as the Gol Gol Regulator) seized up prior to the arrival of the 2022 flood and required the use of a backhoe to force the radial arm gate closed.

S.4 Analysis of Available Stream Gauge Record

Figures 1.1 and **2.1** show the plan location of the various stream gauges that are located on the Murray River, Darling River and Great Darling Anabranch in the vicinity of the four urban centres, while **Table B1.3** in **Appendix B** of this report sets out their dates of operation.

While there are a number of stream gauges located in the vicinity of the four urban centres, water level and flow rate data recorded at the following three stream gauges were principally relied upon for undertaking the present study:

- *Murray River at Euston* stream gauge (Gauging Station (**GS**) 414203, which is located about 260 km upstream of Wentworth (referred to herein as the Euston stream gauge)
- *Darling River at Burtundy* stream gauge (GS 425007) which is located about 135 km upstream of Wentworth (referred to herein as the Burtundy stream gauge).
- *Great Darling Anabranch at Bulpunga* stream gauge (GS 425011) which is located about 125 km upstream of its confluence with the Murray River (referred to herein as the Bulpunga stream gauge)

Figures 2.10, **2.11** and **2.12** show the difference between historic and current rating tables, as well as a number of stream gaugings for the Euston, Burtundy and Bulpunga stream gauges, respectively.

S.5 Flood Frequency Analysis

A flood frequency analysis was undertaken using annual maximum peak flows at the Euston and Burtundy stream gauges on the Murray and Darling rivers, respectively (refer **Annexures B1** and **B5** of **Appendix B** for full record of annual maximum peak flood level and flow data). A log-Pearson Type 3 (**LP3**) distribution was fitted to the annual series of peak flows for the full period of available record ending in the year 2024 using the FLIKE software (refer **Section 2.4** of this report for further discussion). A linear regression analysis was also undertaken to derive design peak flows on the Great Darling Anabranch at the location of the Bulpunga stream gauge.

Table S1 over the page sets out the adopted design peak flow estimates at the location of the Euston, Burtundy and Bulpunga stream gauges.

S.6 Analysis of Available Rain Gauge Data

Members of the Flood Risk Management Committee identified the occurrence of intense bursts of rain that occurred over the period December 2010 to February 2011 which caused nuisance flooding in parts of the study area. The left hand side of **Figure 2.16** shows the cumulative depth of rain that was recorded at the *Mildura Airport AWS* (GS 76031) rain gauge over the period 1 December 2010 to 8 February 2011, while the right hand side shows a comparison of the recorded rainfall with design intensity-frequency-duration curves.

An analysis of the rainfall that was recorded by the *Mildura Airport AWS* (GS 76031) rain gauge found that:

a) the 4 December 2010 storm event approximated a 5% AEP storm event for durations between about 30 minutes and 4.5 hours, reducing to about a 20% AEP storm event for a duration of 6 hours;

b) the 11 January 2011 storm event approximated a 10% AEP storm event for durations between 2 and 12 hours;

c) the 13 January 2011 storm event approximated a 20% AEP storm event for durations longer than 18 hours; and

d) the 4 February 2011 storm event approximated a 0.5% AEP storm event for durations ranging between 2 and 6 hours, a 1% AEP storm event for durations ranging between 6 and 12 hours, and a 0.2% AEP storm event for durations of 18 and 36 hours.

The rainfall that was recorded during the 11 January 2011 and 4 February 2011 storm events were used to validate the hydraulic models that were developed as part of the present study to define the nature of local catchment flooding at the four urban centres.

S.7 Development and Calibration of Flood Models

<u>Murray and Darling River Flooding</u>

Figure 3.1 (2 sheets) shows the layout of a two-dimensional (in plan) hydraulic model that was developed as part of the present study which covered a 420 km reach of the Murray River, a 135 km reach of the Darling River and a 125 km reach of the Great Darling Anabranch using the TUFLOW software (**Murray and Darling River TUFLOW Model**). As part of the model development and calibration process, the structure of the Murray and Darling River TUFLOW Model was modified so that it was representative of floodplain conditions that were current at the time of the 1956, 1974 and 2022 floods.

TABLE S1
ADOPTED DESIGN PEAK FLOW ESTIMATES

Design Flood Event	Euston Stream Gauge		Burtundy Stream Gauge		Bulpunga Stream Gauge	
	(m^3/s)(1)	(ML/d)(2)	(m^3/s)(1)	(ML/d)(2)	(m^3/s)(1)	(ML/d)(2)
Extreme Flood(3)	11,640	1,005,700	2,595	224,210	1,812	156,560
0.2% AEP	6,100	527,040	1,650	142,560	1,301	112,410
0.5% AEP	4,620	399,170	1,130	97,630	840	72,580
1% AEP	3,880	335,230	865	74,740	604	52,190
2% AEP	3,170	273,890	650	56,160	414	35,770
5% AEP	2,300	198,720	435	37,580	223	19,270
10% AEP	1,680	145,150	305	26,350	108	9,330
20% AEP	1,120	96,770	200	17,280	15	1,300

1. Rounded to the nearest 10 m^3/s
2. Rounded to the nearest 10 ML/d
3. The Extreme Flood was assumed to have a peak flow three (3) times that of the 1% AEP flood.

Figures 3.4, **3.5** and **3.6** (6 sheets each) show the TUFLOW model results, as well as the plan location of the available flood marks for the 1956, 1974 and 2022 floods, respectively, while **Figure 3.7** (4 sheets) shows the modelled water surface profiles along the Murray River, Darling River and Great Darling Anabranch for the three historic flood events. **Figures 3.8**, **3.9** and **3.10** show a comparison of the recorded and modelled stage and discharge hydrographs at the Colignan, Lock 10 and Lock 9 stream gauges, respectively.

Based on the outcomes of the model development and calibration process, the Murray and Darling River TUFLOW Model was considered to provide a good match with the available data. While there are some observations of flood behaviour for the 1956 and 2022 floods that couldn't be reproduced by the Murray and Darling River TUFLOW Model, they were considered minor in nature given the assumptions that have been made regarding the conditions that were present on the floodplain at the time of the two flood events.

<u>Local Catchment Flooding</u>

Figures 3.11 (3 sheets), **3.12** (2 sheets) and **3.13** (2 sheets) show the layout of three two-dimensional (in plan) hydraulic (TUFLOW) models that were developed at the urban centres of Gol Gol and Buronga (**Gol Gol and Buronga TUFLOW Model**), Dareton (**Dareton TUFLOW Model**) and Wentworth (**Wentworth TUFLOW Model**) (collectively referred to as the "urban centre TUFLOW models").

Due to the relatively flat nature of the topography, the Direct-Rainfall-on-Grid (**DRoG**) approach in the TUFLOW software was adopted for defining the nature of Local Catchment Flooding at the four urban centres.

While there is no available flood data upon which to formally calibrate the urban centre TUFLOW models, they were used to define the nature of flood behaviour that was likely experienced in the four urban centres at the time of the 11 January 2011 and 4 February 2011 storm events.

Figures 3.17 and **3.18** (3 sheets each) show the indicative extent and depth of inundation that is considered to be generally representative of conditions that arose as a result of the 11 January 2011 and 4 February 2011 storm events, respectively at the urban centres of Gol Gol and Buronga. Similar information is shown on **Figures 3.19** and **3.20** (2 sheets each) at Dareton, and on **Figures 3.21** and **3.22** (2 sheets each) at Wentworth.

S.8 Design Flood Estimation

Figures 4.1, **4.2** and **4.3** show the design discharge hydrographs that were used as input to the Murray and Darling River TUFLOW Model, noting that the hydrographs were derived by factoring the ordinates of the discharge hydrographs that were recorded by the Euston, Burtundy and Bulpunga stream gauges at the time of the 1956 and 2022 floods.

The design storm data that was input to the urban centre TUFLOW models were derived based on the procedures set out in the latest edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) and the publication entitled "*The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"* (Bureau of Meteorology, 2003).

S.9 Key Features of Murray and Darling River Flooding

The key features of Murray and Darling River flooding at the four urban centres and at the Curlwaa Irrigation Area are summarised as follows:

<u>Gol Gol and Buronga</u>

i. Floodwater is generally contained within the inbank area of the Murray River in a 20% AEP flood, except in the vicinity of Alcheringa Oval where floodwater surcharges its right (northern) bank where it inundates land that lies between the river and an existing levee that runs along the southern side of the oval (refer **Figure 5.1**, sheet 3).

ii. Floodwater surcharges the right (northern) bank of the river in a 10% AEP flood and inundates low lying areas in the vicinity of Gol Gol Creek, residential allotments on the southern side of Carramar Drive, residential allotments that are located approximately 550 m to the west of Alcheringa Oval and parkland areas (refer **Figure 5.2**, sheet 3). **F**loodwater also surcharges the right (northern) bank of the river and inundates the Buronga Riverside Caravan Park in a 10% AEP flood.

iii. Floodwater commences to surcharge Punt Road and Carramar Drive and the existing levees that are located to their west in a 2% AEP flood (refer **Figure 5.4**, sheet 3). Floodwater that surcharges the river at this location inundates existing allotments that are located between the highway and the river. It also backwaters across Hendy Road between Dawn Avenue and Midway Drive. Floodwater also overtops existing levees that are located along the right (northern) bank of the river downstream of the Sturt Highway in a 2% AEP flood where it inundates land that lies between the river and River Drive/Silver City Highway.

iv. While peak 1% AEP flood levels along the Murray River at Gol Gol and Buronga are about 0.85-1.0 m higher than peak 2% AEP flood levels, the extent of inundation does not increase significantly (refer **Figure 5.5**, sheet 3).

v. Floodwater commences to surcharge Adelaide Street immediately to the west of the Gol Gol Creek Regulator in a 0.5% AEP flood (refer **Figure 5.6**, sheet 3). While floodwater that surcharges the river at this location discharges to Gol Gol Creek, it does not fill the Lake Gol Gol system that lies further to the north. Floodwater also commences to surcharge the Silver City Highway between its intersections with Corbett Avenue and Arumpo Road in a 0.5% AEP flood, inundating the industrial allotments along Modica Crescent to depth of up to about 0.9 m.

vi. Road access to the townships of Gol Gol and Buronga will become cut in a 0.5% AEP flood (refer **Figure 5.6**, sheet 3).

vii. **T**he volume of floodwater that surcharges the river into the Lake Gol Gol system increases significantly in a 0.2% AEP flood and as a result, causes a level pool that backs up on the upstream (eastern) side of the Silver City Highway (refer **Figure 5.7**, sheet 3).

viii. Floodwater that overtops Adelaide Street in the vicinity of the Gol Gol Creek Regulator in a 0.2% AEP flood inundates existing residential allotments in Adelaide Street, Alderton Drive, Allen Court, Fiona Drive, Gol Gol North Road, John Street, King Street, Kingfisher Road, Modikerr Way, Tapio Street, Wilga Road South, William Street and Wood Street (refer **Figure 5.7**, sheet 3).

ix. Floodwater commences to overtop the Hendy Road between Midway Drive and Melaleuca Street in a 0.2% AEP flood where it inundates existing development that is located in the vicinity of the intersection of Midway Drive and Pitman Avenue (refer **Figure 5.7**, sheet 3).

x. Extreme Flood levels along the Murray River are about 2.2-2.8 m higher than corresponding peak 1% AEP flood levels.

xi. **T**he Extreme Flood will inundate existing development at Buronga and Gol Gol to depths in excess of 3.5 m (refer **Figure 5.8**, sheet 3).

<u>Dareton</u>

i. Floodwater commences to surcharge the levee that runs along the southern side of the Coomealla Golf Course in a 10% AEP flood (refer **Figure 5.2**, sheet 5).

ii. Floodwater inundates Kookaburra Drive and Golf Course Road to the north and east of their intersection in a 5% AEP flood (refer **Figure 5.3**, sheet 5).

iii. Floodwater commences to inundate the rear of the residential allotments that are located on the southern side of Riverview Drive in a 1% AEP flood (refer **Figure 5.5**, sheet 5).

iv. Existing development in Dareton generally remains flood free in the Extreme Flood (refer **Figure 5.8**, sheet 5).

<u>Wentworth</u>

i. Floodwater is generally contained within the banks of the Murray and Darling rivers in the vicinity of Wentworth in a 20% AEP flood, except downstream of Lock 10 where a backwater extends across Logbridge Road into Theoga Lagoon (refer **Figure 5.1**, sheet 6).

ii. Floodwater surcharges the right (western) bank of the Darling River in a 10% AEP flood where it inundates the rear of residential allotments that are located on the eastern side of Adams Street (refer **Figure 5.2**, sheet 6). Floodwater that backwaters into Theoga Lagoon during a 10% AEP flood also inundates the rear of existing residential allotments that are located on the western side of Adams Street.

iii. Floodwater surcharges the right (western) bank of the Darling River to the north of Sheok Lane in a 5% AEP flood where it then flows in a southerly direction on the eastern and western sides of the Wentworth Aerodrome (refer **Figure 5.3**, sheet 6). Road access to the aerodrome is also cut in a flood of this magnitude.

iv. Road access to the north of Wentworth is cut in a 5% AEP flood (refer **Figure 5.3**, sheet 6)

v. Floodwater that surcharges the left (eastern) bank of the Darling River to the north of the urban centre in a 5% AEP flood will inundate existing residential allotments that are located outside of the Eastern Levee along Wentworth Street (refer **Figure 5.3**, sheet 6).

vi. Old Wentworth Road will be cut by floodwater in a 5% AEP flood (refer **Figure 5.3**, sheet 6).

vii. Wentworth will become isolated in a 2% AEP flood as the Silver City Highway is inundated where it runs between Tuckers Creek and the Curlwaa Levee (refer **Figure 5.4**, sheet 6).

viii. The Eastern and Western Levees are overtopped in a 0.2% AEP flood, resulting in maximum depths of inundation in existing development of about 1.8 m and 2.8 m, respectively (refer **Figures 5.7** and **5.10**)

ix. Land internal to the Eastern and Western Levees will be inundated in an Extreme Flood to maximum depths of about 2.5 m and 3.5 m, respectively.

x. Flood levels will exceed the Imminent Failure Flood (**IFF**)[1] level of the Western Levee in the vicinity of the section of concrete wall that is located behind No. 5-7 Perry Street (refer levee chainage 3,750 m) in a 5% AEP flood.

xi. Floodwater will surcharge the Western Levee at the abovementioned location in a 0.2% AEP flood, resulting in maximum depths of inundation in existing development of about 1.8 m (refer **Figures 5.7** and **5.10**).

xii. Flood levels exceed the IFF level of the Eastern Levee along the Silver City Highway (levee chainage 2,380 m) in a 5% AEP flood.

xiii. Floodwater will surcharge the Eastern Levee at the abovementioned location in a 0.2% AEP flood, resulting in maximum depths of inundation in existing development of about 2.8 m (refer **Figures 5.7** and **5.10**).

xiv. Flood levels exceed the IFF level of the Hospital Levee at a low point that is located on the western side of the hospital (levee chainage 320 m) in a 2% AEP flood.

xv. Floodwater will surcharge the Hospital Levee along its entire length in an Extreme Flood.

<u>Curlwaa Irrigation Area</u>

i. Flood levels exceed the IFF level of the Curlwaa Levee at the western end of the earth embankment that runs along the southern side of the Silver City Highway adjacent to its intersection with Abbotsford Road (levee chainage 1,400 m) in a 10% AEP flood.

ii. The Curlwaa Levee is overtopped in a 2% AEP flood at the location of an existing low point on Williamsville Road (levee chainage 330 m), the Silver City Highway (levee chainages 1,400 m, 2,430 m an 8,000 m) and at a gap in the levee that is located approximately 200 m to the north of the Silver City Highway bridge crossing of Tuckers Creek (levee chainage 17,810 m) (refer **Figures 5.4** and **5.10**, sheet 3).

iii. The Curlwaa Levee is overtopped at an additional four locations in a 1% AEP flood, and as a result, the land behind the levee is almost entirely inundated by floodwater (refer **Figures 5.5** and **5.10**, sheet 3).

iv. The land behind the Curlwaa Levee is inundated to depth of 1.5 m of greater in an Extreme Flood (**Figure 5.8**, sheet 3).

S.10 Key Features of Local Catchment Flooding

The key features of local catchment flooding at the four urban centres are summarised as follows:

<u>Gol Gol and Buronga</u>

i. Due to the flat nature of the topography, local catchment flooding is generally typified by floodwater that ponds in the natural low-lying parts of the urban areas.

ii. Depths of inundation will exceed 300 mm in the following naturally occurring trapped low points in a 5% AEP storm (refer **Figure E6.3** in **Appendix E**):

   - in the large allotments that are located between Hendy Road and the Murray River to the west of Alcheringa Oval;

[1] The IFF is the flood which would compromise the 1 m freeboard provision in the levee design. The prediction of a flood higher than the IFF would trigger the evacuation of the protected area, as NSW SES would deem the levee to be at risk of failure.

- in allotments that are located adjacent to the low point in Midway Drive to the south Pitman Avenue;
- in the allotments that are bounded by King Street to the west, William Street to the north, Tapio Street to the east and Adelaide Street to the south; and
- in the allotments that are bounded by Wood Street to the north, Burns Street to the east, William Street to the south and Taipo Street to the west.

iii. In addition to the abovementioned naturally occurring trapped low points, the depth of inundation will exceed 300 mm in a 1% AEP storm at the following locations (refer **Figure E6.5** in **Appendix E**):

- in allotments that are located on the southern side of Moontongue Drive to the east of its intersection with Kari Drive;
- in allotments that are located on the northern side of Crane Drive to the east of its intersection with Tower Court; and
- in industrial allotments that are located in the vicinity of Grace Crescent.

iv. The maximum depth of inundation in the abovementioned low points increases to between 0.7 to 1.2 m in a PMF event (refer **Figure E6.8** in **Appendix E**).

<ins>Dareton</ins>

i. Local catchment runoff generally concentrates along the following two drainage lines:

- a flow path that runs in a south-westerly direction through rural land between the intersection of the Silver City Highway and Pump Station Road, and the Murray River on the southern side of Golf Course Road; and
- a flow path that runs in a north-westerly direction from the intersection of Avoca Street and Oleander Drive towards the intersection of Bogabilla Road and Jacarandra Road.

ii. Existing development is generally unaffected by local catchment flooding during storms up to 2% AEP in intensity (refer **Figures F1.1** to **F1.5** in **Appendix F**).

iii. The local catchment runoff would pond in existing allotments in a 1% AEP storm at the following locations (refer **Figure F1.6** in **Appendix F**):

- on the western side of Oleander Drive in the vicinity of its intersection with Avoca Street;
- on the eastern side of Hawson Street to the south of its intersection with the Silver City Highway; and
- in industrial allotments that are located between Pump Station Road and Tallawalla Road to the north of the latter’s intersection with Scout Road.

<ins>Wentworth</ins>

i. The pipes that extend through the Wentworth town levees generally have sufficient capacity to prevent major flooding from occurring in existing development.

ii. While the depth of inundation would generally not exceed 300 mm in the urbanised parts of Wentworth during a 1% AEP storm, greater depths of inundation would be experienced at the following locations (refer **Figure G6.5** in **Appendix G**):

<ins>**Eastern side of the Darling River**</ins>

- on the eastern side of Wentworth Street to the south of its intersection with Emily Street; and

- on the eastern side of Wentworth Street to the north of its intersection with Armstrong Avenue.

<u>Western side of the Darling River</u>

- between Adams Street and Darling Street to the south of Perry Street;
- on the western side of the Western Levee between Perry Street and Burns Street;
- on the southern side of Neville Street west of its intersection with Darling Street;
- on the western side of Darling Street to the north of its intersection with Helana Street;
- on the northern side of the levee between Adams Street and Darling Street; and
- between Murray Street and Cadell Street to the west of Alice Street.

iii. **A** significant portion of the urban centre of Wentworth would be inundated to depths greater than 300 mm in a PMF event (refer **Figure G6.8** in **Appendix G**).

S.11 Economic Impact of Flooding

The economic consequences of flooding on residential, commercial/industrial and public buildings at the four urban centres were assessed as part of the present study. **Section 5.5** of this report summarises the findings of the economic analysis, while **Appendix H** provides a more detailed discussion on the flood damages assessment.

Figures H7.1, **H7.2** and **H7.3** in **Appendix H** show the location and AEP at which individual dwellings/buildings first become above-floor inundated as a result of Murray and Darling River flooding at the urban centres of Gol Gol/Buronga, Dareton and Wentworth, respectively, while **Figures H7.4**, **H7.5** and **H7.6** show similar information relating to local catchment flooding.

Column C in **Table S2** sets out the total flood damages that would be experienced at the four urban centres for a flood with an AEP of 1%. While the study found that flood damages resulting from Murray and Darling River flooding are greatest at the urban centres of Gol Gol and Buronga at the 1% AEP level of flooding, significant flood damages would commence to be experienced at Wentworth during a flood with an AEP of between 0.5 and 0.2% AEP due to the overtopping of the Wentworth town levees.

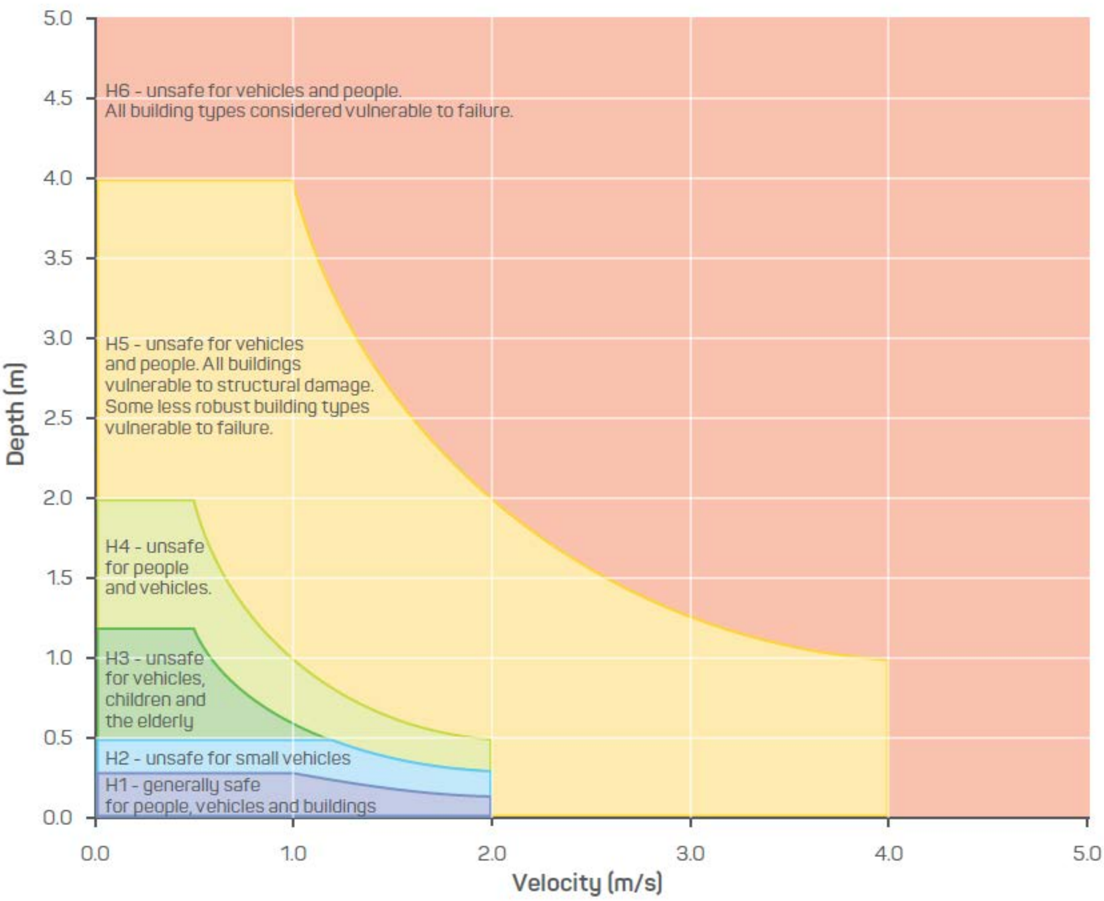
TABLE S2
SUMMARY OF DAMAGES AT THE FOUR URBAN CENTRES
1% AEP LEVEL OF FLOODING
$ MILLION

Flood Mechanism [A]	Urban Centre [B]	Total Flood Damages [C]	Net Present Value of Flood Damages [D]
Murray and Darling River Flooding	Gol Gol	20.2	5.8
	Buronga	13.2	4.6
	Dareton	0	0
	Wentworth	1.8	0.8
Local Catchment Flooding	Gol Gol	0.8	1.3
	Buronga	0.4	0.1
	Dareton	0.1	0.1
	Wentworth	0.6	0.4

The Net Present Value of damages likely to be experienced at the four urban centres for all floods up to 1% AEP in magnitude for a 30 year economic life and a discount rate of 5 per cent is also set out in column D in **Table S2**. One or more flood mitigation schemes costing up to these amounts could be economically justified if they eliminated damages in each urban centre up to the 1% AEP flood event. While schemes costing more than these values would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

S.12 Flood Hazard Classification

Hazard Vulnerability Classification diagrams for the 5%, 1% and 0.2% AEP Murray and Darling River floods, as well as the Extreme Flood based on the velocity-depth relationship that is shown in the illustration below are presented on **Figures 5.11**, **5.12** , **5.13** and **5.14** (6 sheets each), while **Figures E1.9** to **E1.12** (3 sheets each) of **Appendix E**, **Figures F1.9** to **F1.12** (2 sheets each) of **Appendix F** and **Figures G1.9** to **G1.12** (2 sheets each) of **Appendix G** show similar results for local catchment flooding at Gol Gol and Buronga, Dareton and Wentworth, respectively.



The present study found that areas classified as H5 and H6 are generally limited to the inbank area of the rivers and their adjacent riparian zone and offline storages in the vicinity of the four urban centres during a 1% AEP Murray and Darling River flood, except at the following locations:

- in the area bounded by Punt Road to the east, the Sturt Highway/Hendy Road to the north, West Road to the west and the Murray River to the south at Gol Gol and Buronga;
- in the area bounded by the Silver City Highway to the east and north, and the Murray River to the west and south at Buronga;

- in Coomealla Golf Course at Dareton; and
- in the area bounded by Syndicate Road to the east, the Silver City Highway to the south and the Curlwaa levee to the west and north at Curlwaa.

The present study also found that while the four urban centres are generally subject to H1 and H2 type flooding conditions during a 1% AEP local catchment flood, there are several areas that are principally of a ponding nature where H3 and H4 conditions are present.

S.13 Hydraulic Categorisation of the Floodplain

The hydraulic categorisation of the floodplain requires the assessment of the main flow paths. Those areas of the floodplain where a significant discharge of water occurs during floods are denoted *Floodways* and are often aligned with naturally defined channels. *Floodways* are areas that, even if only partially blocked, would cause a significant re-distribution of flood flow or a significant increase in flood levels. The remainder of the floodplain is denoted *Flood Storage* or *Flood Fringe* areas.

Figures 5.15, **5.16** and **5.17** (5 sheets each) show the division of the floodplain into floodway, flood storage and flood fringe areas for Murray and Darling River floods with AEPs of 5% and 1 %, as well as the Extreme Flood. The present study found that floodways are generally limited to the inbank area of the Murray and Darling Rivers and their adjacent riparian zone in the vicinity of the four urban centres during a 1% AEP flood, with the following exceptions:

- on the right bank of the Murray River immediately upstream of the George Chaffey Bridge at Gol Gol and Buronga, where a floodway is present in the area that is bounded by Punt Road to the east, the Sturt Highway/Hendy Road to the north, West Road to the west and the Murray River to the south;
- in the area bounded by the Silver City Highway to the east and north, and the Murray River to the west and south at Buronga; and
- at the western end of Cadell Street at Wentworth in the vicinity of Lock 10.

Figures E1.13 to **E1.16** (3 sheets each) of **Appendix E**, **Figures F1.13** to **F1.16** (2 sheets each) of **Appendix F** and **Figures G1.13**, **G1.14**, **G1.15** and **G1.16** (2 sheets each) of **Appendix G** show the division of the floodplain at Gol Gol and Buronga, Dareton and Wentworth, respectively into floodway, flood storage and flood fringe areas for local catchment floods with AEPs of 5%, 1% and 0.2 %, as well as the PMF. It was found that that floodways are generally limited to the inbank area of the engineered and natural channels that convey local catchment runoff away from the urban centres.

S.14 Sensitivity Analyses

The following analyses were undertaken to test the sensitivity of flood behaviour to:

- an increase in hydraulic roughness;
- a partial blockage of hydraulic structures;
- increases in rainfall intensity associated with future climate change;
- a failure to close the Gol Gol Regulator;
- a partial or complete failure of the Curlwaa and Wentworth town levees; and
- the assumed coincident nature of flooding in the Murray and Darling rivers.

The key findings of the sensitivity analyses were as follows:

i. A 20% increase in the adopted hydraulic roughness values would result in an increase in peak 1% AEP flood levels on the Murray River of about 0.3 m in the vicinity of Gol Gol and Buronga, 0.25 m in the vicinity of Dareton and 0.1 m in the vicinity of Wentworth, noting that the increases would be sufficient to result in floodwater overtopping Adelaide Street where it would discharge to the Gol Gol Lake system.

ii. The partial blockage of hydraulic structures does not significantly alter 1% AEP flood behaviour at the four urban centres.

iii. Future climate change has the potential to exacerbate flooding conditions in the four urban centres due to increases in both peak flows on the river system and the intensity of localised rainfall, with the potential lower and upper bound increases in peak 1% AEP flood levels on the Murray River found to be as follows:

   - increases by between about 0.4 m (lower bound) and 1.1 m (upper bound) in the vicinity of Gol Gol and Buronga;
   - Increases by between about 0.3 m (lower bound) and 0.9 m (upper bound) in the vicinity Dareton; and
   - Increases by between about 0.2 m (lower bound) and 0.4 m (upper bound) in the vicinity of Wentworth.

   Two of the main implications of these potential increases in peak 1% AEP flood levels are:

   a) floodwater would overtop Adelaide Street where it would discharge to the Gol Gol Creek Lake system, noting that this would significantly increase the extent of land that would be inundated by floodwater in the vicinity of Gol Gol and Buronga; and

   b) floodwater would overtop the Wentworth town levees.

iv. The failure to close the Gol Gol Regulator in advance of the arrival of a flood would result in the filling of the Gol Gol Lake system. The present study found that if the Gol Gol Regulator was not closed during a 1% AEP flood on the Murray River, then floodwater would pond to the elevation of the low point in the Silver City Highway to the north of its intersection with Corbett Avenue (i.e. to an elevation of about RL 39.3 m AHD), noting that allotments that back onto Gol Gol Creek immediately north of the regulator would be inundated to depths of up to about 2.2 m.

v. Either a partial or complete failure of the Curlwaa Levee in a 5% AEP flood would result in low lying land being inundated to depths of up to about 4 m.

vi. Either a partial or complete failure of the Wentworth town levees in a 1% AEP flood would result in existing development that is located on the eastern and western side of the Darling River being inundated to depths of up to about 1.8 m and 2.5 m, respectively.

vii. Flooding on the Murray River is the dominant mechanism for maximising peak flood levels at the four urban centres.

S15 Flood Emergency Response Classification

Floodplains can be categorised based upon the flood emergency response classifications which provide an indication of the relative difficulty of the flood emergency management situation at a community or precinct scale. The flood emergency response classifications can also assist in identifying the type and scale of information needed by the emergency managers to assist with emergency response planning.

Flood emergency response classifications were derived as part of the present study for Murray and Darling River floods with AEPs of 5%, 1% and 0.2%, %, as well as the Extreme Flood based on the definitions that are set out in the *Floodplain Risk Management Guideline EM01 Support for Emergency Management Planning*. **Figures 5.30**, **5.31**, **5.32** and **5.33** (5 sheets each) show the outcomes of the assessment, noting that **Section 5.12** of this report contains extracts from the guideline which provide a description of the classifications that are relevant to the study area.

The key findings of the flood emergency response classification mapping were as follows:

- The urban centre of Wentworth becomes a high flood island in a flood as frequent as 5% AEP as vehicular access to higher ground on the northern side of the floodplain is cut at the following locations:
  - the Silver City Highway between Tuckers Creek and the Curlwaa Levee; and
  - Pooncarie Road to the north of the town; and
  - The Silver City Highway to the north of its intersection with Renmark Road.
- The urban centre of Wentworth is considered a low flood island in a 0.2% AEP flood.
- The urban centres of Gol Gol and Buronga are deemed a High Flood Island in a 0.2% AEP Murray and Darling River flood as vehicular access to higher ground on the northern side of the floodplain via the Silver City Highway is cut.

The urban centre of Dareton has rising road access to higher ground on the northern side of the floodplain in flood events up to the Extreme Flood.

S.16 Flood Planning Related Considerations

To assist Council in its assessment of future development that is proposed at the four urban centres prior to the completion of the future *Wentworth FRMS&P*, the present study developed a recommended set of contemporary flood planning related guidelines, details of which are set out in **Appendix I** of this report.

Section 5.13 of this report sets out the approach that has been adopted for defining the extent of the Flood Planning Area (**FPA**) and a preliminary set of Flood Planning Constraint Categories (**FPCCs**) at the four urban centres, while **Figures I1.1** and **I1.2** in **Appendix I** of this report respectively show their spatial extent.

Note that the guidelines, along with the FPA and FPCCs will need to be reviewed at the time of preparing the future *Wentworth FRMS&P*.

1 INTRODUCTION

1.1 Study Background

This report presents the findings of an investigation of flooding in the vicinity of the urban centres of Wenworth, Dareton, Buronga and Gol Gol, all of which are located on the northern bank of the Murray River in the Wentworth Shire Council (**Council**) Local Government Area (**LGA**). The study has been commissioned by Council with financial assistance from the NSW Government, via the Department of Climate Change, Energy, the Environment and Water (**DCCEEW**).

The study objective was to define flood behaviour in terms of flows, water levels, velocities and hazard for floods ranging between 20 and 0.2 per cent Annual Exceedance Probability (**AEP**), as well as for the Extreme Flood and the Probable Maximum Flood (**PMF**). The investigation involved flood frequency analyses to derive design peak flows on the Murray River and Darling River, as well as rainfall-runoff type modelling at the four urban centres to define the nature of local catchment type flooding. The model results were interpreted to present a detailed picture of flood behaviour under present day conditions.

The study focuses on the following two types of flooding which are present in different parts of the study area:

- **Murray and Darling River flooding**, which occurs when floodwater surcharges the inbank area of the Murray and Darling rivers, as well as their many anabranches. Murray and Darling River flooding is typically characterised by relatively deep and faster flowing floodwater in the main channel of the rivers but can include shallower and slower moving floodwater in overbank areas.
- **Local catchment flooding**, which is experienced at the four urban centres during periods of heavy rain. Local catchment flooding is characterised by relatively shallow and slow-moving floodwater.

The study forms the first and second step in the flood risk management process (refer process diagram presented in the Foreword) and is a precursor of the future *Wentworth Flood Risk Management Study and Plan* (***Wentworth FRMS&P***) which will consider measures which are aimed at reducing the existing, future and continuing flood risk in the four urban centres.

1.2 Community Consultation and Available Data

A *Community Survey* was originally prepared and advertised online during March-April 2024 with no responses received during the consultation period. A copy of the *Community Survey* which was prepared by Council and the Consultants is included in **Appendix A** of this report.

A second targeted community consultation was undertaken whereby the *Community Survey* was disseminated to approximately 60 members of the public with known flooding issues in the vicinity of their property. A total of 16 responses were received.

Of those that responded, a total of 12 respondents were affected by flooding in 2022, while two had been affected by flooding in 1956, 1974 and 1990. Respondents provided anecdotal descriptions and photos of flood behaviour in the vicinity of their property in 2022, copies of which are contained in **Appendix B** of this report. **Appendix B** also contains a summary of data that were available for the present study.

1.3 Previous Investigations

The following documents deal with flooding in the study area:

- *The River Murray Flood Problem* (Harrison, 1957)
- *Murray River Flood Plain Management Study* (Gutteridge Haskins & Davey Pty Ltd (**GHD**) et al., 1986)
- *Gol Gol to Abbotsford Bridge Flood Study* (Department of Water Resources (**DWR**), 1990)
- *Audit of Flood Levees for New South Wales – Curlwaa Levee* (Public Works, 1994)
- *Murray River - Gol Gol Bridge to Abbotsford Bridge Floodplain Management Study* (Kinhill Engineers, 1995a)
- *Murray River - Gol Gol Bridge to Abbotsford Bridge Floodplain Management Study Plan* (Kinhill Engineers, 1995b)
- *Rehabilitation of Wentworth Levee - Investigation & Design* (Water Resources Consulting Services (**WRCS**), 1997)
- *Wentworth Shire Council Stormwater Management Plan* (Department of Public Works and Services (**DPWS**), 2007)
- *Wentworth Floodplain Risk Management Study* (Worley Parsons, 2011)
- *Visual Audit of Wentworth Levee* (NSW Public Works Advisory, 2017)
- *Wentworth Levee Owner's Manual* (NSW Public Works Advisory, 2018)
- *Wentworth Flood Study* (Advisian, 2021) – draft report
- *Visual Audit of Curlwaa Levee* (NSW Public Works Advisory, 2022)
- *Wentworth Shire Local Flood Emergency Sub Plan* (NSW SES, 2023)

Refer **Section B2** of **Appendix B** for a brief overview of several of the above reports.

1.4 Layout of Report

Chapter 2 contains background information including a brief description of the Murray and Darling river systems at Wentworth, as well as the key features of the four urban centres, including their stormwater drainage systems. This chapter also includes a brief history of flooding in the study area and an analysis of the available stream gauge record.

Chapter 3 deals with the development and calibration of the TUFLOW hydraulic models which were used to define the nature of both riverine and local catchment flooding in the study area. The major floods that occurred in 1956, 1974 and 2022 were relied upon to calibrate the TUFLOW hydraulic model that was used to define the nature of Murray and Darling River flooding. Three storm events that occurred in the period December 2010 to February 2011 were used to validate the TUFLOW hydraulic models that were used to define the nature of local catchment flooding at the four urban centres. The hydraulic model parameters found to achieve a good match between observed and modelled flood behaviour were then applied to the TUFLOW hydraulic models that were used to define the nature of local catchment flooding at the four urban centres.

Chapter 4 deals with the derivation of design discharge hydrographs which were used as input to the hydraulic models. For the definition of Murray and Darling River flooding, this involved the factoring of the ordinates of recorded discharge hydrographs to match peak flows derived by undertaking an analysis of the available stream gauge record, while for the definition of local catchment flooding, this involved the conversion of rainfall to surface runoff using the direct-rainfall-on-grid type approach within the TUFLOW software.

Chapter 5 details the results of the hydraulic modelling of the design flood events. Results are presented as plans showing indicative extents and depths of inundation for a range of design flood events up to the Extreme Flood/PMF. A summary of the economic impacts of flooding to existing development in the four urban centres is presented in the chapter, along with an assessment of flood hazard and hydraulic categorisation. **Chapter 5** also details the results of various sensitivity analyses that were undertaken using the TUFLOW hydraulic models. This included the assessment of the impact that changes in hydraulic roughness, a partial blockage of the hydraulic structures, partial and complete failure of the existing urban flood protection levees and potential increases in rainfall intensities associated with future climate change could have on flood behaviour.

Chapter 6 contains a list of references, whilst **Chapter 7** contains a list of flood-related terminology that is relevant to the present study.

The following appendices are included in the report:

- **Appendix A** contains a copy of the *Community Survey* that was distributed to members of the public with known flooding issues in the vicinity of their property.
- **Appendix B** contains a list of data that were available for the present study, as well as several photos which show historic flood behaviour in the study area.
- **Appendix C** contains a copy of the design input data that were extracted from the *Australian Rainfall and Runoff (**ARR**) Data Hub* for the four urban centres.
- **Appendix D** summarises the design blockage values that were assigned to the hydraulic structures in the various TUFLOW models.
- **Appendix E** (which is bound in **Volume 2**) contains a set of figures showing the nature of local catchment flooding at Buronga and Gol Gol.
- **Appendix F** (which is bound in **Volume 2**) contains a set of figures showing the nature of local catchment flooding at Dareton.
- **Appendix G** (which is bound in **Volume 2**) contains a set of figures showing the nature of local catchment flooding at Wentworth.
- **Appendix H** contains an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings at the four urban centres.
- **Appendix I – Suggested Wording for Inclusion in Wentworth Development Control Plan** presents guidelines for the control of future urban development in flood prone areas specifically in relation to the study area. The guidelines cater for both Murray and Darling River Flooding and Local Catchment Flooding.

Figures referred in the main body of the report are bound separately in **Volume 2**.

2 BACKGROUND INFORMATION

2.1 Drainage System

2.1.1. Murray-Darling Basin

The Murray–Darling Basin is the largest river system in Australia, covering a 1 million square kilometre area which extends across parts of Queensland, New South Wales, Victoria, South Australia, and the Australian Capital Territory. It is a complex network of rivers, which includes both the Murray and Darling rivers. **Figure 2.1** shows the layout of the Murray and Darling river system in the vicinity of the four urban centres.

The inbank area of the Murray River generally varies in width between 150-200 m where it runs in a westerly direction between the townships of Gol Gol and Wentworth, with available bathymetric survey showing it has an average bed slope of about 0.007%. Available aerial photography shows that vegetation on the immediate overbank area of the river has become denser over time, especially when compared to conditions that were present at the time of the 1956 flood.

A number of earthen levees were erected on both sides of the Murray River in advance of the recent flood that occurred in 2022, limited survey data on which was available for use in the present study. Other notable changes that have occurred along the river include the construction of a new bridge crossing of the Murray River at Mildura and the construction of a large marina on the eastern (upstream) side of the bridge crossing on the Victorian side of the border. Sections 2.1.5 and 2.1.6 also provide background to the construction of several ring levees that have been built to protect existing development and productive farmland from riverine type flooding at Wenworth and the Curlwaa Irrigation Area.

The inbank area of the Darling River immediately upstream of its confluence with the Murray River measures between 50-100 m in width, with available bathymetric survey showing that it also has an average bed slope of about 0.007% at Wentworth.

The Great Darling Anabranch is located to the west of the Darling River and has a bed slope that is effectively flat over a 50 km length upstream of its confluence with the Murray River. Flows in the Great Darling Anabranch are highly regulated due to the operation of the Menindee Lake system, with unregulated flows only being experienced in the watercourse during major floods on the Darling River.

2.1.2. Gol Gol Urban Centre

The township of Gol Gol is situated on the northern bank of the Murray River, approximately 5 km upstream of Mildura and has a population of about 1,950 (2021 census). Gol Gol Creek runs in a south-west direction through the urbanised parts of Gol Gol and discharges to the Murray River to the south of the intersection of the Sturt Highway and Burns Street.

The urbanised parts of Gol Gol consist of large lot residential type development on the eastern side of Gol Gol Creek and general residential and commercial type development in land zoned *RU5 Village* on its west. The western fringe of the town, west of Punt Road, is low lying and flood liable. Recent development in Carramar Drive is on fill to around 0.75 m above the level of the 1956 flood. There are other scattered residential properties in and on the fringes of the low lying land in Punt Road and on the Sturt Highway. New development to the west has been sited on filled ground above the level of the 1956 flood, although access could be affected in larger floods.

Figure 2.2 (3 sheets) shows the layout of the existing stormwater drainage system in the vicinity of Gol Gol. The section of the town between Punt Road and King Street is on elevated ground. The piped stormwater drainage system on the northern side of Wood Street generally drains in a northerly direction and discharges to natural trapped low points on the northern fringe of the town, while the drainage system to the south of Wood Street south to the Murray or south-west where it discharges to a natural low point on the northern side of the Sturt Highway adjacent to its intersection with Punt Road. **Figure 2.2** shows that a network of engineered channels have been constructed to drain the natural low points on the northern side of Gol Gol in a westerly direction to the Murray River floodplain on the northern side of the intersection of River Road and the Silver City Highway in Buronga.

East of King Street the town area is flat, with relatively low areas located to the south of the Sturt Highway near Gol Gol Creek. The piped stormwater drainage system in the area generally drains in an easterly direction and discharges to Gol Gol Creek. Land that lies to the east of Gol Gol Creek generally drains to natural low points that are located around the urban fringe, or in a northerly direction to Gol Gol Creek.

A flow control device commonly known as the Gol Gol Creek Regulator is fitted on the northern (upstream) side of a culvert that is located where Gol Gol Creek runs beneath the Sturt Highway. The Gol Gol Creek Regulator comprises a radial arm gate that is manually wound shut to regulate the volume of water that discharges to the creek from the Murray River, noting that it is understood that the manual closing mechanism failed during the 2022 flood and a backhoe was used to force the gate close. The Gol Gol Creek Regulator was constructed in the 1950s and is operated by the *Gol Gol Creek Community Reference Group* to both regulate flows in the creek and mitigate flooding during Murray River flood events. It is understood that there is no operational manual for the structure and that design plans were lost years ago. While the ownership of the structure was not able to be determine as part of the present study, TfNSW did confirm that it is not one of its assets.

2.1.3. Buronga Urban Centre

The township of Buronga is situated at the junction of the Silver City and Sturt highways on the northern bank of the Murray River opposite Mildura and has a population of about 1,250 in (2021 census). The majority of the township is located along the Sturt Highway on high ground. A disjointed and discontinuous system of private levees that is located along the riverfront and around the boundaries of some individual land holdings provides a measure of local protection from floods on the Murray River.

The scattered houses on the Sturt Highway to the east are mostly on high ground, although some are sited towards the lower ends of the blocks and near or on flood liable land. Some houses are constructed on elevated supports on the riverfront, while others are built on filled ground behind or tied into the ad hoc levees that are located along the river. One group of houses is completely enclosed by a horseshoe shaped levee with the open end tied into high ground at the highway and the closed end tied into a levee that surrounds Alcheringa Oval.

Development along the section of the Sturt Highway that runs the centre of Buronga to the Murray Bridge is all potentially flood liable. The development is a mixture of houses, light industrial installations, motels and semi-rural enterprises on both sides of the road. Some of the structures are elevated or on fill, but many are of a low-level nature and are therefore flood liable.

Figure 2.2 (3 sheets) shows the layout of the existing stormwater drainage system in the vicinity of Buronga, the key features of which are as follows:

- A stormwater drainage line runs in a northerly direction along Midway Drive where it discharges to natural low lying land to the north of the town.
- Land that lies between Midway Drive and Rose Street generally drains in a southerly direction where it discharges to a storage area that is located between the Sturt Highway and Alcheringa Oval, which in turn discharges to the Murray River via a pipe that runs through an existing levee.
- Land that lies to the west of Rose Street and the south of Pittman Avenue generally drains in a southerly direction where it discharges to the Murray River via the Buronga Wetlands.
- Land that lies on the north-eastern side of the intersection of Pittman Avenue and the Silver City Highway drains in a westerly direction where it discharges to the Murray River floodplain on the western side of the highway.
- The industrial land in the vicinity of Corbett Avenue drains to a large, piped drainage system that runs in a westerly direction between the western end of the network of engineered channels and the Murray River floodplain on the western side of the Silvert City Highway.

2.1.4. Dareton Urban Centre

The township of Dareton is situated on the Silver City Highway, about 12 km east of Wentworth and has a population of about 450 (estimate only as 2021 census data not available for the village). The town is set primarily on high ground and comprises a mix of small and large lot residential type development, commercial development along Taipo Street and industrial type development between Pump Station Road and Tallawalla Road. A recent subdivision in Riverview Drive has building levels above the level of the 1956 flood. The only development on flood liable land is the Coomealla Golf Club and its two storey club house that is located on the river flats. One house behind Riverview Drive and a sewerage installation are located close to the flood fringe.

Figure 2.3 (2 sheets) shows the layout of the existing stormwater drainage system in the vicinity of Dareton, the key features of which are as follows:

- Land that lies to the east of Neilpost Street generally drains in a south-westerly direction along an engineered channel where it discharges beneath Golf Course Drive to the Murray River.
- Land that lies to the west of Millie Street and south of the Silver City Highway generally drains in a southerly direction where it discharges to the Murray River in the vicinity of the intersection of Golf Course Road and Kookaburra Drive.
- Land that lies to the west of Neilpost Street and north of Matong Street and the Silvert City Highway drains in a north-westerly direction along an engineered channel where it discharges to rural land to the north of School Road.

2.1.5. Wentworth Urban Centre

The township of Wentworth has a population of about 1,600 people (2021 census) and is located on both sides of the Darling River, immediately upstream of its confluence with the Murray River. As shown on **Figure 2.4** (2 sheets), the urbanised parts of Wentworth are protected from Murray and Darling River Flooding from the following three primary levees (collectively referred to herein as the "Wentworth town levees"), long sections of which are shown on **Figure 2.5** (sheets 1 and 2):

- **<u>Western Levee</u>**, which is about 5.4 km in length and principally comprises an earthen embankment that is generally about 3 m in height and has a design crest width of 3 m but also includes:

  a) a short section of sheet pile/rock gabion wall (levee chainage 1,250 m to 1,430 m); and

  b) four short sections of concrete wall, some with Hebel removable panel inserts, these being located at Wharf Street and Cadell Street.

  A visual audit of the levee that was conducted by Public Works Advisory (**PWA**) in 2017 (PWA, 2017) found that the Hebel panel and bracket arrangement for the concrete wall that is located behind No. 5-7 Perry Street (levee chainage 3,730 m to 3,800 m) have still not been purchased/installed.

  The road crossings of the Western Levee at the entrance to Junction Park (levee chainage 1,160 m) and the Silver City Highway (levee chainage 3,510 m) are identified in the *Wentworth Levee Owner's Manual* (PWA, 2018) as low points that need to be filled with an "*Earth Stockpile 'Floodgate'*" prior to the arrival of the flood wave.

  The Western Levee was originally constructed in response to the 1956 flood before being strengthened and raised above the height of the 1956 flood in 1974. The levee was upgraded in 2000 based on a design that was prepared by WRCS. While WRCS, 1997 set the levee crest at RL 35.75 m AHD, this elevation being 1 m above the then computed 1% AEP flood level, a crest level survey that was subsequently conducted as part of PWA, 2017 (refer **Figure 2.5**, sheet 1) shows that several low points are present along its length.

  A series of stormwater pipes extend through the earthen embankment, the outlets of which are fitted with hinged flood gates, details of which are set out in **Table 2.1**. There are no defined spillways associated with the Western Levee.

- **<u>Eastern Levee</u>**, which is about 2.6 km in length and principally comprises an earthen embankment that is generally about 1.5 m in height and has a design crest width of 3 m. The road crossings of the Eastern Levee at Wentworth Street (levee chainage 840 m) and Armstrong Avenue (levee chainage 1,500 m) are identified in the *Wentworth Levee Owner's Manual* (PWA, 2018) as low points that need to be filled with an "*Earth Stockpile 'Floodgate'*" prior to the arrival of the flood wave.

  Similar to the Western Levee, a design was prepared for the upgrade of the Eastern Levee in 1997 by WRCS, with the levee crest set at an elevation of RL 35.75 m AHD, this elevation being 1 m above the then computed 1% AEP flood level. Similarly, a crest level survey was conducted in combination with a visual audit that was subsequently conducted by PWA in 2017 (PWA, 2017).

  Figure 2.5, sheet 3 shows that the 300 m section of the Eastern Levee that follows the crown of the Silver City Highway (between levee chainages 2,250 m and 2,550 m) lies below the design crest level, noting that this low point is not identified in the *Wentworth Levee Owner's Manual* (PWA, 2018). It is also noted that the "As-Constructed" drawings of the Eastern Levee, a copy of which are contained in PWA, 2017, note that:

  > *"…the road embankment of Silver City Highway acts as the levee. Therefore no rehabilitation works are required."*

  A series of stormwater pipes extend through the earthen embankment, the outlets of which are fitted with hinged flood gates, details of which are set out in **Table 2.1**. There are no defined spillways associated with the Eastern Levee.

TABLE 2.1
DETAILS OF DRAINAGE OUTLETS BENEATH EXISTING LEVEES

Drainage Outlet ID	Levee	Levee Chainage (m)	Location	Pipe Diameter (mm)	Invert Level (m AHD)	Fitted with Flood Gate
WL_01	Western Levee[(2)]	5	Behind 4 Adelaide Street	450	32.96	Yes
WL_02		450	South of the Wentworth District Co-operating Parish	450	31.78	Yes
WL_03		700	South of Beverley Street	675	31.5	Yes
WL_04		915	South of Cadell Street	300	30.9	Yes
WL_05		1,190	South of Berkeley St	450	31.48	Yes
WL_06		1,380	East of the Cadell Street and Louisa Street intersection	300	31.56	Yes
WL_07		1,560	North-East of the Murray Street and Murray Court intersection	450	32.87	Yes
WL_08		2,320	West of Wentworth Sports Complex	600	31.49	Yes
WL_09		2,730	North of the Beverley Street and Francis Street intersection	450	32.34	Yes
WL_10		3,040	West of the Neville Street and Adams Street Intersection	450	33	Yes
WL_11		3,370	Halfway between Perry Street and Burns Street on Silver City Highway	300	33.55	Yes
WL_12		3,810	East of the Perry Street and Darling Street intersection	375	33.23	Yes
WL_13		4,000	Behind 169 Darling Street	300	32.12	Yes
WL_14		4065	North of the eastern end of Burns Street	600	32.42	Yes
WL_15		4205	Behind 151 Darling Street	300	32.56	Yes
WL_16		4290	North of the eastern end of Neville Street	600	32.52	Yes
WL_17		4520	East of the Francis Street and Darling Street intersection	600	32	Yes
WL_18		4780	East of the Arthur Street and Darling Street intersection	600	32.39	Yes

Refer over for footnotes to table.

TABLE 2.1 (Cont'd)
DETAILS OF DRAINAGE OUTLETS BENEATH EXISTING LEVEES

Drainage Outlet ID	Levee	Levee Chainage (m)	Location	Pipe Diameter (mm)	Invert Level (m AHD)	Fitted with Flood Gate
WL_19	Western Levee(2)	5025	North of the eastern end of Helena Street	600	33.14	Yes
WL_20		5225	East of the Darling Street and Armstrong Avenue intersection	450	31.28	Yes
WL_21		5405	East of Wentworth Wharf Boat Ramp	300	30.4	Yes
EL_01	Eastern Levee(2)	20	East of Wentworth Street and Armstrong Avenue intersection	450	31.76	Yes
EL_02		360	Behind 43A Wentworth Street	750	30.94	Yes
EL_03		420	Behind 49 Wentworth Street	750	31.66	Yes
EL_04		475	Behind 78 Wentworth Street	300	32.45	Yes
EL_05		1990	Behind 22 Ryder Cres	450	32.06	Yes
EL_06		2135	Southern end of William Street South	300	31.43	Yes
EL_07		2420	North of Fotherby Park	375	33.2	Yes
EL_08		2495	North of Fotherby Park	450	33.2	Yes
HL_01	Hospital Levee(2)	320	South-west of Wentworth Health Service	300	33.08	Yes
CL_01	Curlwaa Levee(3)	1,460	Abbotsford Road at intersection of Silver City Highway	Unknown	32.14	No
CL_02		1,770	Silver City Highway at intersection with Channel Road	450	34.34	No
CL_03		2,100	Silver City Highway at intersection with Delta Road	375	34.26	Yes
CL_04		2,500	Silver City Highway at intersection with Manly Road	150	34.83	No
CL_05		6,590	Murray Road	150	32.09	No

Refer over for footnotes to table.

TABLE 2.1 (Cont'd)
DETAILS OF DRAINAGE OUTLETS BENEATH EXISTING LEVEES

Drainage Outlet ID	Levee	Levee Chainage (m)	Location	Pipe Diameter (mm)	Invert Level (m AHD)	Fitted with Flood Gate
CL_06	Curlwaa Levee(3)	9,010	Delta Road	400	28.01	No
CL_07		9,110	Delta Road	150	31.63	No
CL_08		9,900	Private Property north of Delta Road	100	33.44	No
CL_09		9,900	Private Property north of Delta Road	100	33.3	No
CL_10		10,050	Private Property north of Delta Road	100	33.24	No
CL_11		10,050	Private Property north of Delta Road	100	33.17	No
CL_12		11,480	Private property west of Channel Road	400	31.16	No
CL_13		12,990	Private property north of Box Tree Lane	400	31.18	No
CL_14		13,180	Private property north of Box Tree Lane	400	31.06	No
CL_15		13,860	Private property north of Billabong Road	400	31.65	No
CL_16		14,950	Creek Lane (Pumped outlet)	225	35.66	No
CL_17		15,120	Creek Lane (Pumped outlet)	225	35.41	No
CL_18		17,310	Creek Road	100	33.31	No
CL_19		18,390	Ryans Road	100	36.13	No
CL_20		19,210	Ryans Road	100	36.53	No

1. Database compiled from survey undertaken by PWA and contained in *Visual Audit of Wentworth Levee* (PWA, 2017) and *Visual Audit of Curlwaa Levee* (PWA, 2022), noting that a unique set of Drainage Outlet ID's were developed as part of the present study.
2. Refer **Figure 2.4**, sheet 2 for plan location.
3. Refer **Figure 2.5** for plan location.

- **Hospital Levee**, which is about 0.55 km in length and principally comprises an earthen embankment that is about 1.8 m in height, with a crest width of about 3 m. **Table 2.1** shows the details of the single drainage outlet through the levee. There are no defined spillways associated with the Hospital Levee.

Figure 2.4 (2 sheets) shows the layout of the existing stormwater drainage system in the vicinity of Wentworth which includes piped drainage systems draining to the Murray River, Darling River and Tuckers Creek through the drainage outlets that are set out in **Table 2.1**. The area bounded by Arthur Street to the north, Adam Street to the east, Sandwych Street and McLeod Oval to the south and the Western Levee to the west discharges to a storage dam that is located to the west of the oval before discharging to the Wentworth Golf Course at Drainage Outlet WL_08. There are no permanent stormwater evacuation pumps installed at any of the drainage outlets.

The Wentworth Aerodrome is located on the northern side of Renmark Road to the west of its intersection with the Silver City Highway. **Figure 2.4**, sheet 1 shows the alignment of a temporary levee that was constructed along the western, northern and eastern sides of the Wentworth Aerodrome to protect it from the 2022 flood. The temporary levee was subsequently demolished by Council following the 2022 flood.

2.1.6. Curlwaa Irrigation Area

The Curlwaa Irrigation Area is located on the northern side of the Murray River immediately to the east of Wentworth. **Figure 2.6** shows that the Curlwaa Irrigation Area is protected from flooding by a 19.5 km long earthen levee (known as the Curlwaa Levee), while **Figure 2.5**, sheet 3 shows a long section along the levee crest. The Curlwaa Levee is owned and maintained by Western Murray Irrigation.

The Curlwaa Levee was originally constructed as a temporary levee prior to the arrival of the 1956 flood wave before being reconstructed in the late 1950s with the crest elevation set at the approximate height of the 1956 flood.[2] However, based on a review of the "Work-As-Executed" drawings that were prepared in 1961, PWA, 2022 concluded that the Curlwaa Levee incorporates a freeboard to the 1956 flood of between 600-900 mm. **Figure 2.5**, sheet 3 shows that based on the available LiDAR survey data, the Curlwaa Levee has a freeboard of 0-1 m above the 1956 flood. PWA, 2022 also identified that there are no designated spillways along the Curlwaa Levee.

Figure 2.5, sheet 3 shows that there are low points are located along the Curlwaa Levee at the following locations:

i. at two locations (levee chainage 0 m and 500 m) along Williamsville Road to the east of Abbotsford Bridge;[3]

ii. in the vicinity of the intersection of Abbotsford Road and the Silver City Highway where the earthen embankment ends (levee chainage 1,400 m);

iii. at the low point in the Silver City Highway that is located approximately 180 m to the east of its intersection with Manly Road (levee chainage 2,500 m);

iv. at the Silver City Highway crossing of the Curlwaa Levee (levee chainage 8,000 m);

v. at the Delta Road crossing of the Curlwaa Levee (levee chainage 8,620 m);

[2] Source: *Audit of Flood Levees for New South Wales – Curlwaa Levee* (Public Works, 1994)

[3] A review of the 2022 flood photography shows that a temporary levee was constructed on the southern side of Williamsville Road.

vi. on private land that is located to the west of the intersection of Delta Road and Channel Road (levee chainage 10,860 m); and

vii. at the gap in the Curlwaa Levee that is located approximately 200 m to the north of the Silver City Highway crossing (levee chainage 17,800 m).[4]

A series of stormwater pipes extend through the Curlwaa Levee, some of which are fitted with hinged flood gates (refer **Table 2.1** for details).

2.2 Flood History

2.2.1. General

The Wentworth Shire LGA is located at the confluence of the Murray and Darling rivers and has experienced several large floods on both river systems since settlement in around 1855. Harrison, 1957 notes that reasonable records are available for floods that occurred in 1870, 1890, 1917, 1931, 1955 and 1956, and that except in the South Australian section of the river where the 1956 flood was higher than previously recorded, the 1870 flood was the highest at most places along the Murray River. More recently, major flooding was experienced in late-2022 and early-2023 on the Murray and Darling rivers, respectively, with the flood event collectively referred to herein as "the 2022 flood".

Table 2.2 over the page provides a comparison of the maximum water levels and peak flows that were recorded at the four stream gauges on the Murray River in the vicinity of the study area for the ten (10) largest floods on record, while **Table 2.3** shows similar information for the Darling River system. Design peak flood levels and flows derived as part of the present study are also presented in **Table 2.2** for comparative purposes. **Table 2.2** shows that the 1870 flood is considered the flood of record on the Murray River.

While **Table 2.3** shows that the 1956 flood is the largest flood that has been recorded by WaterNSWs *Darling River at Burtundy* (GS 425007) stream gauge (**Burtundy stream gauge**), Advisian, 2021 identified the 1890 flood as the flood of record on the Darling River based on the period of record at the *Darling River at Menindee Town* (GS 425001) stream gauge (**Menindee Town stream gauge**) which was in operation between 1881 and 1960.

Figures 2.7, **2.8** and **2.9** show the recorded stage and discharge hydrographs at the stream gauges that are located in the vicinity of the study area for the 1956, 1974, and 2022 flood events, respectively, noting that these three floods have been relied upon to calibrate the hydraulic model that was developed as part of the present study. **Annexures B10** and **B11** contain a series of photographs showing the major flooding that was experienced in the study area in 1956 and 2022.

The following sections of this report provide a description of flooding patterns that were associated with the three calibrating flood events.

2.2.2. 1956 Flood

Figure 2.7 shows the stage and discharge that were recorded by the stream gauges that were in operation at the time of the 1956 flood, while **Plates B10.1** to **B10.12** in **Annexure B10** of **Appendix B** of this report are photographs of the flood behaviour that was observed in the vicinity the study area during the flood event.

[4] A review of the 2022 flood photography shows that works were undertaken to close the gap in the levee that is located to the north of the Silver City Highway crossing.

TABLE 2.2
HISTORIC PEAK FLOOD LEVELS AND FLOWS
MURRAY RIVER STREAM GAUGES[1,2]

Flood Event	Murray River at Euston[3] (GS 414203)		Murray River at Colignan[4] (GS 414207)		Murray River at Mildura[5] (GS 414202)		Murray River at Lock 10 (GS 425010)	
	Stage (m)	Discharge (m^3/s)	Stage (m)	Discharge (m^3/s)	Stage (m AHD)	Discharge (m^3/s)	Stage (m AHD)	Discharge (m^3/s)
Extreme Flood	-[6]	11,640	11.66	11,600	42.07	11,450	35.82	12,540
0.2% AEP	-[6]	6,100	10.20	6,070	40.31	6,010	35.12	6,060
0.5% AEP	-[6]	4,620	9.74	4,580	39.62	4,530	34.88	4,960
1870	10.77	-[8]	-[7]	-[7]	39.37	4,236	34.91	-[8]
1% AEP	-[6]	3,880	9.50	3,850	39.27	3,820	34.75	4,180
1956	10.62	3,493	-[7]	-[7]	39.14	3,565	34.56	-[8]
2% AEP	-[6]	3,170	9.26	3,150	38.89	3,120	34.58	3,380
1931	10.27	2,871	-[7]	-[7]	38.43	2,428	-[7]	-[7]
1917	10.08	2,500	-[7]	-[7]	38.53	2,315	-[7]	-[7]
2022	10.26	2,374	8.96	2,411	-[7]	-[7]	34.14	2,294
1975	9.87	2,367	8.53	1,806	38.17	2,141	-[7]	-[7]
5% AEP	-[6]	2,300	8.92	2,280	38.25	2,270	34.22	2,540
1974	9.83	2,289	-[8]	2,325	38.10	2,123	33.83	-[8]
1955	-[8]	2,007	-[7]	-[7]	38.1	1,793	-[7]	-[7]
1993	9.56	1,973	8.49	1,542	-[7]	-[7]	33.32	1,628
1939	-[8]	1,955	-[7]	-[7]	-[7]	-[7]	-[7]	-[7]
10% AEP	-[6]	1,680	8.61	1,660	37.39	1,650	33.55	1,830
20% AEP	-[6]	1,120	8.09	1,080	35.85	1,070	32.49	1,200

1. Only the ten largest floods to have been recorded at the Euston stream gauge in peak flow terms are listed, with the exception of the 1870 flood which is the known flood of record in the Murray River. Refer **Annexures B1**, **B2**, **B3** and **B4** in **Appendix B** of this report for record of annual maximums and source of data at the Euston, Colignan, Mildura and Lock 10 stream gauges, respectively.
2. Flood events have been ranked based on peak flow in the Murray River, noting that there have been significant changes to the floodplain that have resulted in higher peak flood levels being experienced at the Euston stream gauge for a given flow rate in the river.
3. Gauge zero = RL 41.84 m AHD.
4. Gauge zero = RL 35.06 m AHD.
5. Historic flood data taken from values recorded at discontinued Murray River at Mildura (DGS 414202), while design flood data has been taken at the currently operational Murray River at Downstream Mildura Weir (GS 414216) which is located approximately 600 m downstream of the discontinued site.
6. Stage not defined as gauge is located outside the extent of the two-dimensional model boundary.
7. Gauge not in operation at time of flood.
8. Peak gauge height/discharge not known.

TABLE 2.3
HISTORIC PEAK FLOOD LEVELS AND FLOWS
DARLING RIVER AND GREAT DARLING ANABRANCH STREAM GAUGES(1)

Rank	Flood Event	Darling River at Burtundy(3) (GS425007)		Great Darling Anabranch at Bulpunga(4) (GS 425011)	
		Stage (m)	Discharge (m^3/s)	Stage (m)	Discharge (m^3/s)
1	1890(2)	Unknown			
2	1956	9.61	913	6.30	700
3	1976	9.72	689	5.49	382
4	1950	8.53	396	-(5)	-(5)
5	1974	8.48	374	3.99	110
6	2023	8.27	296	4.58	122
7	1971	7.75	261	2.52	21
8	1990	7.68	256	3.98	114
9	1998	7.69	251	2.67	5

1. Only the eight largest floods to have been recorded at the Burtundy stream gauge in peak flow terms are listed. Refer **Annexures B5** and **B7** in **Appendix B** of this report for record of annual maximums and source of data at the Burtundy and Bulpunga stream gauges, respectively.
2. Based on the period of record at the *Darling River at Menindee Town* (GS 425001) stream gauge, a flood that occurred in 1890 is considered the flood of record on the Darling River.
3. Gauge zero = RL 32.40 m AHD.
4. Gauge zero = RL 32.04 m AHD.
5. Gauge not in operation at time of flood.

Figure 2.7 and **Table 2.4** show that the flood peaked on 6 August 1956 at the Euston stream gauge, 15 September 1956 at the Burtundy stream gauge and 4 October 1956 at the *Great Darling Anabranch at Bulpunga* stream gauge (**Bulpunga stream gauge**). **Table 2.2** shows that the 1956 flood is the second largest on record on the Murray River and that flood levels peaked approximately 0.15 m and 0.35 m lower than the flood of record that occurred in 1870 at the Euston and Lock 10 stream gauges, respectively.

TABLE 2.4
HISTORIC STREAM GAUGE DATA
1956 FLOOD

Stream Gauge	Peak Stage (m)	Peak Discharge (m^3/s)	Date of Peak
Murray River at Euston	10.62	3492	6/08/1956
Murray River at Colignan	Gauge not in operation at time of flood		
Murray River at Lock 10	34.56	Unknown	
Murray River at Lock 9	Unknown		
Darling River at Burtundy	9.61	913	15/09/1956
Great Darling Anabranch at Bulpunga	6.30	708	4/10/1956

As previously mentioned, the 1956 flood is considered the second largest flood on record on the Darling River and Great Darling Anabranch.

Annexure B12 of **Appendix B** contains several photographs that show the configuration of the Sturt Highway bridge/road crossing of the Murray River floodplain at Buronga, which shows the historic bridge crossed the river on the western (downstream) side of the existing George Chaffey Bridge (noting that the southern bridge abutment is still present). These photographs also show that the riparian vegetation along the river appears to be less dense when compared to present day conditions.

As discussed in **Section 2.1.6** and **2.1.7**, the Wentworth town levees and Curlwaa Levee were constructed in response to the 1956 flood. **Plate B10.7** of **Annexure B10** shows that the Curlwaa Levee generally prevents floodwater from inundating the Curlwaa Irrigation Area, while **Plates B10.8** and **B10.10** show floodwater inundated the land that lies between the Darling River and Wentworth Street, indicating that the Eastern Levee was not present or failed during the flood. Plates **B10.10** and **B10.11** also show that the streets in the urbanised parts of Wentworth on the western side of the Darling River were inundated, which indicates that the temporary levee that was constructed prior to the arrival of the flood wave was ineffective.

Figure B1.1 of **Appendix B** shows the plan location of 35 flood marks that were taken from Advisian, 2021 relating to the 1956 flood (refer **Section B1.7** of **Appendix B** for further discussion).

While the 1956 flood has historically been considered to be equivalent to a design flood with an AEP of 1% in both peak flow and flood level terms, the present study found that while the peak flow in the Murray River was equivalent to about a 1% AEP flood, due to changes in the floodplain topography and hydraulic roughness, the peak flood levels that were experienced at the time of the 1956 flood are now generally equivalent to a design flood with an AEP of only 2% (refer **Section 5.2.1** for further discussion).

2.2.3. 1974 Flood

Figure 2.8 shows the stage and discharge that were recorded by the stream gauges that were in operation at the time of the 1974 flood, while **Table 2.5** over the page sets out the peak stage, discharge and time of the flood peak at the five stream gauges that were in operation at the time of the flood.

Table 2.5 shows that the 1974 flood peaked on the Darling River and Great Darling Anabranch on 15 April 1974 and 6 June 1974, respectively, which is four to six months prior to the peak on the Murray River which occurred on 18 October 1974 at the Euston stream gauge. The Murray River peaked three days later at the Colignan stream gauge on 21 October 1974 and then another five days later at Lock 9 on the 26 October 1974.

Figure 2.8 shows that the 1974 flood on the Murray River generally comprised three flood peaks over the months of September to November, with the second flood peak generally being the largest (the exception is at the Colignan stream gauge, where the third flood peak generated the highest recorded peak flood level and hence flow).

Table 2.2 shows that the 1974 flood is the seventh largest on record on the Murray River, while **Table 2.3** shows that it is the fifth largest flood to have been recorded on the Darling River.

TABLE 2.5
HISTORIC STREAM GAUGE DATA
1974 FLOOD

Stream Gauge	Peak Stage (m)	Peak Discharge (m^3/s)	Date of Peak
Murray River at Euston	9.83	2,290	18/10/1974
Murray River at Colignan	Unknown	First: 2,270 Second: 2,325	First: 21/10/1974 Second: 26/11/1974
Murray River at Lock 10	33.83	Unknown	
Murray River at Lock 9	30.04	2,170	26/10/1974
Darling River at Burtundy	8.48	374	15/04/1974
Great Darling Anabranch at Bulpunga	3.99	109	6/06/1974

TABLE 2.6
HISTORIC STREAM GAUGE DATA
2022 FLOOD

Stream Gauge	Peak Stage (m)	Peak Discharge (m^3/s)	Date of Peak
Murray River at Euston	10.26	2,374	9/12/2022
Murray River at Colignan	8.96	2,411	12/12/2022
Murray River at Lock 10	34.14	2,294	18/12/2022
Murray River at Lock 9	30.12	2,284	19/12/2022
Darling River at Burtundy	8.27	296	5/02/2023
Great Darling Anabranch at Bulpunga	4.58	122	28/02/2023

2.2.4. 2022 Flood

Figure 2.9 shows the stage and discharge that were recorded by the stream gauges that were in operation at the time of the 2022 flood, while **Table 2.6** over the page shows the peak stage, discharge and time of flood peak at the six stream gauges that were in operation at the time of the flood.

Table 2.6 shows that the 2022 flood peaked on the Murray River on 9 December 2022 at the Euston stream gauge and then approximately three days later on 12 December 2022 at the Colignan stream gauge.[5]

Table 2.6 shows that the flood levels on the Murray River peaked at Lock 10 and Lock 9 on 18 and 19 December 2022, respectively, nine (9) and ten (10) days after levels peaked at the Euston stream gauge.

[5] **Figure 2.9** shows that the recorded stage (and hence discharge) recorded by the Colignan stream gauge fluctuates during the flood peak which raises questions about whether the readings are erroneous.

Table 2.6 shows that flood levels in the Darling River and Great Darling Anabranch peaked on 5 and 28 February 2023, respectively. **Figure 2.9** shows that flood levels and flows in the Murray River had significantly reduced by the time the flood peaked on the Darling River.

Table 2.2 shows that the 2022 flood is the fifth largest on record on the Murray River, while **Table 2.3** shows that it is the sixth largest flood to have been recorded on the Darling River, noting that the flood peak occurred in February 2023.

Figure 2.1 shows the location and alignment of a significant number of formal and informal levees that were constructed on the northern and southern sides of the Murray River prior to the arrival of the 2022 flood wave. Wentworth Shire Council also constructed a temporary flood protection levee around the Wentworth Aerodrome. The approximate location and alignment of the levees were based on information provided by Wentworth Shire Council and Mildura Rural City Council, as well as the 2022 aerial flood photography. Where crest level survey was not available, the elevation of the crest has been assumed to be about 100 mm above the nearest surveyed flood level. With the exception of the Wentworth Aerodrome Levee, at the time of writing it was not possible to determine which temporary levees (if any) have subsequently been demolished.

Annexure B11 of **Appendix B** contains several photographs that show flood behaviour in the study area during the 2022 flood, while **Figure B1.1** of **Appendix B** shows the plan location of flood marks that were surveyed by Wentworth Shire Council and Mildura Rural City Council during the 2022 flood (refer **Section B1.7** of **Appendix B** for further discussion).

It is understood that the mechanism that is used to manually close the Gol Gol Creek Regulator seized up prior to the arrival of the 2022 flood. As a result, a backhoe was used to manually force the radial arm gate closed which prevented Murray River floodwater discharging to Gol Gol Creek.

The Curlwaa Levee failed in the vicinity of Box Tree Lane (levee chainage 12,850 m) during the 2022 flood and back filled a remnant flood runner that is located on the left (southern) bank of Tuckers Creek. It is understood that the levee failed on 18 December 2022 and was re-established the next day, with machinery used to back fill the approximately 10 m wide breach with earthen fill material.

2.3 Analysis of Available Stream Gauge Data

2.3.1. General

Figure 2.1 shows the plan location of the ten key stream gauges that are located on the Murray River, Darling River and Great Darling Anabranch in the vicinity of the four urban centres, while **Table B1.3** in **Appendix B** sets out their dates of operation.

The following sections of this report provide detailed descriptions of the stream gauges that have been relied upon to derive/verify design peak flow estimates in the Murray River, Darling River and Great Darling Anabranch as part of the present study.

2.3.2. Murray River

Manually-read stream gauges were first installed on the Murray River at Mildura (GS 414202) and Lock 10 (GS 425010) in 1864 and 1872, respectively (**Mildura and Lock 10 stream gauges**).

Plate 1 and **Table 2.7** over the page show that the Mildura stream gauge was located at six different sites between when it was first established in 1864 and when it ceased operation in December 1929, noting that peak flood levels continued to be monitored at Site F during flood events up until 1981.

Plate 1 and **Table 2.7** also show that the Victorian Department of Energy, Environment and Climate Action (**DEECA**) operated *Murray River at Downstream Mildura Weir* (GS 414216) stream gauge (**Downstream Mildura Weir stream gauge**) has been in operation since about May 1992 at a location that is close to Site F. It is noted that while the Downstream Mildura Weir stream gauge records the water level in the river, it does not have a rating curve attached to it, so it is not possible to derive the corresponding peak flow.

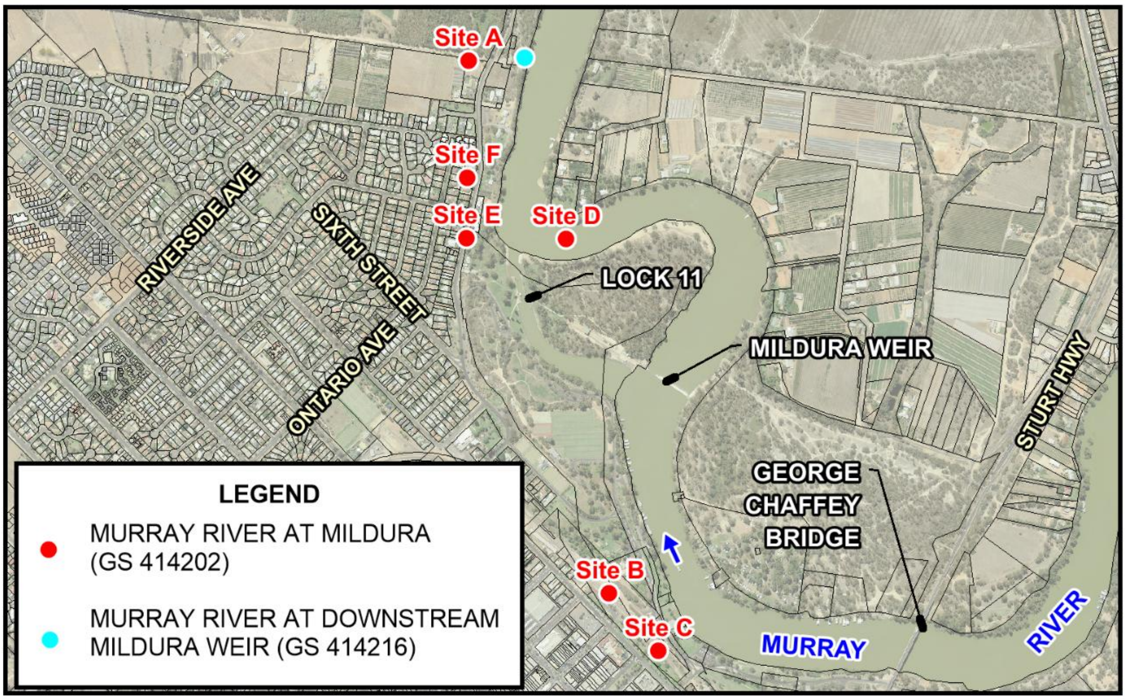


Plate 1 – Plan location of stream gauge sites on the Murray River at Mildura.

TABLE 2.7
DETAILS OF STREAM GAUGES ON MURRAY RIVER AT MILDURA(1)

Gauge Name, Number and Site		Comment on Location	Site Commence	Site Cease
Murray River at Mildura (GS414202)	Site A	Approximately 100m below the Old Mildura Station Homestead, on Pioneer Drive	September 1864	March 1890
	Site B	Township gauge, Deakin Avenue, Mildura	April 1890	April 1893
	Site C	At the old Mildura Wharf	April 1893	April 1926
	Site D	Temporary gauge installed downstream of weir	April 1926	December 1927
	Site E	Immediately downstream of Lock 11	June 1927	February 1929
	Site F	50m downstream of Lock 11	February 1927	December 1929
Murray River at Downstream Mildura Weir (GS414216)		Current Site	May 1992	Ongoing

1. Refer **Plate 1** for plan location of stream gauge.

While WaterNSWs online database states the Lock 10 stream gauge was first installed on the Murray River in August 1872, it was not possible to source any stream flow data prior to when telemetered records commenced in January 1987, noting that this coincides with the date that WaterNSW became the gauge operator.[6]

Based on the above findings, while the stream flow record associated with the two gauges is not suitable for use in undertaking a flood frequency analysis, it was useful in confirming that the 1870 flood is the flood of record on the Murray River. The *Murray River at Euston* (GS 414203) stream gauge (**Euston stream gauge**) was first installed in January 1930 and became telemetered in September 1974. **Figure 2.10** shows the difference between the historic rating tables that were current at the time of the 1956 and 1974 floods, as well the stage-discharge relationship that was current at the time of the 2022 flood. **Figure 2.10** also shows the 830 gaugings that have been taken at the Euston stream gauge site between July 1938 and June 2025.

Figure 2.10 shows that the highest recorded stream gauging was taken on 9 August 1956 when the water level reached RL 10.58 m on the gauge which is about 0.04 m lower than the peak of the flood that occurred three days prior. The gauged flow in the river at the time was 3,460 m^3/s.

Figure 2.10 shows that prior to 2022, the next four highest gaugings were taken during the 1974 flood and a flood that occurred in 1975, and that they lie close to the rating curves that were current at the time of the earlier floods. The three gaugings that were taken in November and December 2022 show that flood levels in the river were higher for similar flows to those that were gauged in the 1970s. As a result, the rating curve that was current at the time of the 2022 flood has a different shape compared to the rating curves for the early flood events. The principal reason for the change in the shape of the rating curve is considered to be the significant increase that has occurred in the density of the riparian vegetation. As the rating curves have been derived from gaugings that were taken near the peak of historic floods on the river, they are considered to accurately reflect the flow that was in the river at the time (i.e. there is no reason to modify their shape based on the results of the flood modelling that has been undertaken as part of the present study).

The *Murray River at Colignan* (GS 414207) stream gauge (**Colignan stream gauge**) was first established in June 1960, with telemetered records dating back to December 1975. While the period of record at the Colignan stream gauge (i.e. 64 years) is suitable for undertaking a flood frequency analysis, it has not been relied upon for the present study as the period of record does not encompass the 1870, 1956 and 1931 floods which are considered the three largest floods that have occurred on the Murray River.

Based on the above findings, the Euston stream gauge data are considered to be best suited for deriving design peak flow estimates on the Murray River for use as part of the present study (refer **Section 2.4** of this report for further details). Its adoption as the basis for deriving design peak flow estimates on the Murray River also permits a direct comparison to be made with the findings of previous studies.

[6] WaterNSW advised that the Lock 10 stream gauge may have been located on the Darling River at the location of an older lock site, while the Bureau of Meteorology advised that it did not maintain any stream gauge data relating to the period when the gauge was not operated by WaterNSW.

2.3.3. Darling River

The *Darling River at Burtundy* (GS 425007) stream gauge (**Burtundy stream gauge**) was installed in March 1940, with telemetered records commencing in March 1940. **Figure 2.11** shows the difference between the historic rating tables that were current at the time of the 1956 and 1974 floods, as well the stage-discharge relationship that was current during the 2022 flood. **Figure 2.11** also shows the 465 gaugings that have been taken at the Burtundy stream gauge site between March 1940 and April 2025.

The highest gauged flow at the site was taken on 23 September 1956 when the water level reached RL 9.39 m, which is about 0.22 m below the peak of the flood that occurred eight days prior. The gauged flow in the river at the time was about 740 m^3/s.

The second highest gauged flow at the site was taken on 6 May 1975 when the water level reached RL 9.53 m, which is about 0.14 m higher than the gauged height during the 1956 flood. The gauged flow in the river was about 618 m^3/s at the time. The reason for the difference between the two highest gaugings is not known.

While the Burtundy stream gauge was not in operation during the record flood of 1890, the available data are considered to be best suited for deriving design peak flow estimates on the Darling River for use as part of the present study (refer **Section 2.4** of this report for further details). Its adoption as the basis for deriving design peak flow estimates on the Darling River also permits a direct comparison to be made with the findings of previous studies.

While the period of record at the *Darling River at Pooncarie* (GS 425005) stream gauge (**Pooncarie stream gauge**) is slightly longer than the Burtundy stream gauge, it does not encompass any additional significant flood events that are not contained in the period of record at Burtundy. As such, it was not necessary to undertake a flood frequency analysis at the Pooncarie stream gauge as part of the present study.

2.3.4. Great Darling Anabranch

The Great *Darling Anabranch at Bulpunga* (GS 425011) stream gauge (**Bulpunga stream gauge**) was installed in November 1954. **Figure 2.12** shows the 131 gaugings that have been taken at the Bulpunga stream gauge site between February 1955 and April 2025. While gaugings were taken at the site as far back as February 1955, a rating curve was not derived for the gauge until May 1985. **Figure 2.12** shows the May 1985 rating curve at the site, as well as the stage-discharge relationship that was current at the time of the 2023 flood.

The highest gauged flow at the site was taken on 24 September 1956 when the water level reached RL 6.16 m, which is about 0.14 m below the peak of the flood that occurred ten days later. The gauged flow in in the anabranch at the time was about 630 m^3/s.

The Great Darling Anabranch is an ephemeral watercourse, the flow in which principally originates from the regulator controlled Menindee Lakes system at Menindee, with unregulated flows only occurring during times of major flood.[7] As such, over the 71 year period of record at the gauge site, there are 17 years when there was no flow in the watercourse and an additional 46 years where the annual maximum flow was less than or equal to 23 m^3/s. Based on this understanding, the stream flow record is not suitable for undertaking a flood frequency analysis from which design peak flow estimates can be derived.

[7] Flow discharging to the Great Darling Anabranch is controlled by the Cawndilla Outlet Regulator, which has a maximum flow rate of 23 m^3/s.

Rather, a linear regression analysis was undertaken based on the annual maximum peak flows that were recorded at the Burtundy and Bulpunga stream gauge sites for the period 1955 to 2024. The resulting line-of-best-fit was then used to derive design peak flow estimates for the Great Darling Anabranch at the Bulpunga stream gauge site (refer **Section 2.4.4** for further details).

2.4 Annual Flood Frequency Analysis

2.4.1. General

Flood frequency analyses were undertaken as part of the present study at the Euston and Burtundy stream gauges on the Murray River and Darling River, respectively, while due to the regulated nature of flow in the Great Darling Anabranch, it was necessary to develop a linear relationship between peak flows in the Darling River with those in the anabranch. The results of these analyses were used as the basis for deriving design discharge hydrographs that were then used as input to the hydraulic model that was developed as part of the present study (refer **Chapter 4** of this report for further details).

2.4.2. Euston Stream Gauge (GS 414203)

Flood frequency analyses have been undertaken for deriving design peak flows at the Euston stream gauge as part of GHD, 1986 and Advisian, 2021. Column B of **Table 2.8** over the page sets out the design peak flow estimates for the 5%, 2% and 1% AEP flood events as set out in GHD, 1986. While GHD, 1986 states that the peak flows were derived as part of a flood frequency analysis that was undertaken by the Rural Water Commission (Victoria), there are no details regarding the period of record or probability model that was relied upon. GHD, 1986 found that the peak 1% AEP flow (i.e. 3,785 m^3/s) was about 8% higher than the peak 1956 flow (i.e. 3;493 m^3/s).

As set out in **Section B2.11** of **Appendix B**, Advisian, 2021 undertook flood frequency analyses at the Euston stream gauge for the following two scenarios:

- **Scenario 1** – Based on the Euston gauge record for the period 1930 to 2017
- **Scenario 2** – Based on an extended Euston gauge record which included the Mildura gauge record for the period 1870 to 1929.

Advisian, 2021 found that the log-Pearson Type 3 (**LP3**) distribution achieved the best fit with the annual maximum data. Columns C and D of **Table 2.8** show the peak flow estimates derived for Scenario 1 and 2, respectively, noting that the results of Scenario 1 were adopted for floods up to 2% AEP in magnitude, with the results of Scenario 2 adopted for rarer floods. The Advisian, 2021 derived peak 1% AEP flow of 3,779 m^3/s is comparable to the flow that was derived as part of GHD, 1986 (refer Column B).

As part of the present study, a LP3 distribution was fitted to the annual series of peak flows using the FLIKE software for the 94-year period of record commencing in 1931 and ending in 2024.[8,9,] A manual independence check of the stream flow data was undertaken to ensure that the annual maximum peak flows were representative of the largest flood in a given year, and not part of the rising or receding limb of a flood that occurred in the previous/following year.

[8] Refer **Annexure B1** of **Appendix B** which contains a list of the adopted annual series of flood peaks at the Euston stream gauge.

[9] A LP3 distribution was preferred over the Generalised Extreme Value (**GEV**) distribution for the present study as previous investigations on the Murray and Darling River systems have found it to achieve a better fit to the historic data.

TABLE 2.8
FLOOD FREQUENCY DERIVED DESIGN PEAK FLOW ESTIMATES
EUSTON STREAM GAUGE
(m^3/s)

Design Flood Event	Previous Studies			Present Study			
	GHD, 1986	Advisian, 2021		1931-2024 All Flows	1931-2024 Low Flows Censored	1931-2024 (+1870) All Flows	1931-2024 (+1870) Low Flows Censored
		Scenario 1 [1930-2017]	Scenario 2 [1870-2017]				
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]
0.2% AEP	-	-	-	11,000	5,300	9,700	6,100
0.5% AEP	-	4,318	4,899	7,000	4,200	6,500	4,620
1% AEP	3,785	3,654	3,779	5,150	3,520	4,800	3,880
2% AEP	3,032	3,012	2,869	3,630	2,940	3,500	3,170
5% AEP	2,188	2,207	1,929	2,350	2,170	2,290	2,300
10% AEP	-	1,638	1,377	1,620	1,630	1,590	1,680
20% AEP	-	-	-	1,050	1,100	1,040	1,120

As the recorded flood peaks are only a small sample of peaks actually occurring over a longer period, an expected probability adjustment was made to remove bias from the estimate using the procedure set out in ARR 2019. The resulting frequency curves, along with 5% and 95% confidence limits are shown on **Figure 2.13** (refer left hand side of sheet 1), while Column E in **Table 2.8** gives the peak flow estimates for a range of AEPs as derived from the above analysis.

By inspection of the left hand side of **Figure 2.14**, sheet 1, both the LP3 and expected probability lines of best fit have a positive skew, principally due to the distorting effect of the inclusion of more frequent flows in the analysis. This in turn results in the two lines of best fit not providing a good match to the larger (i.e. rarer) recorded flood events. As the present study is focused on the definition of flood behaviour on the Murray River for rarer flood events, annual maximum peak flows less than 400 m^3/s were removed from the data set.[10] The right-hand side of **Figure 2.13** and Column F of **Table 2.8** show the results of omitting the 40 annual flows less than 400 m^3/s from the analysis and applying the expected probability adjustment to the remaining data. Omitting flows less than 400 m^3/s reduced the peak 1% AEP flow estimate from 5,150 m^3/s to 3,520 m^3/s, which is comparable to the findings of previous studies.

ARR, 2019 recommends incorporating historic flood data in flood frequency analyses as this effectively increases the sample size of the data and will increase the reliability of the analysis. As the FLIKE software allows for the inclusion of larger floods that are known to have occurred outside the continuous period of record in the flood frequency analysis, the above analyses were updated to include the 1870 flood of record on the Murray River. The results of the revised analyses are shown graphically on **Figure 2.13**, sheet 2, while columns G and H in **Table 2.8** set out the updated peak flow estimates for floods ranging between 20% and 0.2% AEP.

The inclusion of the 1870 flood of record in the analysis and the removal of annual maximum peak flows from the continuous period of record increases the peak 1% AEP flow estimate from 3,520 m^3/s to 3,880 m^3/s, which is slightly higher than the findings of previous studies.

Based on the findings of the flood frequency analysis, the design peak flow estimates set out in Column H of **Table 2.8** were adopted for design flood estimation purposes.

2.4.3. Burtundy Stream Gauge (GS 425007)

Flood frequency analyses were undertaken at the Burtundy stream gauge as part of Advisian, 2021 for the following two scenarios:

- **Scenario 1** – Based on the Burtundy gauge record for the period 1941 to 2017
- **Scenario 2** – Based on the Burtundy gauge record for the period 1941 to 2017 plus one known larger flood (1890) added as censored data.

As was the case for the flood frequency analysis at the Euston stream gauge, Advisian, 2021 found that the LP3 distribution achieved the best fit with the annual maximum data at the Burtundy stream gauge. Columns B and C of **Table 2.9** over the page set out the peak flow estimates that were derived for Scenario 1 and 2, respectively, noting that the results of Scenario 2 were adopted for all floods up to 0.5% AEP in magnitude.

[10] As application of the multiple Grubbs-Beck test to censor low flows as recommended in ARR, 2019 did not identify a low flow threshold, a visual assessment of the fitted frequency was conducted to identify a low flow threshold of 400 m^3/s. Sensitivity analyses found that censoring flows of this magnitude provided the best fit with the historic data.

TABLE 2.9
FLOOD FREQUENCY DERIVED DESIGN PEAK FLOW ESTIMATES
BURTUNDY STREAM GAUGE
(m^3/s)

Design Flood Event [A]	Previous Studies		Present Study			
	Advisian, 2021					
	Scenario 1 [1941-2017] [B]	Scenario 2 [1941-2017] [+1890] [C]	1941-2024 All Flows [D]	1941-2024 Low Flows Censored [E]	1941-2024 (+1870) All Flows [F]	1941-2024 (+1870) Low Flows Censored [G]
0.2% AEP	-	-	910	1,100	985	1,250
0.5% AEP	857	949	770	825	830	915
1% AEP	680	739	675	665	715	730
2% AEP	535	571	575	530	610	580
5% AEP	382	399	430	385	450	405
10% AEP	290	298	320	285	335	295
20% AEP	-	-	207	195	215	198

As part of the present study, a LP3 distribution was fitted to the annual series of peak flows using the FLIKE software for the 84-year period of record commencing in 1941 and ending in 2024.[11,] A manual independence check of the stream flow data was undertaken to ensure that the annual maximum peak flows were representative of the largest flood in a given year, and not part of the rising or receding limb of a flood that occurred in the previous/following year.

As the recorded flood peaks are only a small sample of peaks actually occurring over a longer period, an expected probability adjustment was made to remove bias from the estimate using the procedure set out in ARR 2019. The resulting frequency curves, along with 5% and 95% confidence limits are shown on **Figure 2.14** (refer left hand side of sheet 1), while Column D in **Table 2.9** gives the peak flow estimates for a range of AEPs as derived from the above analysis.

By inspection of the left hand side of **Figure 2.14**, sheet 1, a number of the historic floods sit outside the computed confidence limits. In order to improve the fit to the observed data, annual maximum peak flows less than 85 m^3/s were removed from the data set.[12] The right-hand side of **Figure 2.14** and Column E of **Table 2.6** show the results of omitting the 38 annual flows less than 85 m^3/s from the analysis and applying the expected probability adjustment to the remaining data. Omitting flows less than 85 m^3/s only reduced the peak 1% AEP flow estimate from 675 m^3/s to 665 m^3/s, noting that these values are consistent with the Scenario 1 analysis that was undertaken as part of Advisian, 2021.

As the FLIKE software allows for the inclusion of larger floods that are known to have occurred outside the continuous period of record in the flood frequency analysis, the above analyses were updated to include the 1890 flood of record on the Darling River. The results of the revised analyses are shown graphically on **Figure 2.14**, sheet 2, while columns F and G in **Table 2.9** set out the updated peak flow estimates for floods ranging between 20% and 0.2% AEP. The inclusion of the 1890 flood of record in the analysis and the removal of annual maximum peak flows from the continuous period of period of record increases the peak 1% AEP flow estimate from 665 m^3/s to 730 m^3/s, which is consistent with the Scenario 2 analysis that was undertaken as part of Advisian, 2021.

Based on the findings of the flood frequency analysis, the design peak flow estimates set out in Column G of **Table 2.9** were adopted for design flood estimation purposes.

2.4.4. Bulpunga Stream Gauge (GS 425011)

As previously mentioned, flow in the Great Darling Anabranch principally originates from the regulator controlled Menindee Lakes system at Menindee, with unregulated flows only occurring during times of major flood. As such, it is not feasible to undertake a formal flood frequency analysis on the annual series of maximum peak flows.[13]

Figure 2.15 shows the relationship between annual maximum peak flows that were recorded by the Burtundy and Bulpunga stream gauges for the period 1955 to 2024. In order to derive design peak flow estimates for the Great Darling Anabranch for use in the present study, a linear

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[11] Refer **Annexure B5** of **Appendix B** which contains a list of the adopted annual series of flood peaks at the Burtundy stream gauge.

[12] While the application of the multiple Grubbs-Beck test to censor low flows as recommended in ARR, 2019 identified a low flow threshold of 74 m^3/s, the threshold was increased to 85 m^3/s based on a visual assessment of the fitted frequency curves.

[13] Flow discharging to the Great Darling Anabranch is controlled by the Cawndilla Outlet Regulator, which has a maximum flow rate of 23 m^3/s.

regression analysis was undertaken to define a line-of-best fit (*y = 0.6611x – 73.469*) to annual maximum peak flows greater than 23 m^3/s on the anabranch (identified in red on **Figure 2.15**).[14] **Chapter 4** of this report provides further details relating to the derivation of design peak flow estimates for the Great Darling Anabranch at the location of the Bulpunga stream gauge.

2.5 Analysis of Available Rain Gauge Data

Members of the Flood Risk Management Committee (**FRMC**) identified the occurrence of intense bursts of rain that occurred over the period December 2010 to February 2011 which caused nuisance flooding in parts of the study area. **Figure 1.1** shows the plan location of the *Mildura Airport AWS* (GS 76031) rain gauge (**Mildura Airport rain gauge**), as well as the location of four BoM operated daily read rain gauges that are located in the vicinity of the four urban centres and were operational at the time of the aforementioned storm events. It is noted that the Mildura Airport rain gauge is the only rain gauge in the vicinity of the study area that records rainfall at a period that is less than 24 hours.

The left hand side of **Figure 2.16** shows the cumulative depth of rain that was recorded at the Mildura Airport rain gauge over the period 1 December 2010 to 8 February 2011. **Figure 2.16** shows that during the period identified by the members on the FRMC, there were four significant bursts of rainfall on the following dates:

- between 21:00 hours on 4 December 2010 and 00:20 hours on 5 December 2010, when a total of 52.6 mm of rain fell at Mildura Airport (herein denoted the "4 December 2010 storm event");
- between 18:00 hours and 21:20 hours on 11 January 2011, when a total of 46 mm of rain fell at Mildura Airport (herein denoted "11 January 2011 storm event");
- between 3:00 hours on 13 January 2011 and 2:00 hours on 14 January 2011, when a total of 58 mm of rain fell at Mildura Airport (herein denoted "13 January 2011 storm event"); and
- between 14:00 hours and 17:00 hours 4 February 2011, when a total of 104 mm of rain fell at Mildura Airport (herein denoted "4 February 2011 storm event")

The right hand side of **Figure 2.16** shows a comparison of the recorded rainfall with design intensity-frequency-duration curves, while **Table 2.10** over the page shows the approximate AEP of the four storm bursts.[15]

By inspection of the information shown on **Figure 2.16** and **Table 2.10**, it can be concluded that:

e) the 4 December 2010 storm event approximated a 5% AEP storm event for durations between about 30 minutes and 4.5 hours, reducing to about a 20% AEP storm event for a duration of 6 hours;

f) the 11 January 2011 storm event approximated a 10% AEP storm event for durations between 2 and 12 hours;

g) the 13 January 2011 storm event approximated a 20% AEP storm event for durations longer than 18 hours; and

[14] Note that for the purpose of deriving the line-of-best fit, the data point showing over 100 m^3/s in the anabranch and less than 40 m^3/s in the Darling River was treated as an outlier and therefore ignored.

[15] Note that the Intensity-Frequency-Duration rainfall data has been adjusted to reflect near-term climatic conditions, the definition of which is set out in **Chapter 4** of this report.

h) the 4 February 2011 storm event approximated a 0.5% AEP storm event for durations ranging between 2 and 6 hours, a 1% AEP storm event for durations ranging between 6 and 12 hours, and a 0.2% AEP storm event for durations of 18 and 36 hours.

TABLE 2.10
APPROXIMATE AEP OF RECORDED RAINFALL FOR HISTORIC STORM EVENTS
MILDURA AIRPORT AWS[1,2]
(% AEP)

Historic Storm Event	Storm Duration (hours)												
	0.5	**1**	**1.5**	**2**	**3**	**4.5**	**6**	**9**	**12**	**18**	**24**	**36**	**48**
4 December 2010	10-5%	5%	5%	5%	10-5%	10-5%	10%	20-10%	20-10%	20%	20%	50-20%	50-20%
11 January 2011	50-20%	50-20%	20%	20-10%	10%	10%	10%	10%	20-10%	20-10%	20%	50-20%	50-20%
13 January 2011	1EY - 50%	50%	50%	1EY - 50%	1 EY	1EY - 50%	1EY - 50%	1EY - 50%	1EY - 50%	50-20%	20%	50-20%	50-20%
4 February 2011	5-2%	5-2%	2-1%	0.5-0.2%	0.5-0.2%	0.50%	0.50%	1-0.5%	1-0.5%	0.5-0.2%	0.2-0.1%	0.5%	0.2%

1. AEP = Average Exceedance Probability, EY = Exceedances per Year.
2. Approximate AEP based on near-term climatic conditions, the definition of which is set out in **Chapter 4** of this report.

Table 2.11 shows that the daily rainfall totals at the time of the abovementioned storm events. **Figure 1.1** shows that there are three daily-read rain gauges at the township of Wentworth but none at Dareton, Buronga or Gol Gol. The *Wentworth Post Office* (GS 47053) daily-read rain gauge (**Wentworth Post Office rain gauge**) is located about 10 km to the east of Dareton, while the *Irymple (Arlington)* (GS 76015) daily-read gauge (**Irymple (Arlington) rain gauge**) is located approximately 7 km to the south of Gol Gol and Buronga.

Based on the above, the rainfall that was recorded by the Wentworth Post Office rain gauge is considered to be representative of the rain that fell at Wentworth and Dareton, while the total rainfall that was recorded by the Irymple (Arlington) rain gauge is considered to be representative of the rain that fell at Buronga and Gol Gol.

TABLE 2.11
RECORDED DAILY RAINFALL TOTALS FOR HISTORIC STORM EVENTS(1)

Storm	Rainday(2)	BoM AWS	BoM Daily Read Gauge			
		Mildura Airport AWS (GS 76031)	Wentworth Post Office (GS 47053)	Irymple (Arlington) (GS 76015)	Red Cliffs (Post Office) (GS 76052)	Paringi (Kerribee) (GS 47107)
December 2010	5	52.8	3.0	23.4	-	3.6
	6	4.2	3.8	0	19.0	0
	7	14.0	11.2	10.8	17.8	30.0
	8	27.4	29.2	43.4	40.4	32.0
	9	6.8	11.2	9.6	4.6	16.0
	TOTAL	**105.2**	**58.4**	**87.2**	**81.8**	**81.6**
January 2011	10	3.2	1.6	2.2	-	13.0
	11	1.8	6.6	1.0	-	0.4
	12	61.0	33.2	63.6	83.4	61.0
	13	25.6	12.4	22.0	-	-
	14	32.8	35.2	45.2	62.2	62.0
	15	0.2	0	0	-	0
	TOTAL	**124.6**	**89**	**134**	**145.6**	**136.4**
February 2011	4	0	0.2	Gauge not in operation		0
	5	148.0	60.4			173.0
	6	29.4	42.6			28.0
	TOTAL	**177.4**	**103.2**			**201**

1. Refer **Figure 1.1** for location of rain gauges.
2. A rainday represents the total depth of rain that fell in the preceding 24 hours to 09:00 hours on a given day.

The key findings of an analysis of the daily rainfall totals that are set out in **Table 2.11** were as follows:

- **4 December 2010 storm event** – While 52.8 mm of rainfall was recorded at Mildura Airport on the rainday of 5 December 2010, only 3 mm and 23.4 mm were recorded by the Wentworth Post Office and Irymple (Arlington) rain gauges, respectively over the same period. While the 4 December storm event was equivalent to a 5% AEP storm event at Mildura Airport, it is likely that it was equivalent to a more frequent storm event at the four urban centres and as such was not used to validate the hydraulic models that were developed as part of the present study.
- **11 January 2011 storm event** – **T**he total depth of rain that was recorded at Mildura Airport is similar to the depth of rain that was recorded by the Irymple (Arlington) rain gauge. Based on this finding, it is reasonable to assume that the rainfall that was recorded at the airport is representative of the rain that fell over Buronga and Gol Gol. A total rainfall depth of 33.2 mm was recorded by the Wentworth Post Office rain gauge which is about half of the total that was recorded at Mildura Airport.
- **13 January 2011 storm event** – While the total depth of rain that was recorded at Mildura Airport is generally comparable to the rain that was recorded by the Wentworth Post Office and Irymple (Arlington) rain gauges, the storm event has not been used to validate the hydraulic models that were developed as part of the present study due to it being a relatively frequent storm event (i.e. between 1 EY and 20% AEP).
- **4 February 2011 storm event** – As the Irymple (Arlington) rain gauge was not in operation during the storm event, the rainfall that was recorded at Mildura Airport could be assumed as being representative of the rain that fell in Buronga and Gol Gol given it is the closest gauge that was in operation at the time. The total rainfall depth that was recorded by the Wentworth Post Office rain gauge was less than half the total that was recorded at Mildura Airport over the same period of time.

Based on the above findings, the rainfall that was recorded by the Mildura Airport rain gauge at the time of the 11 January 2011 and 4 February 2011 storm events was used for model validation purposes, noting that the raw rainfall data was adopted for defining local catchment flooding conditions at Buronga and Gol Gol, while it was factored down to be more representative of the rain is believed to that fell at Dareton and Wentworth (refer **Section 3.4** of this report for further discussion).

3 HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

3.1 General

The present study required the use of a hydraulic model that is capable of analysing the time varying effects of flow in both the rivers and local stormwater drainage system, as well as the two-dimensional nature of flow on both the floodplain and in the four urban centres. The TUFLOW modelling software was adopted as it is a few commercially available hydraulic models which contain all the required features that is widely used in Australia.

This chapter deals with the development and calibration of a TUFLOW model which covered a 420 km reach of the Murray River and a 135 km reach of the Darling River using the available flood data from the 1956, 1974 and 2022 floods (**Murray and Darling River TUFLOW Model**).

This chapter also deals with the development and calibration of three smaller TUFLOW models which cover the urban centres of Wentworth (**Wentworth TUFLOW Model**), Dareton (**Dareton TUFLOW Model**), Buronga and Gol Gol (**Buronga and Gol Gol TUFLOW Model**) (collectively referred to herein as the "**urban centre TUFLOW models**") using data that were available for the 11 January 2011 and 4 February 2011 storm events.

3.2 The TUFLOW Modelling Approach

TUFLOW is a true two-dimensional hydraulic model which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave through the system.

The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. Consequently, the model is "fully dynamic" and once tuned will provide an accurate representation of the passage of the flood wave through the drainage system in terms of flood extent, depth, velocity and distribution of flow.

TUFLOW solves the equations of flow at each point of a rectangular grid system which represent overland flow on the floodplain. The choice of grid point spacing depends on the need to accurately represent features on the floodplain which influence hydraulic behaviour and flow patterns (e.g. buildings, streets, changes in channel and floodplain dimensions, hydraulic structures which influence flow patterns, etc.).

Pipe drainage and channel systems can be modelled as one-dimensional elements embedded in the larger two-dimensional domain which typically represents the wider floodplain. Flows are able to move between the one and two-dimensional elements of the model depending on the capacity characteristics of the drainage system being modelled.

The TUFLOW models that have been developed as part of the present study will also allow for the assessment of potential flood management measures as part of the future *Wentworth FRMS&P*.

3.3 Murray and Darling River TUFLOW Model Development and Calibration

3.3.1. Model Structure

Figure 3.1 (2 sheets) shows the layout of the Murray and Darling River TUFLOW Model, while **Figure 3.2** (2 sheets) shows the spatial variation in hydraulic roughness values that form part of its structure. The following sections of this report provide further details of the development and calibration of the Murray and Darling River TUFLOW Model.

3.3.2. Two-Dimensional Model Domain

An important consideration of two-dimensional modelling is how best to represent the roads, levees, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive, and it is not practicable to use a mesh of very fine elements without excessive times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

A grid spacing of 160 m with smaller nested grids of 40 m and 20 m was found to provide an appropriate balance between the need to define features on the floodplain versus model run times, noting that the 40 m nested grid generally spanned the inbank area of the two rivers and their immediate overbank areas, while the 20 m nested grid was used to more accurately define flood behaviour at the four urban centres, as well as the waterway area where the available width of flow on the Murray River narrows a short distance downstream of Lock 11 (refer **Figure 3.1** for extent). The sub-grid sampling modelling approach was also incorporated in the Murray and Darling River TUFLOW Model to more accurately represent the variations in floodplain topography.[16]

The ground surface elevations that were assigned to the model grid points were initially based on the LiDAR derived DEMs (refer **Section B1.2** of **Appendix B** for further details of LiDAR survey data relied upon for the present study). While bathymetric survey is available over defined lengths of the Murray River, it was necessary to incorporate a 2d_zsh layer in the model which lowered the LiDAR derived DEM to the bed level of the river over a constant 160 m width, noting that the bed level of the river was derived by interpolating between known points, such as at the locks and the start and end points of the available bathymetric survey.

While the available bathymetric survey on the Darling River and Great Darling Anabranch near their confluence with the Murray River was incorporated in the Murray and Darling River TUFLOW Model, a 2d_zsh layer approach was not adopted in the upstream reaches due to their remoteness to the study area.

The bridge crossings of the Murray and Darling rivers were incorporated in the two-dimensional model domain as layered flow constriction elements, which themselves were based on cross sectional survey data.

As the sub-grid sampling modelling approach was adopted, ridge lines were added to the TUFLOW model in order to accurately represent important topographic features which influence the passage of flow on the floodplain such as road embankments and the flood protection levees. While the elevations for these ridge lines were initially determined from inspection of the LiDAR survey data, it was necessary to make further adjustments to take into account changes that have occurred since the capture of the data.

The location and alignment of the levees that were present during the 2022 flood were derived from information provided by Council and Mildura Rural City Council where available, else they were located based on the available aerial flood photography. The crest elevations of the levees were based on survey data were provided by Council, else they were assumed to be elevated about 100 mm higher than the nearest surveyed flood mark.

[16] A sub-gird sampling frequency of 9 was adopted which resulted in a sub-grid sample size of 16 m, 4 m and 2 m being incorporated in the 160 m, 40 m and 20 m grid cells, respectively.

It was also necessary to make changes to the structure of the Murray and Darling River TUFLOW Model to account for changes that have occurred on the floodplain since the capture of the LiDAR survey data, including the following:

- The George Chaffey Bridge was upgraded in the mid-1980s, meaning that changes needed to be made to both the bridge alignment and its associated embankment works in order to calibrate the model to the 1956 and 1974 floods. The alignment and elevation of the road and dimensions of the bridge openings were approximated using the historic photos contained in **Annexure B13** of **Appendix B** and the current LiDAR survey data.

- The marina that is located immediately upstream of the George Chaffey Bridge in Mildura wasn't present at the time of these earlier floods. A TUFLOW 2d_zsh layer was used to approximate the pre-marina ground levels based on the historic photos contained in **Annexure B13** of **Appendix B** and the current LiDAR survey data

- The temporary flood protection levee around the Wentworth Aerodrome wasn't present at the time of these earlier floods was omitted from the model.

3.3.3. One-dimensional Model Elements

The Gol Gol Creek Regulator was incorporated in the Murray and Darling River TUFLOW Model as a one-dimensional element based on the dimensions contained in Transport for New South Wales asset database. The regulator was assumed to be closed during the historic and design flood events but was assumed open as part of a subsequent sensitivity analysis that was undertaken as part of the present study (refer **Section 5.7** for further discussion).

3.3.4. Model Parameters

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces encompassed by the model. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as "Manning's n".

Table 3.1 over the page sets out the Manning's n values which were found to achieve a good match with observed data for the three historic flood events that were relied upon for model calibration purposes, while **Figure 3.2** (2 sheets) shows their spatial extent, noting that the vegetation mapping data that is available via the NSW Government's SEED portal and the Victorian Government's equivalent were initially used as the basis for defining the extent of the vegetated areas, with adjustments made in some areas following a review of the available aerial photography.

Column B of **Table 3.1** sets out the Manning's n values which were found to achieve a good match with observed data for the historic flood events that occurred in 1956 and 1974, while Column C shows that a higher Manning's n value needed to be applied to the very densely vegetated areas which currently flank parts of the river in order to achieve a good match with flood data that was captured at the peak of the 2022 flood. The extent of the very heavily vegetated areas was defined based on the available flood photography.

The details of individual roads and buildings were not incorporated in the model as their footprint is generally less that the smallest cell size in the model (i.e. 20 m). The default Manning's n value of 0.045 was considered suitable for representing the urbanised areas on the floodplain due to the generally open nature of the development.

TABLE 3.1
BEST ESTIMATE HYDRAULIC ROUGHNESS VALUES
MURRAY AND DARLING RIVER TUFLOW MODEL

Surface Treatment [A]	Manning's n Value	
	Pre-1974 Floodplain Conditions [B]	Present Day Floodplain Conditions [C]
Standing Waterbodies	0.03	
General floodplain roughness/urbanised areas (default)	0.045	
Moderately Vegetated Area	0.06	
Densely Vegetated Area	0.07	
Very Densely Vegetated Area	0.07	0.15

3.3.5. Model Boundary Conditions

Figure 3.1, sheet 1 shows the three locations where inflow hydrographs were applied to the Murray and Darling River TUFLOW Model, noting that these aligned with the main arms of the Murray and Darling rivers, as well as the Great Darling Anabranch. **Figure 3.3** shows the discharge hydrographs that were used as input to the Murray and Darling River TUFLOW Model on both the Murray and Darling rivers for the three historic flood events, noting that for the 1956 flood it was necessary to source the hydrograph from the Euston stream gauge.

The downstream boundaries of the model comprised a "free discharge" outlet, where a TUFLOW derived normal depth calculation was used to define hydraulic conditions at the outlet of the Murray and Darling River TUFLOW Model.

3.3.6. Hydraulic Model Calibration

As mentioned in **Section 2.2.1**, the 1956, 1974 and 2022 floods were chosen for model calibration purposes. **Figures 3.4**, **3.5** and **3.6** (6 sheets each) show the TUFLOW model results, as well as the plan location of the available flood marks for the 1956, 1974 and 2022 floods, respectively, while **Figure 3.7** (4 sheets) shows the modelled water surface profiles along the Murray River, Darling River and Great Darling Anabranch for the historic flood events. **Figures 3.8**, **3.9** and **3.10** show a comparison of the recorded and modelled stage and discharge hydrographs at the Colignan, Lock 10 and Lock 9 stream gauges, respectively.

Tables 3.2, **3.3** and **3.4** over the page provide a comparison of modelled versus recorded peak flood levels for the 1956, 1974 and 2022 floods, respectively.

TABLE 3.2
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
AUGUST1956 FLOOD

Point No.[(1)]	Location	Peak Flood Level (m AHD)		Difference[(2)] (m)	Comment
		Recorded	Modelled		
1956.01	First Street	40.20	40.36	+0.17	Reasonable match
1956.02	Keating Avenue	40.20	40.38	+0.15	Reasonable match
1956.03	Billabong Road	40.22	40.33	+0.09	Good match
1956.04	Irymple Avenue	40.25	40.28	+0.02	Good match
1956.05	Loop Road	40.08	40.23	+0.13	Reasonable match
1956.06	McGinniskin Road	39.87	40.05	+0.15	Reasonable match
1956.07	Karadoc Avenue	39.73	39.94	+0.14	Reasonable match
1956.08	Karadoc Avenue	39.71	39.96	+0.22	Reasonable match
1956.09	The Cobb and Co Way	40.08	40.26	+0.17	Reasonable match
1956.10	Murray Street	40.02	40.11	+0.08	Good match
1956.11	Riverside Golf Club	40.11	39.99	-0.14	Good match
1956.12	Mildura Racecourse	39.60	39.81	+0.19	Reasonable match
1956.13	Murray River	39.75	39.78	+0.01	Good match
1956.14	Hendy Road	39.63	39.73	+0.08	Good match
1956.15	Murray River	39.62	39.70	+0.06	Good match
1956.16	Etiwanda Avenue	39.49	39.61	+0.10	Good match
1956.17	Upstream of Mildura Bridge	39.14	39.53	+0.37	Accuracy of flood mark is questionable as it is lower than surveyed flood marks that are located immediately downstream (refer 1956.18 and 1956.19)
1956.18	Mildura War Memorial	39.32	39.38	+0.04	Good match
1956.19	Hodges Way	39.26	39.34	+0.06	Good match

Refer over for footnotes to table.

TABLE 3.2 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
AUGUST1956 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[2] (m)	Comment
		Recorded	Modelled		
1956.20	West Road	39.02	39.11	+0.06	Good match
1956.21	Pitman Avenue West	39.11	39.14	0	Good match
1956.22	Mildura Lock 11	39.41	39.15	-0.29	Reasonable match
1956.23	West Road	39.10	39.07	-0.07	Good match
1956.24	Apex Park	38.81	38.81	-0.01	Good match
1956.25	River Road	37.61	38.50	+0.89	Accuracy of flood mark is questionable as it is significantly lower than adjacent surveyed flood marks (refer 1956.24 and 1956.26)
1956.26	Murray River	38.46	38.47	-0.01	Good match
1956.27	Murray River	38.28	38.18	-0.12	Good match
1956.28	Flora Avenue	38.15	37.79	-0.38	Flood mark is behind a levee that is located on southern side of river. It is unknown if the levee was present at the time of the 1956 flood.
1956.29	Grape Farm	38.02	-	-0.05	
1956.30	Ranfurly Way	37.82	37.82	-0.02	Good match
1956.31	Mitford Street	37.10	37.79	+0.67	Accuracy of flood mark is questionable as it is significantly lower than adjacent surveyed flood mark (refer 1956.32)
1956.32	Ranfurly Way	37.83	37.79	-0.06	Good match
1956.33	Blandowski Walk	37.72	37.64	-0.12	Good match
1956.34	Abbotsford Bridge	36.39	35.95	-0.47	The reason for the difference in modelled and recorded peak flood levels is not known
1956.35	Wentworth Lock 10	34.56	34.43	-0.13	Good match

1. Refer **Figure 3.4** (6 sheets) for location of flood marks.
2. Note that a positive value indicates that the modelled flood level is higher, and conversely a negative value indicates that the modelled flood level is lower than the observed flood level.

TABLE 3.3
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
1974 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[2] (m)	Comment
		Recorded	Modelled		
1974.1	Lock 10	33.83	33.75	-0.10	Good match
1974.2	50 m downstream of Lock 11	38.10	38.18	+0.07	Good match
1974.3	Carramar Drive	38.75	38.80	+0.04	Good match

1. Refer **Figure 3.5** (6 sheets) for location of flood marks.
2. Note that a positive value indicates that the modelled flood level is higher, and conversely a negative value indicates that the modelled flood level is lower than the observed flood level.

TABLE 3.4
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.01	Murray at Euston stream gauge	52.1	-	-	Located outside extent of Murray and Darling TUFLOW Model
2022.02	Murray River at Colignan stream gauge	44.02	44.01	-0.01	Good match
2022.03	Coligan	43.32	43.32	0	Good match
2022.04	Nangiloc	42.11	41.96	-0.15	Good match
2022.05	Johns Road Crossing	40.72	40.59	-0.13	Good match
2022.06	Edey Road Pump	40.67	40.48	-0.19	Reasonable match
2022.07	Red Cliffs Boat Ramp	40.06	40.02	-0.04	Good match
2022.08	Bruce's Bend Boat Ramp	39.62	39.63	+0.01	Good match
2022.09	The Cobb and Co Way	39.57	39.61	+0.04	Good match
2022.10	Wilga Road	39.27	39.4	+0.13	Good match
2022.11	Adelaide Street	39.3	39.4	+0.10	Good match
2022.12	Punt Road	39.04	39.16	+0.12	Good match
2022.13	Mildura Racecourse	39.26	39.16	-0.10	Good match
2022.14	Mildura Ski Club Boat Ramp	38.88	39.07	+0.19	Reasonable match
2022.15	River Drive	38.95	38.99	+0.04	Good match
2022.16	Caravan Park Road	38.64	38.67	+0.03	Good match
2022.17	George Chaffey Bridge	38.77	38.75	-0.02	Good match
2022.18	Marina	38.8	38.85	+0.05	Good match
2022.19	Riverfront / Nowingi	38.69	38.71	+0.02	Good match
2022.20	Café 1909	38.68	38.72	+0.04	Good match

Refer over for footnotes to table.

TABLE 3.4 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.21	Mildura Lock 11 Down Stream	38.55	38.48	-0.07	Good match
2022.22	Mildura (Chaffeys)	38.35	38.33	-0.02	Good match
2022.23	Pitman Avenue	38.27	38.31	+0.04	Good match
2022.24	Apex Park	38.35	38.16	-0.19	Reasonable match
2022.25	River Road	38.14	38.19	+0.05	Good match
2022.26	End of Flora Ave	37.78	37.88	+0.10	Good match
2022.27	Pump Hill Boat Ramp	37.23	37.21	-0.02	Good match
2022.28	Sandbar Road	36.22	36.22	0	Good match
2022.29	Golf Course Road	36.22	36.12	-0.10	Good match
2022.30	Golf Course Road	36.2	36.11	-0.09	Good match
2022.31	Kookaburra Drive	36.16	36.05	-0.11	Good match
2022.32	Kookaburra Drive	36.18	36.05	-0.13	Good match
2022.33	Silver City Highway	35.49	35.44	-0.05	Good match
2022.34	Silver City Highway	35.44	35.44	0	Good match
2022.35	Silver City Highway	35.47	35.44	-0.03	Good match
2022.36	Silver City Highway	35.49	35.44	-0.05	Good match
2022.37	Silver City Highway	35.5	35.44	-0.06	Good match
2022.38	Silver City Highway	35.5	35.44	-0.06	Good match
2022.39	Silver City Highway	35.53	35.44	-0.09	Good match
2022.40	Silver City Highway	35.48	35.44	-0.04	Good match

Refer over for footnotes to table.

TABLE 3.4 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.41	Silver City Highway	35.48	35.43	-0.05	Good match
2022.42	Curlwaa Boat Ramp	35.5	35.4	-0.10	Good match
2022.43	Silver City Highway	35.49	35.4	-0.09	Good match
2022.44	Old Wentworth Road Upstream	34.76	34.57	-0.19	Reasonable match
2022.45	Old Wentworth Road Upstream	34.66	34.57	-0.09	Good match
2022.46	Old Wentworth Road Upstream	34.7	34.57	-0.13	Good match
2022.47	Old Wentworth Road Upstream	34.64	34.57	-0.07	Good match
2022.48	Old Wentworth Road Upstream	34.68	34.57	-0.11	Good match
2022.49	Old Wentworth Road Upstream	34.62	34.57	-0.05	Good match
2022.50	Old Wentworth Road Upstream	34.68	34.57	-0.11	Good match
2022.51	Old Wentworth Road Upstream	34.63	34.57	-0.06	Good match
2022.52	Old Wentworth Road Upstream	34.68	34.57	-0.11	Good match
2022.53	Old Wentworth Road Upstream	34.63	34.57	-0.06	Good match
2022.54	Old Wentworth Road Upstream	34.68	34.57	-0.11	Good match
2022.55	Old Wentworth Road Upstream	34.72	34.57	-0.15	Good match
2022.56	Old Wentworth Road Upstream	34.62	34.57	-0.05	Good match
2022.57	Old Wentworth Road Upstream	34.62	34.57	-0.05	Good match
2022.58	Old Wentworth Road Upstream	34.68	34.57	-0.11	Good match
2022.59	Old Wentworth Road Upstream	34.58	34.57	-0.01	Good match
2022.60	Old Wentworth Road Upstream	34.62	34.57	-0.05	Good match

Refer over for footnotes to table.

TABLE 3.4 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.61	Old Wentworth Road Upstream	34.67	34.57	-0.10	Good match
2022.62	Old Wentworth Road Upstream	34.61	34.57	-0.04	Good match
2022.63	Old Wentworth Road Upstream	34.67	34.57	-0.10	Good match
2022.64	Old Wentworth Road Upstream	34.61	34.57	-0.04	Good match
2022.65	Old Wentworth Road Upstream	34.7	34.57	-0.13	Good match
2022.66	Old Wentworth Road Upstream	34.62	34.57	-0.05	Good match
2022.67	Old Wentworth Road Upstream	34.69	34.57	-0.12	Good match
2022.68	Old Wentworth Road Upstream	34.63	34.57	-0.06	Good match
2022.69	Old Wentworth Road Upstream	34.7	34.57	-0.13	Good match
2022.70	Old Wentworth Road Upstream	34.62	-	-	Flood marks are located outside the known flood extent. It is not known if the "surveyed flood levels" are flood levels or road levels along the Old Wentworth Road.
2022.71	Old Wentworth Road Upstream	34.70	-	-	
2022.72	Old Wentworth Road Upstream	34.62	-	-	
2022.73	Old Wentworth Road Upstream	34.71	-	-	
2022.74	Old Wentworth Road Upstream	34.71	-	-	
2022.75	Old Wentworth Road Upstream	34.74	-	-	
2022.76	Old Wentworth Road Upstream	34.88	-	-	
2022.77	Old Wentworth Road Upstream	35.01	-	-	
2022.78	Old Wentworth Road	35.02	-	-	
2022.79	Old Wentworth Road Upstream	35.00	-	-	
2022.80	Old Wentworth Road Upstream	35.03	-	-	

Refer over for footnotes to table.

TABLE 3.4 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.81	Old Wentworth Road Upstream	35.14	34.84	-0.30	Reasonable match
2022.82	Old Wentworth Road Upstream	35.18	34.83	-0.35	Reasonable match
2022.83	Old Wentworth Road Upstream	35.06	34.83	-0.23	Reasonable match
2022.84	Old Wentworth Road Upstream	35.06	34.83	-0.23	Reasonable match
2022.85	Little Manly Lane	34.91	34.9	-0.01	Good match
2022.86	Murray River at Lock 10 Wentworth	34.14	34.28	+0.14	Good match
2022.87	Murray River at Lock 9 Downstream	30.12	29.95	-0.17	Reasonable match
2022.88	Darling River at Pooncarie	45.47	-	-	Located outside extent of Murray and Darling TUFLOW Model
2022.89	High Darling Road	45.18	-	-	
2022.90	High Darling Road	43.64	-	-	
2022.91	Darling Rive at Burtundy	40.67	40.96	+0.29	Reasonable match
2022.92	Fletchers Lake Road Upstream	33.94	34.57	+0.63	Accuracy of flood mark is questionable as it is 0.5 m lower than adjacent surveyed flood marks (refer 2022.92)
2022.93	Fletchers Lake Road Upstream	34.40	34.57	+0.17	Reasonable match
2022.94	Fletchers Lake Road Upstream	34.55	34.57	+0.02	Good match
2022.95	Fletchers Lake Road Downstream	34.56	34.57	+0.01	Good match
2022.96	Fletchers Lake Road Downstream	34.59	34.57	-0.02	Good match
2022.97	Pooncarie Road	34.73	34.74	+0.01	Good match
2022.98	Pooncarie Road	34.37	34.74	+0.37	Flood mark is located in an area that is inundated by floodwater that extended up Three Mile Creek. Accuracy of flood mark is questionable as it is lower than other flood marks in the backwater flooded area (refer 2022.105 and 2022.12)

Refer over for footnotes to table.

TABLE 3.4 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.99	Florence Point	34.72	34.71	-0.01	Good match
2022.100	Darling View Road	34.24	34.7	+0.46	Flood marks are located in an area that is inundated by floodwater that extended up Three Mile Creek. Accuracy of flood marks are questionable as they are lower than other flood marks in the backwater flooded area (refer 2022.105 and 2022.12)
2022.101	Pooncarie Road	34.30	34.7	+0.40	
2022.102	Pooncarie Road	34.21	34.7	+0.49	
2022.103	Darling View Road	34.69	34.71	+0.02	Good match
2022.104	Darling View Road	34.99	34.7	-0.29	Reasonable match
2022.105	Pooncarie Road	34.61	34.67	+0.06	Good match
2022.106	Pooncarie Road	34.25	34.67	+0.42	Flood marks are located in an area that is inundated by floodwater that extended up Three Mile Creek. Accuracy of flood marks are questionable as they are lower than other flood marks in the backwater flooded area (refer 2022.105 and 2022.12)
2022.107	Pooncarie Road	34.04	34.7	+0.66	
2022.108	Pooncarie Road	33.97	34.65	+0.68	
2022.109	Pooncarie Road	34.57	34.56	-0.01	Good match
2022.110	Pooncarie Road	34.56	34.57	+0.01	Good match
2022.111	Pooncarie Road	34.54	34.57	+0.03	Good match
2022.112	Pooncarie Road	34.60	34.56	-0.04	Good match
2022.113	Wentworth Aerodrome	34.15	34.22	+0.07	Good match
2022.114	Wentworth Aerodrome	34.14	34.18	+0.04	Good match
2022.115	Wentworth Aerodrome	34.15	34.26	+0.11	Good match
2022.116	Wentworth Aerodrome	34.13	34.17	+0.04	Good match
2022.117	Wentworth Aerodrome	33.99	33.93	-0.06	Good match
2022.118	Wentworth Aerodrome	34.15	34.16	+0.01	Good match

Refer over for footnotes to table.

TABLE 3.4 (Cont'd)
COMPARISON OF MODELLED VERSUS RECORDED PEAK FLOOD LEVELS
2022 FLOOD

Point No.[1]	Location	Peak Flood Level (m AHD)		Difference[1] (m)	Comments
		Recorded	Modelled		
2022.119	Renmark Road	33.97	34.16	+0.19	Reasonable match
2022.120	Wentworth Street	34.56	34.48	-0.08	Good match
2022.121	Wentworth Street	34.55	34.48	-0.07	Good match
2022.122	Wentworth Street	34.55	34.49	-0.06	Good match
2022.123	Adams Street	33.78	-	-	Flood mark is located internal to Wentworth Town Levee
2022.124	Darling Street	34.42	34.45	+0.03	Good match
2022.125	Old Wentworth Road Downstream	34.56	34.53	-0.03	Good match
2022.126	Old Wentworth Road Downstream	34.57	34.53	-0.04	Good match
2022.127	Old Wentworth Road Downstream	34.58	34.53	-0.05	Good match
2022.128	Old Wentworth Road Downstream	34.59	34.53	-0.06	Good match
2022.129	Old Wentworth Road Downstream	34.58	34.53	-0.05	Good match
2022.130	Pavilion Road	34.56	34.53	-0.03	Good match
2022.131	Pavilion Road	34.55	34.53	-0.02	Good match
2022.132	Darling Anabranch at Bulpunga	36.30	-	-	Located outside extent of Murray and Darling TUFLOW Model

1. Refer **Figure 3.4** (6 sheets) for location of flood marks.
2. Note that a positive value indicates that the modelled flood level is higher, and conversely a negative value indicates that the modelled flood level is lower than the observed flood level.

The key findings of the calibration of the Murray and Darling River TUFLOW Model are as follows:

<u>1956 Flood</u>

- **Table 3.2** shows that the modelled peak flood levels are generally higher than the observed flood levels that are located upstream of the bridge crossing of the Murray River at Mildura by up to about 0.21 m (refer Flood Mark IDs 1956.01 to 1956.17). This is likely due to the approximate nature of the floodplain topography in this area (for example, the adoption of conditions that are considered to be representative of the floodplain at the time of the flood, such as the now demolished Sturt Highway bridge crossing of the floodplain and natural ground levels in the vicinity of the Mildura Marina).
- **Table 3.2** shows that the model achieved a good match with the observed flood data downstream of the Sturt Highway bridge crossing of the Murray River, with four exceptions where the accuracy of the flood marks was deemed questionable (refer comments in **Table 3.2** for further discussion).
- **Figure 3.7** shows that the model results generally matched the shape of the gauged discharges at Lock 10 and the recorded stage hydrograph at Lock 9, noting that the modelled peak flood level was about 0.29 m lower than the flood peak that was recorded at the lock.

<u>1974 Flood</u>

- **Table 3.3** shows that the modelled peak flood levels generally match the observed flood levels to within +/- 0.1 m.
- **Figure 3.8** shows that the model results generally matched the shape of the gauged stage hydrograph at Colignan and Lock 10. **Figure 3.8** also shows that the model results achieved a good match with the recorded stage and discharge hydrographs at Lock 9.

<u>2022 Flood</u>

- **Table 3.4** shows that of the 97 surveyed flood levels that are located within the extent of the two-dimensional model domain or within the known flood extent[17], 77 achieved a good match (i.e. within +/- 0.15 m) and an additional 12 achieved a reasonable match (i.e. within +/- 0.3 m) with the surveyed levels. **Table 3.4** sets out the reasons why the modelled peak flood levels did not match the surveyed levels at eight locations.
- **Figure 3.9** shows that the results of the Murray and Darling River TUFLOW Model generally matched the shape of the recorded stage hydrographs at Colignan, Lock 10 and Lock 9.
- While **Figure 3.9** shows that the results of the Murray and Darling River TUFLOW Model generally matched the shape of the recorded discharge hydrographs at Colignan, Lock 10 and Lock 9, it generated slightly higher peak flows at Locks 10 and 9.
- While it is understood that the Curlwaa Levee was breached during the 2022 flood, the timing of when the breach occurred and was repaired was not known. The breach was not modelled as it would have had a negligible impact on the distribution of flow on the floodplain external to the levee, noting that there were no surveyed flood levels internal to the levee.

[17] A total of 17 surveyed flood marks were located outside of the two-dimensional model domain or in areas that were located outside the known flood extent (for example, inside the Western Levee and along Old Wentworth Road east of Fletchers Creek).

Based on the above findings, the Murray and Darling River TUFLOW Model is considered to provide a good match with the available data. While there are some observations of flood behaviour for the 1956 and 2022 floods that couldn't be reproduced by the Murray and Darling River TUFLOW Model, they are considered minor in nature given the assumptions that have been made regarding the conditions that were present on the floodplain at the time of the two flood events.

As such, the hydraulic model parameters set out in **Sections 3.3.4**, and in particular the hydraulic roughness values set out in **Column C** of **Table 3.1** are considered appropriate for use in defining contemporary nature of flooding on the Murray and Darling Rivers over the full range of design flood events.

3.4 Gol Gol and Buronga, Dareton and Wentworth TUFLOW Model Development and Calibration

3.4.1. Model Structure

Figures 3.11 (3 sheets), **3.12** (2 sheets) and **3.13** (2 sheets) show the layout of the Gol Gol and Buronga, Dareton and Wentworth TUFLOW models, respectively (collectively referred to as the "urban centre TUFLOW models"). The following sections of this report provide further details of the development and calibration of the urban centre TUFLOW models.

3.4.2. Two-dimensional Model Domain

A grid spacing of 6 m with a smaller 3 m grid spacing embedded internal to the urban centre TUFLOW models in the vicinity of existing development was found to provide an appropriate balance between the need to define features on the floodplain versus model run times and was adopted for the investigation. Ground surface elevations for model grid points were initially assigned using the LiDAR derived DEMs for the study area. The sub-grid sampling modelling approach was also incorporated in the urban centre TUFLOW models to avoid artificial depression storage artefacts.[18]

Figure 3.11 (3 sheets) shows the location of six subdivisions that have been constructed in Gol Gol and Buronga since the LiDAR survey data were captured in December 2020. As finished surface levels within the subdivisions were not available for use in the present study, the Gol Gol and Buronga TUFLOW model does not represent contemporary (i.e. post-development) conditions in these areas.

Ridge and gully lines were added to the urban centre TUFLOW models where the grid spacing was considered to be too coarse to accurately represent important topographic features which influence the passage of overland flow. The elevations for these ridge and gully lines were determined from inspection of the LiDAR survey data or site-based measurements.

Gully lines were also used to represent the major drainage lines at each urban centre. The use of gully lines ensured that positive drainage was achieved along the full length of these watercourses and thus avoided creation of artificial ponding areas as artefacts of the 'bumpy' nature of the underlying LiDAR survey data.

[18] A sub-gird sampling frequency of five was adopted which resulted in a sub-grid sample size of 1.2 m being incorporated in the 6 m grid cells, while a sub-grid size of 0.6 m being incorporated in the smaller 3 m grid cells in the vicinity of the urban areas.

It was not practicable to model the individual fences surrounding the many allotments at the four urban centres. For the purpose of the present study, it was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways. Individual allotments where development is present were digitised and assigned a high hydraulic roughness value (although not as high as for individual buildings) to account for the reduction in conveyance capacity which will result from obstructive fences, such as Colorbond or brick, and other obstructions stored on these properties (refer **Section 3.4.4** of this report for adopted Manning's n values).

3.4.3. One Dimensional Model Elements

Council's stormwater asset database was used as the primary source of details relating to the piped drainage system. These data were supplemented with information that was shown on plans relating to a number of recently constructed residential subdivisions and field measurements that were undertaken by Council. An assumed cover of 700 mm was adopted for those drainage elements where invert levels or depth measurements were not available. Adjustments were then made to the assumed invert levels where this approach resulted in a negatively graded reach of pipe or culvert.

Several types of pits are identified on **Figures 3.11, 3.12** and **3.13**, including junction pits which have a closed lid and inlet pits which are capable of accepting overland flow. Inlet pit types and dimensions were incorporated in the urban centre TUFLOW models based on a visual inspection of the existing stormwater drainage system. Inlet pit capacity relationships were taken from those in-built to the DRAINS software where appropriate, else they were calculated using an in-house spreadsheet model. **Table 3.5** summarises the pit and pipe data that were incorporated into the urban centre TUFLOW models.

TABLE 3.5
SUMMARY OF MODELLED DRAINAGE STRUCTURES
URBAN CENTRE TUFLOW MODELS

Urban Centre TUFLOW Model	Pipes		Box Culverts		Inlet Pits	Junction Pits	Headwalls
	No.	Length (m)	No.	Length (m)	No.	No.	No.
Gol Gol and Buronga	738	24,755	2	54	544	152	120
Dareton	167	5,194	3	37	118	38	33
Wentworth	490	13,305	13	746	389	85	86

Pit losses throughout the various piped drainage networks were modelled using the Engelhund approach in TUFLOW. This approach provides an automatic method for determining time-varying energy loss coefficients at pipe junctions that are recalculated each time step based on a range of variables including the inlet/outlet flow distribution, the depth of water within the pit, expansion and contraction of flow through the pit, and the horizontal deflection and vertical drop across the pit. The losses derived using the automated Engelhund approach in TUFLOW are generally within the range of expected values derived using other methods.

3.4.4. Model Parameters

Table 3.6 over the page sets out the Manning's n values which were adopted for defining the nature of local catchment flooding in the four urban centres, while **Figures 3.14** (3 sheets), **3.15** (2 sheets) and **3.16** (2 Sheets) show the spatial extent over which each applied. The values contained in

Table 3.6 were derived from the values that were found to achieve a good match with recorded flood data on the Murray and Darling rivers for vegetation and general floodplain roughness, and values that have been adopted for defining local catchment flooding in other regional urban centres in NSW (for roads, allotments and buildings). The vegetation mapping that was adopted for the Murray and Darling River TUFLOW Model was also applied to the urban centre TUFLOW models.

TABLE 3.6
BEST ESTIMATE HYDRAULIC ROUGHNESS VALUES
URBAN CENTRE TUFLOW MODELS

Surface Treatment	Manning's n Value
Concrete piped elements	0.015
Asphalt or concrete road surface	0.02
Standing Waterbodies	0.03
General floodplain roughness (default)	0.045
Moderately Vegetated Area	0.06
Heavily Vegetated Area	0.07
Allotment (between buildings) in urban centres	0.10
Very Heavily Vegetated Area	0.15
Buildings	0.02 for depths <0.05 m 10 for depths > 0.05 m

The footprints of individual buildings located in the two-dimensional model domain were derived from the NSW state-wide building database that was provided by DCCEEW, with manual adjustments made to ensure flow paths between adjacent structures. **Table 3.6** shows that buildings were assigned a depth-varying roughness value. This was done to allow for the initial rainfall that falls within the building footprint to more freely discharge to adjacent areas, with the higher roughness value used to represent the blocking effect that buildings have on overland flow while maintaining a correct estimate of floodplain storage in the model.

3.4.5. Model Boundary Conditions

Due to the relatively flat nature of the topography, the Direct-Rainfall-on-Grid (**DRoG**) approach in the TUFLOW software was adopted for defining the nature of Local Catchment Flooding at the four urban centres.

As discussed in **Section 2.5**, the Mildura Airport rain gauge is the only pluviographic rain gauge that is located in the vicinity of the four urban centres. While the rainfall that fell at Mildura Airport is suitable for defining the rain that fell at Gol Gol and Buronga, it was necessary to factor the rainfall to make it more representative of the rainfall that was experienced at Dareton and Wentworth. **Table 3.7** over the page sets out the details of the rainfall that was applied to the urban centre TUFLOW Models, noting that initial and continuing loss values of 11.2 mm[19] and 2.5 mm/hr[20], respectively were adopted for model calibration purposes.

[19] Based on the Probability Neutral Burst Initial Loss value for a 1% AEP 6 hour duration storm event.

[20] As the *ARR Data Hub* does not contain a continuing loss rates for the study area, a value of 2.5 mm/hr has been adopted based on the value recommended in Walsh et. al., 1991.

The downstream boundaries of the urban centre TUFLOW models comprised:

a) a static water level in the Murray River which was based on the water level in the river at the time of the capture of the LiDAR survey data; and

b) "free discharge" outlets where surface runoff discharges in a northerly direction away from the river, where a TUFLOW derived normal depth calculation was used to define hydraulic conditions at each discharge location.

TABLE 3.7
RAINFALL DATA INCORPORATED IN URBAN CENTRE TUFLOW MODELS
HISTORIC STORM EVENTS[1]

Historic Storm Event	TUFLOW Model	Pluviographic Rainfall Station		Rainfall Depth Nearest Rain Gauge		Rainfall Multiplier
		Location	Rainfall Total (mm)	Source	Rainfall Total (mm)	
11 January 2011	Gol Gol and Buronga	Mildura Airport	61	Irymple (Arlington)	63.6	1
	Dareton			Wentworth Post Office	33.2	0.54[2]
	Wentworth					
4 February 2011	Gol Gol and Buronga	Mildura Airport	177.4	Mildura Airport	177.4	1
	Dareton			Wentworth Post Office	103	0.58[2]
	Wentworth					

1. Refer **Table 2.11** for rainfall that fell on consecutive days at the rain gauges that are located in the vicinity of the four urban centres.
2. Derived based on a comparison of the 24-hour rainfall totals recorded by the Mildura Airport and Wentworth Post Office rain gauges.

3.4.6. Hydraulic Model Validation

While there is no available flood data upon which to formally calibrate the urban centre TUFLOW models, they were used to define the nature of flood behaviour that was likely experienced in the four urban centres at the time of the 11 January 2011 and 4 February 2011 storm events.

Figures 3.17 and **3.18** (3 sheets each) show the indicative extent and depth of inundation that is considered to be generally representative of conditions that arose as a result of the 11 January 2011 and 4 February 2011 storm events, respectively at the urban centres of Gol Gol and Buronga. Similar information is shown on **Figures 3.19** and **3.20** (2 sheets each) at Dareton, and on **Figures 3.21** and **3.22** (2 sheets each) at Wentworth.

A comparison of **Figures 3.17** and **3.18** shows that the local catchment flooding at Gol Gol and Buronga during the 4 February 2011 storm event was more extensive than during the 11 January 2011 storm event. **Figure 3.18** shows that existing development was impacted by notable depths of inundation at the following locations:

- in the large allotments that are located between Hendy Road and the Murray River to the west of Alcheringa Oval;
- in residential allotments that are located adjacent to the low point in Midway Drive to the south Pitman Avenue;

- in the allotments that are bounded by King Street to the west, William Street to the north, Tapio Street to the east and Adelaide Street to the south;
- in the allotments that are bounded by Wood Street to the north, Burns Street to the east, William Street to the south and Taipo Street to the west; and
- in allotments that are located on the northern side of Crane Drive to the east of its intersection with Tower Court.

Figures 3.19 to **3.22** show that no existing development in the urban centres of Dareton and Wentworth were subject to depths of inundation greater than 0.3 m in the 11 January 2011 and 4 February 2011 storm events.

4 DERIVATION OF DESIGN FLOOD HYDROGRAPHS

4.1 Murray and Darling River Flooding

Figures 4.1, **4.2** and **4.3** show the design discharge hydrographs that were used as input to the Murray and Darling River TUFLOW Model, noting that these were derived by factoring the recorded discharges hydrographs of historic floods that were of similar magnitude (where available). For example, the discharge hydrographs that were recorded at the Euston, Burtundy and Bulpunga stream gauges during the 2022 flood were used as the basis for the deriving hydrographs for design floods with AEPs of 20%, 10% and 5%, while those recorded for the 1956 flood were used as the basis for the deriving hydrographs for design floods with AEPs of 2%, 1%, 0.5% and 0.2%. The discharge hydrographs for the Extreme Flood were derived by factoring the ordinates of the 1% AEP design discharge hydrographs by three (3). **Table 4.1** at the end of this chapter sets out the adopted design peak flow estimates at the Euston, Burtundy and Bulpunga stream gauges, the representative historic flood hydrograph and the factor that was used to adjust their ordinates.

The recorded hydrographs have been relied upon as they represent real floods that have occurred, noting that timing of the flood peaks in the Murray and Darling rivers did not align during either event which is consistent with what historically occurs in the two river systems. As this is a naturally occurring feature of the river system, the timing of the hydrographs was not adjusted for design flood estimation as part of the present study.

4.2 Local Catchment Flooding

4.2.1. Rainfall Intensity

The procedures used to obtain temporally and spatially accurate and consistent Intensity-Frequency-Duration (**IFD**) design rainfall curves for the assessment of local catchment flooding at in the four urban centres are presented in ARR 2019. Design storms for frequencies of 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP were derived for storm durations ranging between 30 minutes and seven days. The IFD dataset was downloaded from the Bureau of Meteorology's *2016 Rainfall IFD Data System* (**BoM 2016 IFD**)

A recent update to ARR 2019 (**ARR 2019 Rev 4.2**) contains a series of tables of projected increases in rainfall intensity with varying Shared Socioeconomic Pathways (**SSPs**),[21] projection date and storm duration. The values provided in the *ARR 2019 Data Hub* have been derived based on:

i. an analysis of the predicted temperature increases from global climate models across each of the eight Natural Resource Management clusters set out in the Commonwealth Science Industrial Research Organisation's *Future Climates Tool* website, combined with:

ii. research into the impact of increasing temperature on rainfall intensities as presented in the paper entitled *A systematic review of climate change science relevant to Australian design flood estimation* (Wasko, et al, 2024), which shows that temperature increases are predicted to have a greater effect on rainfall intensities for shorter duration storms.

Based on a near-term projection date of 2030, ARR 2019 Rev 4.2 states that the predicted increase in the BoM 2016 IFD data for SSPs of between 1-2.6 best-case climate change projections) and 5-8.5 (worst-case climate change projections) is between 18 and 20 percent. In the knowledge that the findings of the present study will likely be utilised by Council extending out to the year 2030 and noting the small range in the best- and worst-case climate change projections, the

[21] SSPs are climate change scenarios of projected socioeconomic global changes. The SSPs are named according to the radiative forcing values (W m-2) in the year 2100 relative to pre-industrial values.

multiplication factors derived from the *ARR Data Hub* for SSP2-4.5 Year 2030 conditions were applied to the BoM 2016 IFD data for the purpose of defining the nature of local catchment flooding at the four urban centres.

4.2.2. Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR 2019 are applicable strictly to a point. In the case of a catchment of over tens of square kilometres area, it is not realistic to assume that the same rainfall intensity can be maintained. An Areal Reduction Factor (**ARF**) is typically applied to obtain an intensity that is applicable over the entire catchment. However, as the local catchments at the four urban centres are relatively small, the reduction in rainfall intensity would be quite small. Accordingly, no reduction in design point rainfalls was made for this the purpose of undertaking the present study (i.e. an ARF of 1.0 was adopted).

4.2.3. Temporal Patterns

ARR 2019 prescribes the analysis of 10 temporal patterns per storm duration for various zones in Australia. These patterns are used in the conversion of a design rainfall depth with a specific AEP into a design flood of the same frequency. The patterns may be used for AEP's down to 0.2 per cent where the design rainfall data is extrapolated for storm events with an AEP less than 1 per cent.

The temporal patterns ensembles for Frequent (more frequent than 14.4% AEP), Intermediate (between 3.2 and 14.4% AEP) and Rare (rarer than 3.2% AEP) storm events were obtained from the *ARR Data Hub*[22], while those for the very rare events were taken from the BoM's update of *Bulletin 53* (BoM, 2003). A copy of the data extracted from the *ARR Data Hub* for the study area is contained in **Appendix C**.

4.2.4. Probable Maximum Precipitation

Estimates of Probable Maximum Precipitation (**PMP**) were made using the Generalised Short Duration Method as described in the BoM, 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 3 hours.

The steps involved in assessing PMP for the four urban centres are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.
- Factor the PMP estimate up by 20% to reflect conditions that are representative of the year 2030 and an SSP 2-4.5.
- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data but modified in the light of Australian experience.[23]
- Derive storm hyetographs using the eleven temporal distributions contained in BoM, 2003, and Jordan et. al., 2005 which are based on pluviographic traces recorded in major Australian storms.

[22] It is noted that the temporal pattern data set for the *Murray-Darling Basin* region is suitable for use at the four urban centres.

[23] Due to the relatively small size of the four urban centres, point PMP rainfall was adopted for the purpose of the present study.

4.2.5. Design Rainfall Losses

The initial and continuing loss values to be applied in design flood estimation were derived from the NSW jurisdictional specific procedures set out in the *ARR Data Hub*.

The raw Probability Neutral Burst Initial Loss values obtained from the *ARR Data Hub* were reviewed and adjusted to remove inconsistencies in values with varying storm probability and durations. **Figure 4.4** shows the original Probability Neutral Burst Initial Loss curves derived from the tables obtained from the *ARR Data Hub*, together with the adopted Probability Neutral Burst Initial Loss curves following the adjustments that were made for the purpose of the present study, noting that these losses were adjusted to reflect SSP2-4.5 Year 2030 conditions based on the values set out in the *ARR Data Hub*.

As the *ARR Data Hub* does not contain a continuing loss rate for the study area, a value of 2.7 mm/hr has been adopted based on the value recommended in Walsh et. al., 1991 (i.e. 2.5 mm/hr) which was then adjusted to reflect SSP2-4.5 Year 2030 conditions based on the values set out in the *ARR Data Hub*.

TABLE 4.1
DATA USED TO DERIVE DESIGN DISCHARGE HYDROGRAPHS
UPSTREAM BOUNDARY OF MURRAY AND DARLING RIVER TUFLOW MODEL

Design Flood Event	Representative Discharge Hydrograph	Euston Stream Gauge		Burtundy Stream Gauge		Bulpunga Stream Gauge	
		Design Peak Flow (m^3/s)	Multiplication Factor	Design Peak Flow (m^3/s)	Multiplication Factor	Design Peak Flow (m^3/s)	Multiplication Factor
Extreme	1956 Flood	11,640	3.33	2,595	3.12	1,812	2.56
0.2% AEP		6,100	1.75	1,650	1.78	1,301	1.84
0.5% AEP		4,620	1.32	1,130	1.30	840	1.19
1% AEP		3,880	1.11	865	1.04	604	0.85
2% AEP		3,170	0.91	650	1.55	414	0.58
5% AEP	2022 Flood	2,300	0.97	435	1.08	223	1.83
10% AEP		1,680	0.71	305	1.00	108	0.89
20% AEP		1,120	0.47	200	0.67	15	0.12

5 HYDRAULIC MODELLING OF DESIGN FLOOD EVENTS

5.1 Hydraulic Model Structure

As per the requirements of ARR 2019, the potential for the existing drainage system to experience a partial blockage during a flood event was taken into account when deriving the design flood envelopes. **Tables D1**, **D2** and **D3** in **Appendix D** provide a summary of the blockage factors that were derived for each individual headwall structure in the Gol Gol and Buronga, Dareton and Wentworth TUFLOW Models, respectively based on the procedures set out in ARR 2019. As per the recommendations in ARR 2019, an L_{10}[24] of 1.5 m was adopted for the blockage assessment, which is the recommended minimum value that should be adopted for urban areas in the absence of a record of past debris accumulated at the structure. Blockage factors of 20% and 50% were applied to on-grade and sag stormwater inlet pits, respectively.

Blockage factors were not applied to the bridges in the Murray and Darling River TUFLOW Model as there is no record of the bridges experiencing a blockage as a result of the build-up of woody debris.

5.2 Critical Duration and Temporal Patterns

The critical storm durations and associated median temporal patterns for the design storm events were derived based on the results of running a coarse version of the urban centre TUFLOW models.[25] For example, design discharge hydrographs for the ensemble of temporal patterns for storm durations ranging between 15 minutes and 7 days were run through the coarse TUFLOW models. The assessment was undertaken for the 20%, 5% and 1% AEP storm events which represent the three temporal pattern bins (i.e. frequent, infrequent and rare, respectively) that were downloaded from the *ARR Data Hub.*

A similar process was adopted for determining the critical durations for the PMF using the procedures set out in BoM, 2003 and Jordan et al., 2005, whereby design discharge hydrographs for storm durations ranging between 15 minutes and 3 hours were run through the coarse TUFLOW models. **Table 5.1** over the page sets out the storm durations and temporal patterns that were adopted as being critical for AEPs ranging from 20% and 0.2%, as well as the PMF.

5.3 Presentation of Results

5.3.1. Accuracy of Hydraulic Modelling

The accuracy of results depends on the precision of the numerical finite difference procedure used to solve the partial differential equations of flow, which is also influenced by the time step used for routing the floodwave through the system and the grid spacing adopted for describing the natural surface levels in the floodplain. Channels are described by cross-sections normal to the direction of flow, so their spacing also has a bearing on the accuracy of the results. The results are also heavily dependent on the size of the two-dimensional grid, as well as the accuracy of the LiDAR survey data which has a design accuracy based on 95% of points within +/- 150 mm. Given the uncertainties in the LiDAR survey data and the definition of features affecting the passage of flow,

[24] L_{10} is defined as the average length of the longest 10% of the debris reaching the site.
[25] In order to reduce model runs times, the coarse version of the urban centre TUFLOW models incorporates a 12 m cell sizes. It also omits buildings to prevent the artificial blocking of overland flow paths.

maintenance of a depth of flow of at least 200 mm is required for the definition of a "continuous" flow path in the areas subject to shallow overland flow. Lesser modelled depths of inundation may be influenced by the above factors and therefore may be spurious, especially where that inundation occurs at isolated locations and is not part of a continuous flow path. In areas where the depth of inundation is greater than the 200 mm threshold and the flow path is continuous, the likely accuracy of the hydraulic modelling in deriving peak flood levels is considered to be between 100 and 150 mm.

Use of the flood study results when applying flood related controls to development proposals should be undertaken with the above limitations in mind. Proposals should be assessed with the benefit of a site survey to be supplied by applicants in order to allow any inconsistencies in results to be identified and given consideration. This comment is especially appropriate in the areas subject to shallow overland flow, where the inaccuracies in the LiDAR survey data or obstructions to flow would have a proportionally greater influence on the computed water surface levels than in the deeper flooded areas.

The aim of the present study is to define flood behaviour on the NSW (northern) side of the Murray River in the immediate vicinity of the four urban centres. While the Murray and Darling River TUFLOW Model covers a 420 km reach of the Murray River, it is only suitable for use in defining flood behaviour on the northern side of the river between Trentham Cliffs and a location approximately 10 km upstream (east) of Lock 9, the reasons for this being:

a) localised features on the Victorian (southern) side of the river and on the Murray River floodplain upstream of Trentham Cliff which influence flood behaviour may not be incorporated in the model; and

b) it was found during the calibration process that the model did not necessarily reproduce peak flood levels that were recorded at the Locks 7 ,8 and 9 on the Murray River, principally due to downstream model boundary effects.

That said, in order to demonstrate how floodwater interacts with different parts of the floodplain in the vicinity of the study area, flood mapping has been prepared for the full modelled reach of the Murray and Darling rivers.[26]

5.3.2. Design Flood Mapping

The following sets of figures showing the results of the TUFLOW modelling for design flood events ranging between 20% and 0.2% AEP, as well as the Extreme Flood (in the case of Murray and Darling River flooding) and the PMF (in the case of local catchment flooding) are contained in **Volume 2** of this report:

- **Figures 5.1** to **5.18**, which show the flood behaviour resulting from Murray and Darling River flooding in the vicinity of the four urban centres;
- **Figures E1.1** to **E1.16** in **Appendix E**, which show the flood behaviour resulting from local catchment flooding at Gol Gol and Buronga;
- **Figures F1.1** to **F1.16** in **Appendix F**, which show the flood behaviour resulting from local catchment flooding at Dareton; and
- **Figures G1.1** to **G1.16** in **Appendix G**, which show the flood behaviour resulting from local catchment flooding at Wentworth.

[26] Note that the mapping of flood function, Flood Emergency Response Classifications and Flood Planning Constraint Categories is limited to the immediate vicinity of the four urban centres.

TABLE 5.1
CRITICAL DURATIONS AND TEMPORAL PATTERNS

Design Storm Event	Temporal Pattern Bin	Critical Storm Duration and Temporal Pattern[1]		
		Buronga and Gol Gol	**Dareton**	**Wentworth**
20%	Frequent	30 minute, Storm Burst 8 [3838] 2 hour, Storm Burst 2 [3950] 24 hour, Storm Burst 5 [4154] 168 hour, Storm Burst 5 [4348]	3 hour, Storm Burst 8 [3987] 4.5 hour, Storm Burst 4 [4014] 12 hour, Storm Burst 2 [4093]	1.5 hour, Storm Burst 5 [3924] 3 hour, Storm Burst 4 [3983] 12 hour, Storm Burst 2 [4093]
10% 5%	Intermediate	1 hour, Storm Burst 1 [3879] 6 hour, Storm Burst 5 [4037] 24 hour, Storm Burst 5 [4141] 168 hour, Storm Burst 4 [2868]	1 hour, Storm Burst 7 [3885] 2 hour, Storm Burst 2 [3901] 3 hour, Storm Burst 7 [3975] 9 hour, Storm Burst 10 [4067]	1 hour, Storm Burst 7 [3885] 1.5 hour, Storm Burst 8 [3915] 2 hour, Storm Burst 6 [3944] 9 hour, Storm Burst 8 [4065]
2% 1% 0.5% 0.2%	Rare	30 minute, Storm Burst 6 [3815] 1 hour, Storm Burst 3 [3847] 6 hour, Storm Burst 2 [3862] 12 hour, Storm Burst 7 [4036] 168 hour, Storm Burst 3 [2736]	0.5 hour, Storm Burst 6 [3815] 1 hour, Storm Burst 3 [3847] 3 hour, Storm Burst 9 [3964] 6 hour, Storm Burst 7 [4039] 9 hour, Storm Burst 7 [4054]	0.5 hour, Storm Burst 6 [3815] 1 hour, Storm Burst 6 [3873] 1.5 hour, Storm Burst 3 [3890] 6 hour, Storm Burst 1 [3802]
PMF	Extreme	3 hour, Broome 1997 temporal pattern 15 minute, Melbourne 1972 temporal pattern 45 minute, Melbourne 1972 temporal pattern 2 hour, Melbourne 1972 temporal pattern 3 hour, Melbourne 1972 temporal pattern	0.25 hour, Melbourne 1972 temporal pattern 0.75 hour, Broome 1997 temporal pattern 1 hour, Seventeen Mile Ck1998 temporal pattern 2 hour, Alice Springs 1966 temporal pattern 3 hour, Alice Springs 1966 temporal pattern	0.25 hour, Melbourne 1972 temporal pattern 0.5 hour, Melbourne 1972 temporal pattern 0.75 hour, Melbourne 1972 temporal pattern 1 hour, Melbourne 1972 temporal pattern

2. Value in [ ] represent the Event ID for the critical storm duration and temporal pattern

In order to create realistic results which remove most of the anomalies caused by inaccuracies in the LiDAR survey data, a filter was applied to remove depths of inundation over the natural surface less than 100 mm (refer below for further discussion). This has the effect of removing the very shallow depths which are more prone to be artefacts of the model, but at the same time giving a reasonable representation of the various overland flow paths. The depth grids shown on the figures have also been trimmed to the building polygons, as experience has shown that property owners incorrectly associate depths of above-ground inundation at the location of buildings with depths of above-floor inundation.

5.4 Description of Flood Behaviour

5.4.1. Murray and Darling River Flooding

Table 5.2 over the page sets out the design peak flood levels at key locations along the Murray River for the range of assessed design flood events, while the plan location of the peak flood level points is shown on **Figures 5.1** to **5.8** (6 sheets each). **Figure 5.9** (5 sheets) shows design water surface profiles along the Murray and Darling rivers, as well as the Great Darling Anabranch, while **Figure 5.10** (3 sheets each) shows the water surface profiles along the alignment of the Wentworth town and Curlwaa levees.

The key features of Murray River Flooding at the urban centres of Gol Gol and Buronga (refer sheet 3 in the series) are as follows:

i. **Figure 5.1** shows that floodwater is generally contained within the inbank area of the Murray River in a 20% AEP flood, except in the vicinity of Alcheringa Oval where floodwater surcharges its right (northern) bank where it inundates land that lies between the river and an existing levee that runs along the southern side of the oval.

ii. **Figure 5.2** shows that floodwater surcharges the right (northern) bank of the river in a 10% AEP flood and inundates low lying areas in the vicinity of Gol Gol Creek, residential allotments on the southern side of Carramar Drive, residential allotments that are located approximately 550 m to the west of Alcheringa Oval and parkland areas. **Figure 5.2** also shows that floodwater surcharges the right (northern) bank of the river and inundates the Buronga Riverside Caravan Park in a 10% AEP flood.

iii. While **Table 5.2** shows that peak 5% AEP flood levels along the Murray River at Gol Gol and Buronga are about 0.8-1.0 m higher than peak 10% AEP flood levels, **Figure 5.3** shows that the extent of inundation does not increase significantly.

iv. **Figure 5.4** shows that floodwater commences to surcharge Punt Road and Carramar Drive and the existing levees that are located to their west in a 2% AEP flood. Floodwater that surcharges the river at this location inundates existing allotments that are located between the highway and the river. It also backwaters across Hendy Road between Dawn Avenue and Midway Drive. **Figure 5.4** also shows that floodwater overtops existing levees that are located along the right (northern) bank of the river downstream of the Sturt Highway in a 2% AEP flood where it inundates land that lies between the river and River Drive/Silver City Highway.

v. While **Table 5.2** shows that peak 1% AEP flood levels along the Murray River at Gol Gol and Buronga are about 0.85-1.0 m higher than peak 2% AEP flood levels, **Figure 5.5** shows that the extent of inundation does not increase significantly.

TABLE 5.2
COMPARISON OF DESIGN PEAK FLOOD LEVELS AT THE FOUR URBAN CENTRES
MURRAY AND DARLING RIVER FLOODING

Peak Flood Level Location Identifier[1]	Watercourse	Urban Centre	Location	Peak Flood Level (m AHD)							
				20% AEP	10% AEP	5% AEP	2%AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood
H01	Murray River	Gol Gol	Knights Road	36.81	38.55	39.46	40.16	40.59	41.00	41.67	43.28
H02			Confluence with Gol Gol Creek	36.66	38.38	39.31	40.02	40.46	40.87	41.53	43.09
H03			King Street	36.59	38.30	39.25	39.98	40.42	40.84	41.52	43.10
H04			End of Punt Road	36.50	38.18	39.08	39.81	40.26	40.68	41.38	42.97
H05		Buronga	Alcheringa Oval	36.43	38.10	39.00	39.72	40.17	40.59	41.29	42.87
H06			Carbone Court	36.24	37.88	38.86	39.61	40.05	40.48	41.19	42.74
H07			George Chaffey Bridge	36.09	37.69	38.65	39.37	39.77	40.16	40.86	42.55
H08			Upstream of Mildura Weir	36.01	37.59	38.54	39.21	39.58	39.94	40.60	42.32
H09			Western end of Pitman Avenue	35.85	37.39	38.25	38.89	39.26	39.61	40.30	42.06
H10			1.4 km Downstream of Pitman Avenue	35.79	37.31	38.16	38.80	39.17	39.51	40.20	41.96
H11		Dareton	0.3 km upstream of Intersection of Kookaburra Road and Golf Course Road	33.88	35.22	36.09	36.81	37.25	37.60	38.17	39.53
H12			Intersection of Kookaburra Road and Golf Course Road	33.85	35.18	36.05	36.78	37.22	37.56	38.12	39.46
H13			Adjacent to Coomealla Golf Club	33.80	35.13	36.00	36.74	37.18	37.53	38.09	39.43

Refer over for footnotes to table.

TABLE 5.2 (Cont'd)
COMPARISON OF DESIGN PEAK FLOOD LEVELS AT THE FOUR URBAN CENTRES
MURRAY AND DARLING RIVER FLOODING

Peak Flood Level Location Identifier[1]	Watercourse	Urban Centre	Location	Peak Flood Level (m AHD)							
				20% AEP	10% AEP	5% AEP	2%AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood
H14	Murray River	Wentworth	Lock 10	32.45	33.51	34.17	34.52	34.69	34.81	35.06	35.77
H15	Darling River		550m Upstream of end of Perry Street	32.62	33.75	34.50	34.87	35.06	35.22	35.49	36.10
H16			End of Perry Street	32.61	33.74	34.49	34.87	35.06	35.22	35.49	36.12
H17			End of Francis Street	32.61	33.73	34.48	34.86	35.06	35.22	35.49	36.14
H18			Upstream of Silver City Highway Bridge - Darling River	32.60	33.73	34.47	34.86	35.06	35.22	35.49	36.14
H19			End of Short Street	32.57	33.67	34.39	34.79	34.98	35.13	35.39	36.06
H20			End of Alice Street	32.55	33.63	34.33	34.71	34.89	35.03	35.28	35.95
H21	Tuckers Creek		Adjacent to Wentworth Showgrounds	32.65	33.80	34.54	34.91	35.09	35.25	35.58	36.32
H22			Upstream of Silver City Highway - Tuckers Creek	32.61	33.74	34.48	34.87	35.06	35.22	35.51	36.18
H23	Theago Lagoon		End of West Street	32.35	33.34	33.93	34.26	34.42	34.54	34.83	35.72
H24			770m Downstream of end of West Street	32.34	33.34	33.93	34.26	34.42	34.54	34.83	35.72

1. Refer **Figures 5.1** to **5.8** for location of Peak Flood Levels Location.

vi. **Figure 5.6** shows that floodwater commences to surcharge Adelaide Street immediately to the west of the Gol Gol Creek Regulator in a 0.5% AEP flood. While floodwater that surcharges the river at this location discharges to Gol Gol Creek, it does not fill the Lake Gol Gol system that lies further to the north. **Figure 5.6** also shows that floodwater commences to surcharge the Silver City Highway between its intersections with Corbett Avenue and Arumpo Road in a 0.5% AEP flood, inundating the industrial allotments along Modica Crescent to depth of up to about 0.9 m.

vii. **Figure 5.6** shows that road access to the townships of Gol Gol and Buronga will become cut in a 0.5% AEP.

viii. **Figure 5.7** shows that the volume of floodwater that surcharges the river into the Lake Gol Gol system increases significantly in a 0.2% AEP flood and as a result, causes a level pool that backs up on the upstream (eastern) side of the Silver City Highway.

ix. **Figure 5.7** shows that floodwater that overtops Adelaide Street in the vicinity of the Gol Gol Creek Regulator in a 0.2% AEP flood inundates existing residential allotments in Adelaide Street, Alderton Drive, Allen Court, Fiona Drive, Gol Gol North Road, John Street, King Street, Kingfisher Road, Modikerr Way, Tapio Street, Wilga Road South, William Street and Wood Street.

x. **Figure 5.7** shows that floodwater commences to overtop the Hendy Road between Midway Drive and Melaleuca Street in a 0.2% AEP flood where it inundates existing development that is located in the vicinity of the intersection of Midway Drive and Pitman Avenue.

xi. **Table 5.2** shows that Extreme Flood levels along the Murray River are about 2.2-2.8 m higher than corresponding peak 1% AEP flood levels. **Figure 5.8** shows that the Extreme Flood will inundate existing development at Buronga and Gol Gol to depths in excess of 3.5 m.

The key features of Murray River Flooding at the urban centre of Dareton (refer sheet 5 in the series) are as follows:

i. **Figure 5.2** shows that floodwater commences to surcharge the levee that runs along the southern side of the Coomealla Golf Course in a 10% AEP flood.

ii. **Figure 5.3** shows that floodwater inundates Kookaburra Drive and Golf Course Road to the north and east of their intersection in a 5% AEP flood.

iii. **Figure 5.5** shows the floodwater commences to inundate the rear of the residential allotments that are located on the southern side of Riverview Drive in a 1% AEP flood.

iv. **Figure 5.8** shows that existing development in Dareton generally remains flood free in the Extreme Flood.

The key features of Murray River Flooding in the vicinity of the Curlwaa Irrigation Area (refer sheet 6 of relevant figures) are as follows:

i. **Figures 5.4** and **5.10**, sheet 3 show that the Curlwaa Levee is overtopped in a 2% AEP flood at the location of an existing low point on Williamsville Road (levee chainage 330 m), the Silver City Highway (levee chainages 1,400 m, 2,430 m an 8,000 m) and at a gap in the levee that is located approximately 200 m to the north of the Silver City Highway bridge crossing of Tuckers Creek (levee chainage 17,810 m).

ii. **Figures 5.5** and **5.10**, sheet 3 show that the Curlwaa Levee is overtopped at an additional four locations in a 1% AEP flood, and as a result, the land behind the levee is almost entirely inundated by floodwater.

iii. **Figure 5.8** shows the land behind the Curlwaa Levee is inundated to depth of 1.5 m or greater in an Extreme Flood.

The key features of Murray and Darling River Flooding at the urban centre of Wentworth (refer sheet 6 in the series) are as follows:

i. **Figure 5.1** shows that floodwater is generally contained within the banks of the Murray and Darling rivers in the vicinity of Wentworth in a 20% AEP flood, except downstream of Lock 10 where a backwater extends across Logbridge Road into Theoga Lagoon.

ii. **Figure 5.2** shows that floodwater surcharges the right (western) bank of the Darling River in a 10% AEP flood where it inundates the rear of residential allotments that are located on the eastern side of Adams Street. **Figure 5.2** also shows that floodwater that backwaters into Theoga Lagoon during a 10% AEP flood inundates the rear of existing residential allotments that are located on the western side of Adams Street.

iii. **Figure 5.3** shows that floodwater surcharges the right (western) bank of the Darling River to the north of Sheok Lane in a 5% AEP flood where it then flows in a southerly direction on the eastern and western sides of the Wentworth Aerodrome. Road access to the aerodrome is also cut in a flood of this magnitude.

iv. **Figure 5.3** shows that road access to the north of Wentworth is cut in a 5% AEP flood

v. **Figure 5.3** shows that floodwater that surcharges the left (eastern) bank of the Darling River to the north of the urban centre in a 5% AEP flood will inundate existing residential allotments that are located outside of the Eastern Levee along Wentworth Street.

vi. **Figure 5.3** shows that the Old Wentworth Road will be cut by floodwater in a 5% AEP flood.

vii. **Figure 5.4** shows that Wentworth will become isolated in a 2% AEP flood as the Silver City Highway is inundated where it runs between Tuckers Creek and the Curlwaa Levee.

viii. **Figures 5.7** and **5.10** show that the Eastern and Western Levees are overtopped in a 0.2% AEP flood, resulting in maximum depths of inundation in existing development of about 1.8 m and 2.8 m, respectively.

ix. **Figure 5.8** shows that the land internal to the Eastern and Western Levees will be inundated in an Extreme Flood to maximum depths of about 2.5 m and 3.5 m, respectively.

Table 5.3 over the page sets out the minimum freeboard that is available to the crest of the existing Wentworth town and Curlwaa levees at the location of existing low points. The key features of Murray and Darling River flooding as it relates to the existing Wentworth town and Curlwaa levees are as follows:

Western Levee

- Flood levels will exceed the Imminent Failure Flood (**IFF**)[27] level of the Western Levee in the vicinity of the section of concrete wall that is located behind No. 5-7 Perry Street (refer levee chainage 3,750 m) in a 5% AEP flood.
- Floodwater will surcharge the Western Levee at the abovementioned location in a 0.2% AEP flood.

Eastern Levee

- Flood levels exceed the IFF level of the Eastern Levee along the Silver City Highway (levee chainage 2,380 m) in a 5% AEP flood.
- Floodwater will surcharge the Eastern Levee at the abovementioned location in a 0.2% AEP flood.

[27] The IFF is the flood which would compromise the 1 m freeboard provision in the levee design. The prediction of a flood higher than the IFF would trigger the evacuation of the protected area, as NSW SES would deem the levee to be at risk of failure.

TABLE 5.3
MINIMUM AVAILABLE FREEBOARD TO CREST OF EXISTING LEVEES(1,2,3)

Levee	Levee Chainage	Location	Available Freeboard (m)							
			20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood
Western	3750	Perry Street	2.76	1.63	0.89	0.51	0.32	0.16	-0.11	-0.73
	121	Burns Street	2.95	1.82	1.08	0.69	0.50	0.34	0.07	-0.57
	4300	Neville Street	3.04	1.91	1.17	0.78	0.59	0.43	0.16	-0.48
	4520	Francis Street	3.00	1.88	1.13	0.75	0.55	0.39	0.12	-0.53
	4690		2.99	1.87	1.12	0.74	0.54	0.38	0.11	-0.54
	4940		3.10	1.98	1.24	0.85	0.65	0.49	0.22	-0.43
	5170	70 m north of Armstrong Avenue Bridge	2.97	1.84	1.10	0.71	0.51	0.35	0.08	-0.57
Eastern	2380	Silver City Highway	-	1.62	0.88	0.49	0.29	0.13	-0.14	-0.80
Hospital	320		3.13	2.01	1.27	0.87	0.67	0.52	0.25	-0.41
Curlwaa	0	Williamsville Road	2.91	1.60	0.74	0.06	-0.32	-0.60	-1.04	-2.22
	330		2.31	1.00	0.15	-0.52	-0.89	-1.16	-1.57	-2.66
	1400	Silver City Highway	2.20	0.94	0.13	-0.46	-0.75	-0.95	-1.24	-2.12
	2430	Silver City Highway	2.54	1.29	0.51	-0.04	-0.30	-0.49	-0.75	-1.48
	5000		2.70	1.40	0.69	0.10	-0.09	-0.21	-0.42	-1.05
	5630		2.73	1.56	0.85	0.40	0.17	0.01	-0.22	-0.84
	8000	Silver City Highway	-	-	0.42	-0.02	-0.26	-0.44	-0.75	-1.45
	8630	Delta Road	-	1.00	0.26	-0.08	-0.35	-0.49	-0.81	-1.53
	10860	Private Property	2.44	1.24	0.51	0.15	-0.02	-0.17	-0.50	-1.33
	17810	200 m north of Silver City Highway	2.72	1.20	0.16	-0.61	-0.98	-1.25	-1.51	-2.12

1. Crest levels taken from crest level survey undertaken by PWA in 2017, except for the Curlwaa Levee which was taken from LiDAR survey data.
2. A negative value represents the maximum depth to which the crest of the existing levee would be overtopped in the absence of any wind or wave action.
3. Green cells indicate that the peak flood level is lower than the IFF level, yellow cells indicate that the peak flood level is above the IFF level but below the levee crest and red cells indicate that the peak flood level is above the elevation of the levee crest (i.e. the levee is overtopped).

Hospital Levee

- Flood levels exceed the IFF level of the Hospital Levee at a low point that is located on the western side of the hospital (levee chainage 320 m) in a 2% AEP flood.
- Floodwater will surcharge the Hospital Levee along its entire length in an Extreme Flood.

Curlwaa Levee

- Flood levels exceed the IFF level of the Curlwaa Levee at the western end of the earth embankment that runs along the southern side of the Silver City Highway adjacent to its intersection with Abbotsford Road (levee chainage 1,400 m) in a 10% AEP flood.
- Floodwater will surcharge the Curlwaa Levee in a 2% AEP flood at the following locations:
  - Williamsville Road (levee chainage 330 m);
  - the Silver City Highway adjacent to its intersection with Abbotsford Road (levee chainages 1,400 m);
  - the low point in the Silver City Highway that is located approximately 180 m to the east of its intersection with Manly Road (levee chainages 2,430 m);
  - at the western Silver City Highway crossing of the levee (levee chainages 8,000 m); and
  - at a gap in the levee that is located about 200 m to the north of the Silver City Highway bridge crossing of Tuckers Creek (levee chainage 17,810 m).

While the 1956 flood has historically been considered to be equivalent to a design flood with an AEP of 1% in both peak flow and flood level terms, the results of the Murray and Darling Rivers TUFLOW Model show that while the peak flow in the Murray River was slightly less than a 1% AEP flood, **Figure 5.10** (3 sheets) shows that the peak flood levels that were experienced at the time of the 1956 flood are now generally equivalent to a design flood with an AEP of only about 2%. This is due to more changes in the floodplain topography and hydraulic roughness which have resulted in higher peak flood levels on the Murray and Darling River floodplains for a given rate of flow.

5.4.2. Local Catchment Flooding

Figures E1.1 to **E1.8** (3 sheets each) in **Appendix E** show the indicative extent and depth of inundation resulting from local catchment flooding at Gol Gol and Buronga for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP floods, as well as the PMF.

The key features of local catchment flooding at the urban centres of Gol Gol and Buronga are as follows:

i. Due to the flat nature of the topography, local catchment flooding is generally typified by floodwater that ponds in the natural low-lying parts of the urban areas.

ii. **Figure E1.3** shows that the depth of inundation will exceed 300 mm in the following naturally occurring trapped low points in a 5% AEP storm:
  - in the large allotments that are located between Hendy Road and the Murray River to the west of Alcheringa Oval;
  - in allotments that are located adjacent to the low point in Midway Drive to the south Pitman Avenue;
  - in the allotments that are bounded by King Street to the west, William Street to the north, Tapio Street to the east and Adelaide Street to the south; and

- in the allotments that are bounded by Wood Street to the north, Burns Street to the east, William Street to the south and Taipo Street to the west.

iii. **Figure E1.5** shows that in addition to the abovementioned naturally occurring trapped low points, the depth of inundation will exceed 300 mm in a 1% AEP storm at the following locations:

  - in allotments that are located on the southern side of Moontongue Drive to the east of its intersection with Kari Drive;
  - in allotments that are located on the northern side of Crane Drive to the east of its intersection with Tower Court; and
  - in industrial allotments that are located in the vicinity of Grace Crescent.

iv. **Figure E1.8** shows that the maximum depth of inundation in the abovementioned low points increases to between 0.7 to 1.2 m in a PMF event.

Figures F1.1 to **F1.8** (2 sheets each) in **Appendix F** show the indicative extent and depth of inundation resulting from local catchment flooding at Dareton for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP floods, as well as the PMF. The key features of local catchment flooding at the urban centre of Dareton are as follows:

i. Local catchment runoff generally concentrates along the following two drainage lines:

  - a flow path that runs in a south-westerly direction through rural land between the intersection of the Silver City Highway and Pump Station Road, and the Murray River on the southern side of Golf Course Road; and
  - a flow path that runs in a north-westerly direction from the intersection of Avoca Street and Oleander Drive towards the intersection of Bogabilla Road and Jacarandra Road.

ii. **Figures F1.1** to **F1.5** show that existing development is generally unaffected by local catchment flooding during storms up to 2% AEP in intensity.

iii. **Figure F1.6** shows the local catchment runoff would pond in existing allotments in a 1% AEP storm at the following locations:

  - on the western side of Oleander Drive in the vicinity of its intersection with Avoca Street;
  - on the eastern side of Hawson Street to the south of its intersection with the Silver City Highway; and
  - in industrial allotments that are located between Pump Station Road and Tallawalla Road to the north of the latter's intersection with Scout Road.

Figures G1.1 to **G1.8** (2 sheets each) in **Appendix G** show the indicative extent and depth of inundation resulting from local catchment flooding at Wentworth for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP floods, as well as the PMF. These diagrams assume the absence of coincident flooding in the Murray and Darling rivers meaning that the pipes through the Wentworth town levees are free draining.

The key features of local catchment flooding at the urban centre of Wentworth are as follows:

i. The pipes that extend through the Wentworth town levees generally have sufficient capacity to prevent major flooding from occurring in existing development.

ii. **Figure G6.5** shows that while the depth of inundation would generally not exceed 300 mm in the urbanised parts of Wentworth during a 1% AEP storm, greater depths of inundation would be experienced at the following locations:

Eastern side of the Darling River

- on the eastern side of Wentworth Street to the south of its intersection with Emily Street; and
- on the eastern side of Wentworth Street to the north of its intersection with Armstrong Avenue.

Western side of the Darling River

- between Adams Street and Darling Street to the south of Perry Street;
- on the western side of the Western Levee between Perry Street and Burns Street;
- on the southern side of Neville Street west of its intersection with Darling Street;
- on the western side of Darling Street to the north of its intersection with Helana Street;
- on the northern side of the levee between Adams Street and Darling Street; and
- between Murray Street and Cadell Street to the west of Alice Street.

iii. **Figure G6.8** shows that a significant portion of the urban centre of Wentworth would be inundated to depths greater than 300 mm in a PMF event.

5.5 Economic Impacts of Flooding

The economic consequences of floods are discussed in **Appendix H** of this report, which assessed flood damages to residential, commercial/industrial and publicly owned properties in areas that are affected by both Murray and Darling River Flooding and Local Catchment Flooding in the study area. The assessment relied on the procedures set out in *Flood Risk Management Guideline MM01 – Flood Risk Management Measures* (DPE, 2023) and the associated *NSW Flood Risk Management Tool DT01* to estimate both the tangible and intangible damages resulting from flooding in the study area.

Table 5.4 over the page sets out the number of properties that are flood affected (i.e. floodwater on the allotment), as well as the number of buildings that would be above-floor inundated during floods on the Murray and Darling rivers of between 20% AEP and the Extreme Flood. **Table 5.5** sets out the corresponding total flood damages that would be incurred in the four urban centres as a result of local catchment flooding.

Figures H7.1, **H7.2** and **H7.3** in **Appendix H** show the location and AEP at which individual dwellings/buildings first become above-floor inundated as a result of Murray and Darling River flooding at the urban centres of Gol Gol/Buronga, Dareton and Wentworth, respectively, while **Figures H7.4**, **H7.5** and **H7.6** show similar information relating to local catchment flooding.

While flood damages resulting from Murray and Darling River flooding are greatest at the urban centres of Gol Gol and Buronga for floods less than 0.2% AEP in magnitude, significant flood damages are experienced at Wentworth during a flood of this magnitude due to the overtopping of the Wentworth town levees. Flood damages resulting from Murray and Darling River flooding at Dareton are negligible over the full range of potential flood events.

Flood damages resulting from local catchment flooding are similarly greater at Gol Gol and Buronga when compared to those at Dareton and Wentworth.

A detailed description of the flood damages that would be incurred to existing dwellings, as well as commercial/industrial and public buildings that are located in the four urban centres is set out in **Sections H4.2**, **H5.2** and **H5.3** of **Appendix H**.

TABLE 5.4
SUMMARY OF FLOOD DAMAGES
MURRAY AND DARLING RIVER FLOODING

Urban Centre	Design Flood Event (% AEP)	Number of Properties						Total Damage ($ Million)
		Residential		Commercial/ Industrial		Public		
		Flood Affected	Flood Above Floor Level	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Above Floor Level	
Gol Gol	20	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0
	2	17	10	14	13	0	0	13.1
	1	37	22	15	15	0	0	20.2
	0.5	127	61	20	15	5	2	32.2
	0.2	224	207	21	21	12	10	83.1
	Extreme	434	412	26	25	12	12	190.6
Buronga	20	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0
	5	6	3	0	0	0	0	0.7
	2	31	29	1	1	0	0	8.6
	1	43	40	6	3	0	0	13.2
	0.5	57	45	28	12	0	0	19.5
	0.2	84	74	53	49	1	1	66.9
	Extreme	137	134	62	60	4	4	146.8
Dareton	20	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0
	0.5	0	0	0	0	0	0	0
	0.2	0	0	0	0	0	0	0
	Extreme	1	1	0	0	0	0	0.1
Wentworth	20	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0
	5	4	2	0	0	0	0	0.4
	2	10	4	0	0	0	0	1
	1	14	9	0	0	0	0	1.8
	0.5	19	12	0	0	0	0	2.7
	0.2	567	553	50	48	17	17	185.3
	Extreme	594	592	50	50	23	23	256.7

TABLE 5.5
SUMMARY OF FLOOD DAMAGES
LOCAL CATCHMENT FLOODING

Urban Centre	Design Flood Event (% AEP)	Number of Properties						Total Damage ($ Million)
		Residential		Commercial/ Industrial		Public		
		Flood Affected	Flood Above Floor Level	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Above Floor Level	
Gol Gol	20	6	1	0	0	0	0	0
	10	14	1	1	0	0	0	0.3
	5	23	1	2	0	0	0	0.4
	2	31	2	2	0	1	0	0.4
	1	50	3	3	0	1	0	0.8
	0.5	69	7	4	0	1	0	1.3
	0.2	86	10	4	0	1	0	1.8
	PMF	322	112	18	5	7	2	25.1
Buronga	20	0	0	1	0	0	0	0
	10	2	0	4	0	0	0	0
	5	6	0	7	1	1	0	0
	2	10	0	8	1	1	0	0.2
	1	27	2	10	1	1	1	0.4
	0.5	41	4	14	1	1	1	0.8
	0.2	49	11	16	1	1	1	1.4
	PMF	179	71	41	18	5	1	20
Dareton	20	1	0	0	0	0	0	0
	10	4	0	0	0	0	0	0
	5	6	0	0	0	0	0	0
	2	11	0	0	0	0	0	0.1
	1	16	0	0	0	1	0	0.1
	0.5	19	0	1	0	1	0	0.1
	0.2	25	1	1	0	1	0	0.1
	PMF	109	21	7	2	4	0	4.9
Wentworth	20	8	0	0	0	0	0	0
	10	9	0	0	0	0	0	0
	5	18	0	0	0	0	0	0.1
	2	33	1	2	0	0	0	0.2
	1	54	2	2	0	1	0	0.6
	0.5	68	5	2	0	2	0	0.6
	0.2	89	7	2	0	3	0	1.4
	PMF	414	218	25	7	9	5	45

The Net Present Value (NPV) of damages likely to be experienced at the four urban centres for all floods up to floods of 5% and 1% AEP in magnitude for a 30 year economic life and a discount rate of 5 per cent are set out in **Table 5.6**. One or more flood mitigation schemes costing up to these amounts could be economically justified if they eliminated damages in each urban centre up to the 1% AEP flood event. While schemes costing more than these values would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility

TABLE 5.6
NET PRESENT VALUE OF DAMAGES AT FOUR URBAN CENTRES(1)
$ MILLION

Flood Mechanism	Urban Centre	All Floods up to 5% AEP	All Floods up to 1% AEP
Murray and Darling River Flooding	Gol Gol	0	5.8
	Buronga	0.3	4.6
	Dareton	0	0
	Wentworth	0.2	0.8
Local Catchment Flooding	Gol Gol	1.0	1.3
	Buronga	0	0.1
	Dareton	0.1	0.1
	Wentworth	0.3	0.4

5.6 Flood Hazard Zones and Floodways

5.6.1. Flood Hazard Vulnerability Classification

Flood hazard categories may be assigned to flood affected areas in accordance with the definitions contained in ARR 2019. Flood prone areas may be classified into six hazard categories based on the depth of inundation and flow velocity that relate to the vulnerability of the community when interacting with floodwater as shown in the illustration over the page which has been taken from ARR 2019.

Hazard Vulnerability Classification diagrams for the 5%, 1% and 0.2% AEP Murray and Darling River floods, as well as the Extreme Flood are presented on **Figures 5.11**, **5.12** , **5.13** and **5.14** (6 sheets each), while **Figures E1.9** to **E1.12** (3 sheets each) of **Appendix E**, **Figures F1.9** to **F1.12** (2 sheets each) of **Appendix F** and **Figures G1.9** to **G1.12** (2 sheets each) of **Appendix G** show similar results for local catchment flooding at Gol Gol and Buronga, Dareton and Wentworth, respectively.

Figure 5.12 shows that areas classified as H5 and H6 are generally limited to the inbank area of the rivers and their adjacent riparian zone and offline storages in the vicinity of the four urban centres during a 1% AEP Murray and Darling River flood, except at the following locations:

- in the area bounded by Punt Road to the east, the Sturt Highway/Hendy Road to the north, West Road to the west and the Murray River to the south at Gol Gol and Buronga (refer sheet 3);

- in the area bounded by the Silver City Highway to the east and north, and the Murray River to the west and south at Buronga (refer sheet 3);
- in Coomealla Golf Course at Dareton (refer sheet 5); and
- in the area bounded by Syndicate Road to the east, the Silver City Highway to the south and the Curlwaa levee to the west and north at Curlwaa (refer sheet 6).

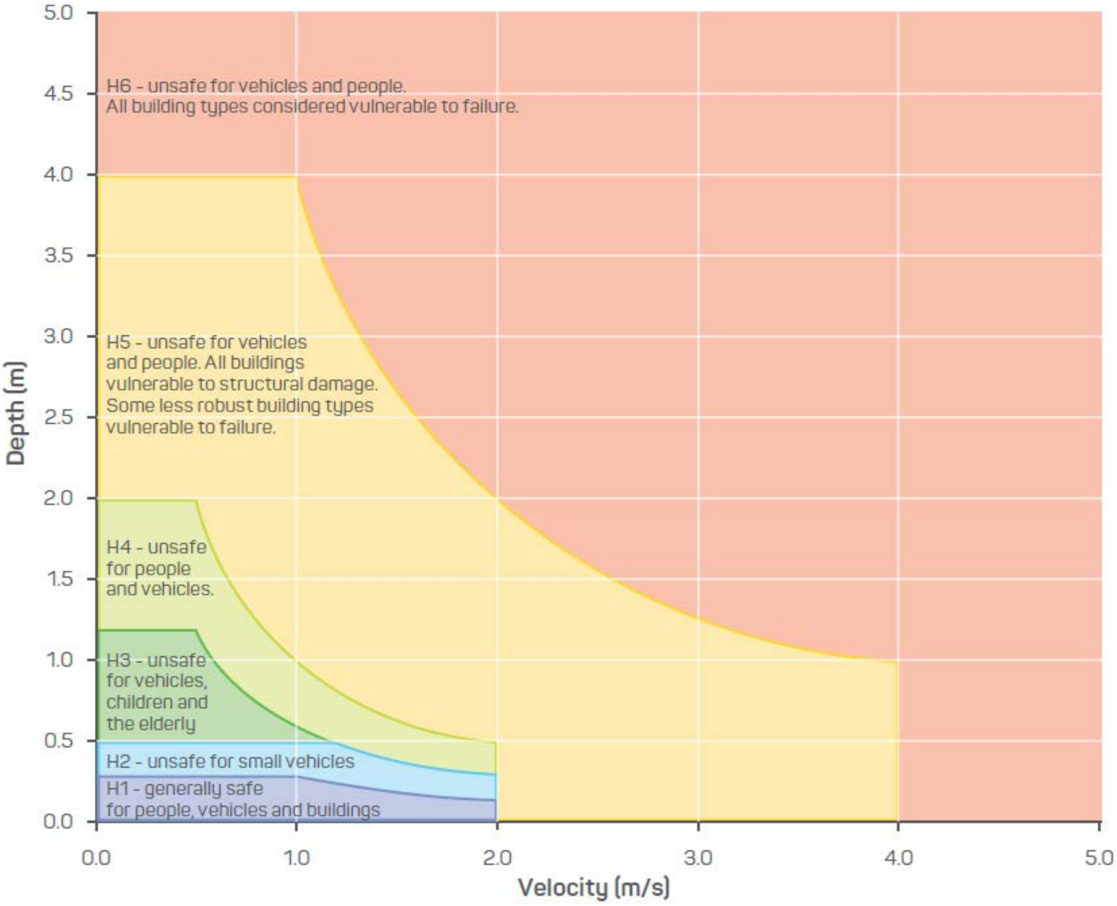


Figure 5.13 shows that in a 0.2% Murray and Darling River flood, additional areas subject to the H5 to H6 type flooding are found at the following locations:

- on the eastern and western banks of Gol Gol Creek in Gol Gol (refer sheet 3);
- on the northern side of Hendy Road to the west of its intersection with Dawn Avenue in Gol Gol (refer sheet 3); and
- while the parts of Wentworth that are located internal to the Wentworth town levees are generally subject to H3 and H4 type flooding, there is a pocket of land that is classified as H5 type flooding in the vicinity of Macleod Oval.

Figure E1.10 shows that local catchment flooding in the urban centres of Gol Gol and Buronga in a 1% AEP storm is generally classified as H1 and H2, except in the natural trapped low points where H3 or H4 type flood conditions are generally present. The inbank area of Gol Gol Creek is also classified as H3.

Figure F1.10 shows that local catchment flooding in the urban centre of Dareton in a 1% AEP storm is generally classified as H1, except where floodwater ponds on the upstream side of roads and in the natural trapped low points where it is generally classified as either H2 or H3.

Figure G1.10 shows that local catchment flooding in the urban centre of Wentworth in a 1% AEP storm is generally classified as H1 and H2, with isolated pockets of H3 type flooding where floodwater ponds against the levees. **Figure G1.10** also shows that local catchment flooding in the vicinity of the Wentworth Aerodrome in a 1% AEP storm is generally classified as H1 and H2, with isolated pockets of H3 occurring in the grassed lined channels that run parallel to the runways and in the flood runner that runs in a southerly direction to the west of the aerodrome.

5.6.2. Hydraulic Categorisation of the Floodplain

According to the FRMM, the floodplain may be subdivided into the following three hydraulic categories:

- Floodways;
- Flood storage; and
- Flood fringe.

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant re-distribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Flood Risk Management Guideline FB02 Floodway Function offers guidance in relation to two alternative procedures for identifying the portion of the floodplain that functions as floodways, flood storage and flood fringe areas.

The indicator technique set out in *Howells et al, 2003* was used to identify the preliminary extent of the floodway based on velocity of flow and depth. Based on the findings of a trial and error process, the following criteria were adopted for identifying those areas which operate as a "floodway" in a 1% AEP event:

- Velocity x Depth greater than 0.1 m^2/s **and** Velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Manual assessment and cleaning of the raw model output data was then undertaken as recommended in *Flood Risk Management Guideline FB02 Floodway Function*.

Flood storage areas were identified as those areas which do not operate as floodways in a 1% AEP event but where the depth of inundation exceeds 1 m for Murray and Darling River Flooding and 0.3 m for Local Catchment Flooding, while the remainder of the flood affected area was classified as flood fringe.

Figures 5.15, **5.16** and **5.17** (5 sheets each) show the division of the floodplain into floodway, flood storage and flood fringe areas for the 5% and 1 % AEP Murray and Darling River flood, as well as the Extreme Flood.

Figure 5.16 shows that floodways are generally limited to the inbank area of the rivers and their adjacent riparian zone in the vicinity of the four urban centres during a 1% AEP Murray and Darling River flood, with the following exceptions:

- on the right bank of the Murray River immediately upstream of the George Chaffey Bridge at Gol Gol and Buronga, where a floodway is present in the area that is bounded by Punt Road to the east, the Sturt Highway/Hendy Road to the north, West Road to the west and the Murray River to the south (refer sheet 3);
- in the area bounded by the Silver City Highway to the east and north, and the Murray River to the west and south at Buronga (refer sheet 3); and
- at the western end of Cadell Street at Wentworth in the vicinity of Lock 10.

Figure 5.17 shows that floodways impact additional land at the four urban centres in a 0.2% AEP Murray and Darling River flood at the following locations:

- on the right bank of the Murray River in the vicinity of its confluence with Gol Gol Creek (refer sheet 3);
- along Punt Road and Carramar Drive (refer sheet 3);
- along the alignment of Syndicate Road and Channel Road internal to the Curlwaa levee (refer Sheet 5); and
- across Adams Street to the north of the Western Levee (refer sheet 5).

Figures E1.13 to **E1.16** (3 sheets each) of **Appendix E**, **Figures F1.13** to **F1.16** (2 sheets each) of **Appendix F** and **Figures G1.13**, **G1.14**, **G1.15** and **G1.16** (2 sheets each) of **Appendix G** show the division of the floodplain at Gol Gol and Buronga, Dareton and Wentworth, respectively into floodway, flood storage and flood fringe areas in a 5%, 1% and 0.2 % AEP local catchment storm, as well as for the PMF. It is noted that floodways are generally limited to the inbank area of the engineered and natural channels that convey local catchment runoff away from the urban centres.

5.7 Sensitivity Studies

5.7.1. General

The sensitivity of the hydraulic model was tested to variations in model parameters such as hydraulic roughness and the partial blockage of the major hydraulic structures by woody debris. The main purpose of these studies was to give some guidance on:

a) the freeboard to be adopted when setting minimum floor levels of development in flood prone areas, pending the completion of the future *Wentworth FRMS&P*; and

b) areas where additional flood related planning controls should be implemented due to the development of new hazardous flow paths.

5.7.2. Sensitivity of Flood Behaviour to an Increase in Hydraulic Roughness

Figure 5.19 (6 sheets) shows the difference in peak flood levels (i.e. referred to as “afflux”) for the 1% AEP flood resulting from an assumed 20% increase in hydraulic roughness (compared to the values given in Column C of **Table 3.1**). The typical increases in peak 1% AEP flood level in the areas subject to Murray and Darling River flooding are generally 0.3 m in the vicinity of Gol Gol and Buronga, 0.25 m in the vicinity of Dareton and 0.1 m in the vicinity of Wentworth. **Figure 5.19** shows that the increase in peak flood levels associated with an assumed 20% increase in hydraulic roughness at Gol Gol result in floodwater overtopping Adelaide Street and discharging to the Gol Gol Lake system.

Figures E1.17 (3 sheets) of **Appendix E**, **Figures F1.17** (2 sheets) of **Appendix F** and **Figures G1.17** (2 sheets) of **Appendix G** show similar results for local catchment flooding at Gol Gol and Buronga, Dareton and Wentworth, respectively. Increases in peak 1% AEP flood levels in the areas that are subject to local catchment flooding at the four urban centres are generally limited to no greater than 20 mm. The exception is at Gol Gol and Buronga where there are localised areas where peak 1% AEP flood levels are lowered by up to 20 mm as the flow along the flow paths is attenuated due to the higher hydraulic roughness.

5.7.3. Sensitivity of Flood Behaviour to a Partial Blockage of Hydraulic Structures

The mechanism and geometrical characteristics of blockages in hydraulic structures and piped drainage systems are difficult to quantify due to a lack of recorded data and would no doubt be different for each system and also vary with flood events. Realistic scenarios would be limited to waterway openings becoming partially blocked during a flood event (no quantitative data are available on instances of blockage of the drainage systems which may have occurred during historic flood events).

As per the requirements of ARR 2019, the potential for the existing drainage system to experience a partial blockage during a storm event was taken into account when deriving the design flood envelopes. **Section 5.1** sets out the approach that was adopted for assigning blockage factors to the individual elements of the existing stormwater drainage system, while **Figures E1.18** (3 sheets) of **Appendix E**, **Figures F1.18** (3 sheets) of **Appendix F** and **Figures G1.18** (3 sheets) of **Appendix G** show the impact that the removal of the blockage factors for a 1% AEP local catchment storm at the urban centres of Gol Gol and Buronga, Dareton and Wentworth, respectively.

The removal of the blockage factors does not significantly alter 1% AEP flood behaviour at the four urban centres.

5.8 Climate Change Sensitivity Analysis

5.8.1. General

At the present flood study stage, the principal issue regarding climate change is the potential increase in flood levels and extents of inundation throughout the study area. In addition it is necessary to assess whether the patterns of flow will be altered by new floodways being developed for key design events, or whether the provisional flood hazard will be increased.

DCCEEW currently recommends that the advice set out in Section 3.7.4 of *Floodplain Risk Management Guide - Incorporating 2016 Australian Rainfall and Runoff in studies* (Office of Environment and Heritage (**OEH**), 2019) be used as the basis for examining climate change in projects undertaken under the State Floodplain Management Program and the FRMM. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.[28]

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce a 0.2% AEP event.

The impacts of climate change and associated effects on the viability of flood risk management options and development decisions may be significant and will need to be taken into account in the future flood risk management study and plan for the four urban centres using site specific data.
In preparing the flood risk management study and plan it will be necessary to consider the impact of climate change on flood damages to existing development. Consideration will also be given both to setting floor levels for future development (over and above that set out in **Sections 5.13** and **5.14** of this report) and in the formulation of works and measures aimed at mitigating adverse effects expected within the service life of development.

Mitigating measures which could be considered in the future flood risk management study and plan include the implementation of structural works such as levees and channel improvements, improved flood warning and emergency management procedures and education of the population as to the nature of the flood risk.

5.8.2. Sensitivity to Increased Rainfall Intensities

As mentioned, the investigations undertaken at the flood study stage are mainly seen as sensitivity studies pending more detailed consideration in the future flood risk management study and plan. For the purposes of the present study, flood events with AEPs of 0.5% and 0.2% were adopted as being analogous to flooding that could be expected to occur should present day 1% AEP rainfall intensities increase by 10 and 30 per cent, respectively.

Figure 5.20 (6 sheets) shows the impact that a 10 per cent increase in 1% AEP rainfall intensities would have on Murray and Darling River flooding, while **Figures E1.19** (3 sheets) of **Appendix E**, **Figures F1.19** (2 sheets) of **Appendix F** and **Figures G1.19** (2 sheets) of **Appendix G** show similar results for local catchment flooding at the urban centres of Gol Gol and Buronga, Dareton and Wentworth, respectively. The key impacts that a 10% increase in 1% AEP rainfall intensities would have on flood behaviour are as follows:

- Peak flood levels along the Murray and Darling rivers would be increased by up to 0.43 m in the vicinity of Gol Gol and Buronga, 0.34 m in the vicinity of Dareton and 0.16 m in the vicinity of Wentworth.

[28] While ARR 2019 updated the advice in relation to the impact that climate change will have on the BoM, 2016 design rainfall intensities, as well as initial and continuing losses for design flood estimation in late 2024, due to the timing of its release, the advice set out in OEH, 2019 has been adopted for undertaking the present study.

- Floodwater commences to overtop Adelaide Street and discharge to the Gol Gol Creek Lake system, which significantly increases the extent of land inundated in the vicinity of Gol Gol and Buronga.
- Peak flood levels for local catchment flooding at the four urban centres would generally increase by between 10 to 50 mm, with isolated increases of up to 200 mm shown to occur where floodwater ponds in the natural low points on the floodplain.

Figure 5.21 (6 sheets) shows the impact that a 30 per cent increase in 1% AEP rainfall intensities would have on Murray and Darling River flooding, while **Figures E1.20** (3 sheets) of **Appendix E**, **Figures F1.20** (2 sheets) of **Appendix F** and **Figures G1.20** (2 sheets) of **Appendix G** show similar results for local catchment flooding at the urban centres of Gol Gol and Buronga, Dareton and Wentworth, respectively. The key impacts that a 30% increase in 1% AEP rainfall intensities would have on flood behaviour are as follows:

- Peak flood levels along the Murray and Darling rivers would be increased by up to 1.1 m in the vicinity of Gol Gol and Buronga, 0.9 m in the vicinity of Dareton and 0.4 m in the vicinity of Wentworth.
- Floodwater overtops Adelaide Street and discharges to the Gol Gol Creek Lake system, which significantly increases the extent of land inundated in the vicinity of Gol Gol and Buronga.
- Floodwater overtops the Eastern and Western Levees at Wentworth.
- Peak flood levels for local catchment flooding at the four urban centres would generally increase by between 20 to 100 mm, with isolated increases of up to 300 mm shown to occur where floodwater ponds in the natural low points on the floodplain.

Figure 5.23 (6 sheets) shows the increase in the extent of land affected by Murray and Darling River flooding should 1% AEP rainfall intensities increase by 10 or 30 per cent, while **Figures E1.22** (3 sheets) of **Appendix E**, **Figures F1.22** (2 sheets) of **Appendix F** and **Figures G1.22** (2 sheets) of **Appendix G** show similar results for local catchment flooding at the urban centres of Gol Gol and Buronga, Dareton and Wentworth, respectively.

The extent of land that is affected by Murray and Darling River flooding increases on the floodplain, while the extent of inundation along the alignment of the river remains relatively unchanged, with the following exceptions.

- in the Gol Gol Creek Lake system where the extent of inundation will increase significantly once Adelaide Street is overtopped; and
- internal to the Western and Eastern Levees at Wentworth which would be overtopped as a result of a 30% increase in rainfall intensity.

The increases in the extent of land that is affected by local catchment should 1% AEP rainfall intensities increase by 10 or 30 per cent flooding at the four urban centres is negligible.

Consideration will need to be given to the identified changes that occur in flood behaviour during the preparation of the future flood risk management study and plan.

5.9 Potential Impact of a Failure to Close Gol Gol Creek Regulator

While the Gol Gol Creek Regulator is generally considered to prevent flooding in a significant number of properties during floods on the Murray River, there is no manual that sets out the procedures for operating the regulator during times of flood. It is also noted that the manual closing mechanism of the Gol Gol Creek Regulator failed during the 2022 flood and a backhoe was used to force the gate closed.

The Murray and Darling River TUFLOW Model was used assess the potential impact that the failure to close the Gol Gol Creek Regulator would have on flood behaviour in a 1% AEP flood.

Figure 5.23 shows the indicative depth and extent of inundation in the vicinity of Gol Gol and Buronga that would result from a failure to close the Gol Gol Creek Regulator. **Figure 5.23** shows that floodwater would fill the Gol Gol Lake system, ponding to the elevation of the low point in the Silver City Highway to the north of its intersection with Corbett Avenue (i.e. to an elevation of about RL 39.3 m AHD), noting that the inset shows that allotments that back onto the creek immediately north of the regulator would be inundated to depths of up to about 2.2 m.

5.10 Potential Impact of a Failure of the Existing Levees

As set out in **Section 5.4.1**, the IFF for the existing levees at Curlwaa and Wentworth have been assessed as being equivalent to floods equal to or more frequent than 10% and 5% AEP, respectively and as such would be deemed by NSW SES to be at risk of failure during larger flood events. The Murray and Darling River TUFLOW Model has therefore been used to assess the impact that a partial and complete failure of the Curlwaa and Wentworth town levees would have on flood behaviour for a 5% and 1% AEP flood, respectively.

Figure 5.24 shows the extent and depth of inundation resulting from a partial failure of the Curlwaa Levee in a 5% AEP Murray and Darling River flood, as well as the length over which it was assumed the levee would fail, while **Figure 5.25** shows similar information for a complete failure of the levee. **Figures 5.24** and **5.25** show that low lying land that lies within the Curlwaa Levee would be inundated by depths of up to about 4 m should the levee partially or completely fail in a 5% AEP flood.

Figure 5.26 shows the extent and depth of inundation resulting from a partial failure of the Wentworth town levees in a 1% AEP Murray and Darling River flood, as well as the length over which it was assumed the leave would fail, while **Figure 5.27** shows similar information for a complete failure of the levees. **Figures 5.26** and **5.27** show that the eastern and western side of Wentworth would be inundated by depths of up to about 1.8 m and 2.5 m, respectively should the levees partially or completely fail in a 1% AEP flood.

5.11 Potential Impact of Coincident Flooding in the Murray and Darling Rivers

For design flood estimation purposes, the present study assumes that the magnitude of the flow on the Murray and Darling rivers has the same AEP, noting that the flood peaks in the two rivers have historically not occurred at the same time (refer **Section 4.1** for further discussion).

The Murray and Darling River TUFLOW Model was used to test the sensitivity of 1% AEP flood behaviour at the four urban centres assuming the following alternative combination of design flood flows on the two river systems:

- **Scenario 1** - 5% AEP flood on the Darling River and Great Darling Anabranch in combination with a 1% AEP flood on the Murray River.
- **Scenario 2** - 1% AEP flood on the Darling River and Great Darling Anabranch in combination with a 5% AEP flood on the Murray River.

Figure 5.28 (2 sheets) shows that under Scenario 1 conditions, peak 1% AEP flood levels at Wentworth would only be reduced by less than 0.1 m, while there is effectively no change in peak 1% AEP flood levels at Gol Gol, Buronga and Dareton. **Figure 5.29** (2 sheets) shows that under Scenario 2 conditions, peak 1% AEP flood levels would be reduced by more than 1 m at Gol Gol, Buronga and Dareton and by between 0.5-1.0 m at Wentworth.

The above findings demonstrate that the Murray River is the dominant flooding mechanism at the four urban centres and that varying the magnitude of the flood on the Darling River system does not significantly alter peak 1% AEP flood levels in their vicinity.

5.12 Flood Emergency Response Classification

Floodplains can be categorised based upon the flood emergency response classifications which provide an indication of the relative difficulty of the flood emergency management situation at a community or precinct scale. The flood emergency response classifications can also assist in identifying the type and scale of information needed by the emergency managers to assist with emergency response planning.

Figures 5.30, **5.31**, **5.32** and **5.33** (5 sheets each) show the flood emergency response classifications for the 5%, 1% and 0.2% AEP flood on the Murray and Darling Rivers, as well as the Extreme Flood, respectively based on the definitions set out in the *Floodplain Risk Management Guideline EM01 Support for Emergency Management Planning*. The illustrations over the page have been taken from the guideline and provide a description of the flood emergency response classifications that are applicable to the study area.

For the purpose of the defining the flood emergency response classifications as part of the present study, potential vehicular evacuation routes were defined using the '*roadsegment'* layer downloaded from the NSW Governments SixMaps database, and vehicular evacuation was deemed cut if the road was subject to h2 to h6 type hazardous flooding.

The key findings of the flood emergency response classification mapping are as follows:

- The urban centre of Wentworth becomes a high flood island in a flood as frequent as 5% AEP as vehicular access to higher ground on the northern side of the floodplain is cut at the following locations:
  - the Silver City Highway between Tuckers Creek and the Curlwaa Levee; and
  - Pooncarie Road to the north of the town; and
  - The Silver City Highway to the north of its intersection with Renmark Road.
- The urban centre of Wentworth is considered a low flood island in a 0.2% AEP flood.
- The urban centres of Gol Gol and Buronga are deemed a High Flood Island in a 0.2% AEP Murray and Darling River flood as vehicular access to higher ground on the northern side of the floodplain via the Silver City Highway is cut.

The urban centre of Dareton has rising road access to higher ground on the northern side of the floodplain in flood events up to the Extreme Flood.

High flood island. The flood island has land higher than the limit of flooding for the event being considered (Figure 7 shows a high flood island in the PMF). During a flood these high islands are isolated from other areas of the community by floodwater, terrain, development, or infrastructure. However, there is an opportunity for people to retreat to higher ground within the island, and therefore, the direct risk to life is reduced. The area may require resupply by boat or air if not evacuated before the road is cut. If it is not possible to provide adequate support (such as community and medical facilities) during the period of isolation, evacuation will have to take place before isolation occurs. Isolation without these services is more likely to result in fatal decisions to cross floodwaters.

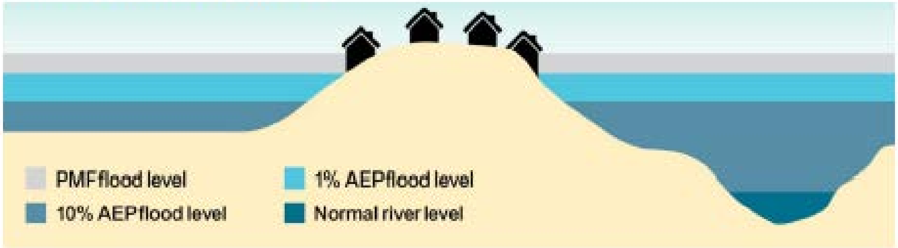


Figure 7 **High flood island**

Low flood island. The flood island is lower than the limit of flooding for the event being considered (Figure 8 and Figure 9 show a low flood island in the PMF). During a flood event the area initially becomes isolated by floodwater, terrain, development or infrastructure. If floodwater continues to rise after it is isolated, the land on the island will eventually be completely inundated by floodwaters. Evacuation of the community will be required prior to evacuation routes being closed as people left stranded on the island may drown.

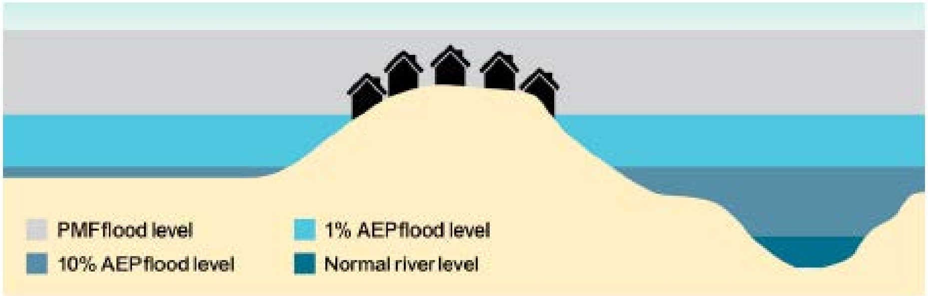


Figure 8 **Low flood island**

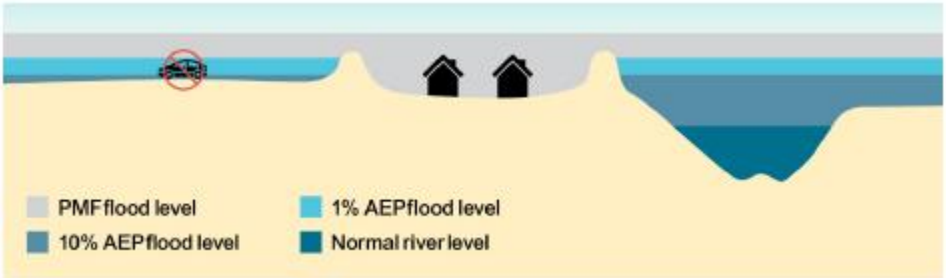


Figure 9 **Low flood island created by a ring levee**

Areas with rising road access are those areas where access roads rise steadily uphill and away from the rising floodwaters (Figure 12 and Figure 13). The community will not be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes, for example, people living in 2-storey homes may initially decide to stay but reconsider after water surrounds them.

These communities contain low-lying areas from which people will be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river system or by localised flooding from creeks.

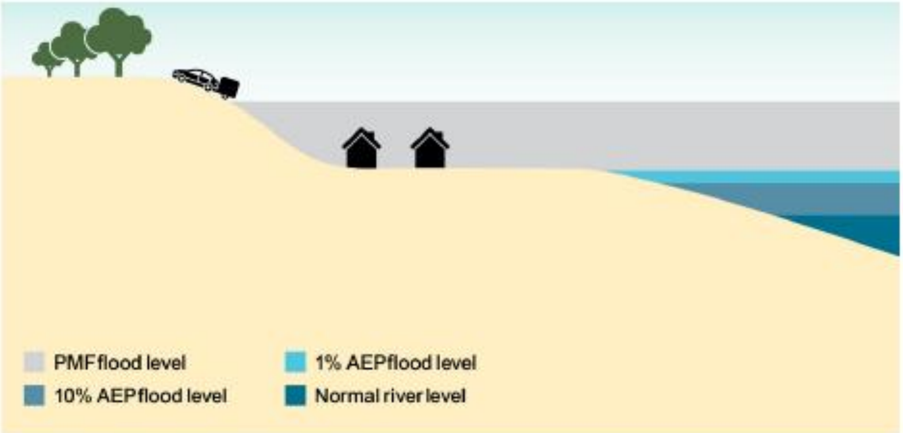


Figure 12 Area with rising road access

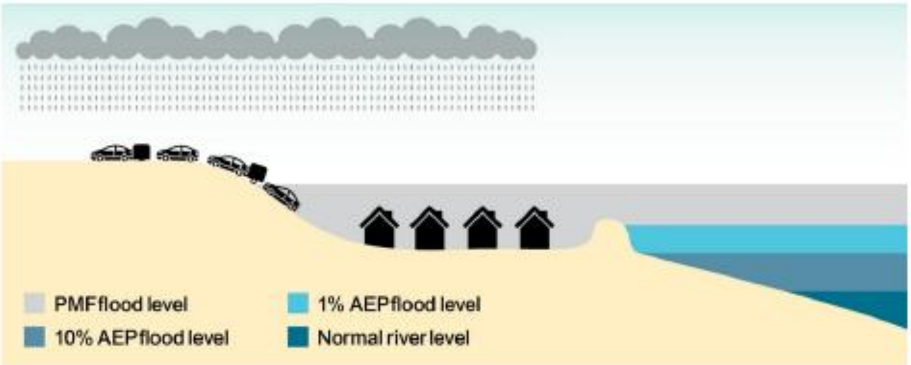


Figure 13 Area protected by a levee with rising road access

Areas with overland escape route are those areas where escape from rising floodwater is possible by traversing overland to higher ground (Figure 14). The area may also have access roads to flood-free land that cross lower-lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater after roads are cut is possible but involves traversing overland to higher ground. Anyone not able to walk out before access roads are cut must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.

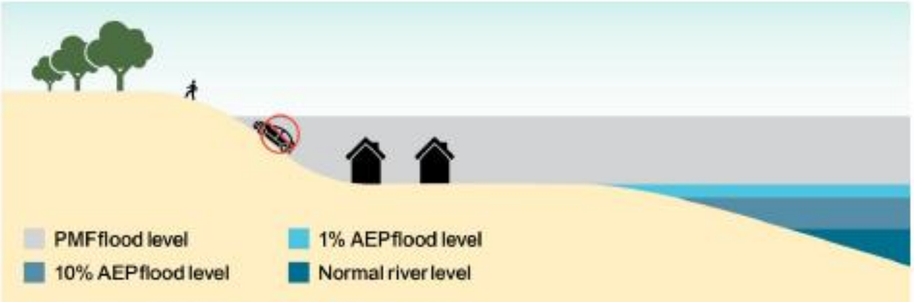


Figure 14 Area with overland escape route

5.13 Flood Planning Related Considerations

5.13.1. General

To assist Council in its assessment of future development that is proposed at the four urban centres prior to the completion of the future flood risk management study and plan, a recommended set of contemporary flood planning related guidelines that are consistent with the NSW Government's Flood Prone Land policy have been prepared as part of the present study. **Appendix I** of this report presents guidelines for the control of future urban development in flood prone areas specifically in relation to the study area, noting that they cater for Murray and Darling River Flooding, as well as Local Catchment Flooding.

The followings sections of this chapter set out the approach that has been adopted for defining the extent of the Flood Planning Area (**FPA**) and a preliminary set of Flood Planning Constraint Categories (**FPCCs**), both of which form part of the development assessment process.

Note that the guidelines that are set out in this report, as well as the FPA and FPCCs will need to be reviewed as part of the future flood risk management study and plan for Wentworth.

5.13.2. Derivation of Flood Planning Areas

After consideration of the TUFLOW model results and the findings of sensitivity analyses outlined in **Sections 5.7** to **5.11**, the following criteria were adopted for defining the FPA in the immediate vicinity of the four urban centres:

- in areas subject to Murray and Darling River Flooding, the extent of the FPA was defined as land lying at or below the peak 1% AEP flood level plus a freeboard allowance of 0.5 m (**Murray and Darling River Flooding FPA**); and
- in areas subject to Local Catchment Flooding and that also lie outside the extent of Murray and Darling River Flooding FPA, the extent of the FPA was defined as land inundated to a depth greater than 100 mm or within the extent of the floodway (**Local Catchment Flooding FPA**).[29]

Figure I1.1 (5 sheets) in **Appendix I** of this report shows the extent of both the Murray and Darling River Flooding FPA and the Local Catchment Flooding FPA in the immediate vicinity of the four urban centres.

Note that the flooding that would occur as a result of a failure to close the Gol Gol Regulator during a 1% AEP flood was adopted for setting the extent of the Murray and Darling River Flooding FPA in the Gol Gol Lake system, the principal reasons being that there are no formal procedures in place for its operation during a flood, its manually operated closing mechanism recently failed during in 2022 and that the FPL on the Murray River is higher than low points in both the Sturt Highway at Gol Gol and the Silver City Highway at Buronga, resulting in the FPA extending to the north beyond the road corridor.

[29] The extent of the Local Catchment Flooding FPA was filtered to remove pockets of flooding where the area external to the footprint of existing buildings was less than 200 m^2, and where it was confined to exiting road reserves and farm dams.

Note further that the adoption of the Local Catchment Flooding FPA internal to the Wentworth town levees (as opposed to the Murray and Darling River Flooding FPA) assumes that Council will implement a formal set of procedures which will raise the crest height of the levees to their design height of RL 35.75 m AHD in advance of the arrival of the flood wave on the Murray and/or Darling rivers.

Prior to the preparation of the future *Wentworth Flood Risk Management Study and Plan*, it is recommended that Council consider applying freeboards of 0.3 m and 0.5 m to peak 1% AEP flood levels derived as part of the present study when setting the minimum habitable floor levels of future development that is located within the extent of the Local Catchment Flooding FPA and Murray and Darling River Flooding FPA, respectively. An assessment should also be undertaken by Council as part of any future Development Application to confirm that the proposed development will not form an obstruction to the passage of flow through the subject site.

While **Figure I1.1** also shows the extent of the *Outer Floodplain*, which is the area that lies between the FPA and the extent of the Extreme Flood/PMF, as Council chose not to include clause 5.22 titled "special flood considerations" in the *Wentworth Local Environmental Plan 2011* at the time the NSW Government recently updated all Local Environmental Plans, no flood related controls would apply to future development in this area. That said, consideration of the possible inclusion of this clause in *Wentworth Local Environmental Plan 2011* will need to be given during the preparation of the future flood risk management study and plan.

5.13.3. Preliminary Flood Planning Constraint Categories

To assist Council in assessing the merits of future development at the four urban centres prior to the preparation of the *Wentworth Flood Risk Management Study and Plan*, the following set of preliminary FPCCs was developed as part of the present study.

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls that are set out in **Appendix I** of this report.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises areas that lie between the FPA and the extent of the Extreme Flood/PMF where no flood related development controls currently apply. This area is identical to the *Outer Floodplain* shown on **Figure I1.1**.

Figure I1.2 (5 sheets) in **Appendix I** of this report shows the spatial extent of the four aforementioned FPCCs in the vicinity of the four urban centres.

The derivation of the four FPCCs firstly involved the derivation of a number of sub-regions which were based on the nature of flooding in the vicinity of the four urban centres, the sub-categories of which are set out in **Table 5.7**. These sub-regions were then combined, with the resulting extents further refined in order to improve the area over which each FPCC applied, noting that this included the removal of isolated pockets, as well as the trimming of sub-regions in areas where they would have no bearing on future development (for example, in road reserves and in allotments where they fell within standard boundary offsets).

TABLE 5.7
KEY ELEMENTS COMPRISING FLOOD PLANNING CONSTRAINT CATEGORIES

Flooding	FPCC	Sub-category	Constraint
Murray and Darling River Flooding	1	a	1% AEP Floodway
		b	1% AEP Flood Hazard Vulnerability Classification H6
	2	a	1% AEP Flood Storage
		b	1% AEP Flood Hazard Vulnerability Classification H5
		c	0.2% AEP Flood Hazard Vulnerability Classification H5 and H6
		d	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Submerged)
		e	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Elevated)
		f	0.2% AEP Floodway
	3	-	Flood Planning Area (1% AEP + Freeboard)
	4	-	Extent of Extreme Flood
Local Catchment Flooding	1	-	1% AEP Floodway AND Flood Hazard Vulnerability Classification H4 - H6
	2	a	1% AEP Floodway AND Flood Hazard Vulnerability Classification H1 - H3
		b	1% AEP Flood Storage Area
		c	0.2% AEP Flood Hazard Vulnerability Classification H5 and H6
	3	-	Flood Planning Area (Area where depths are greater than 100mm)
	4	-	Extent of PMF

6 REFERENCES

Advisian, 2021. ***"Wentworth Flood Study"*** [Draft report]

BoM (Bureau of Meteorology), 2003. ***"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"***

Department of Water Resources, 1990. ***"Flood Study Report – Wentworth Shire – Gol Gol to Abbotsford Bridge"***

DPWS (NSW Department of Public Works and Services), 2007. ***"Wenworth Shire Council – Stormwater Management Plan"***

Geoscience Australia, 2019. ***"Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia"***

GHD et al (Gutteridge Haskins & Davey, Cameron McNamara and Laurie Montgomerie & Pettit), 1986. ***"Murray River Flood Plain Management Study – Summary Report"***

Harrison, 1957. ***"Report on the River Murray Flood Problem"***

Howells et al, 2004. ***"Defining the Floodway - Can One Size Fit All?"*** FMA NSW Annual Conference, Coffs Harbour, February 2004.

Jordan et. al. (Jordan, P., Nathan, R., Mittiga, L. and Taylor, B.), 2005. ***"Growth Curves and Temporal Patterns for Application to Short Duration Extreme Events"***. Aust J Water Resources, 9(1), 69-80.

Kinhill Engineers, 1995a. ***"Floodplain Management Study – Murray River Gol Gol Bridge to Abbotsford Bridge"***

Kinhill Engineers, 1995b. "***Floodplain Management Plan –Gol Gol to Abbotsford Bridge (NSW only)***"

NSW SES (NSW State Emergency Service), 2023. ***" Wentworth Shire Local Flood Emergency Sub Plan"***

OEH (Office of Environment and Heritage), 2019. ***"Floodplain Risk Management Guide - Incorporating 2016 Australian Rainfall and Runoff in studies"***

PWA (NSW Public Works Advisory), 2017. ***"Visual Audit of Wentworth Levee"***

PWA (NSW Public Works Advisory), 2018. ***"Wentworth Levee Owner's Manual"***

PWA (NSW Public Works Advisory), 2022. ***"Visual Audit of Curlwaa Levee"***

Walsh et al (Walsh, M.A, Pilgrim, D.H, Cordery, I), 1991. ***"Initial Losses for Design Flood Estimation in New South Wales"*** Intn'l Hydrology & Water Resources Symposium, Perth.

Worley Parsons, 2010. ***"Wentworth Flood Study – Extending Downstream from Gol Gol on the Murray River and Downstream from Pomona on the Darling River"*** [Draft report superseded by Advisian, 2021]

Worley Parsons, 2011. ***"Wentworth Floodplain Risk Management Study – Extending Downstream from Gol Gol on the Murray River and Downstream from Pomona on the Darling River"*** [Draft Report]

WRCS (Water Resources Consulting Services), 1997. ***"Rehabilitation of Wentworth Levee - Investigation & Design"***

7 FLOOD-RELATED TERMINOLOGY

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Extreme Flood	The Extreme Flood defines the upper limit of potential flooding on the Murray and Darling rivers and has been assessed to have a peak flow three (3) times that of the 1% (1 in 100) AEP flood event
Floodplain	Area of land which is subject to inundation by floods up to and including the Extreme Flood/Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie within the extent of the Flood Planning Area where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie within the extent of the *Flood Planning Area* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies between the extent of the Flood Planning Area and the Extreme Flood/PMF. Given the extended warning time available to areas within the Wentworth Shire Local Government Area, no flood related controls apply to development that is located in this zone. This area is identical to the Outer Floodplain shown on the Flood Planning Map.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted flood risk management study and plan, or as part of a site specific study In the absence of an adopted flood risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the Extreme Flood/PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the *Flood Planning Level*.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Murray and Darling River Flooding	Occurs when floodwater surcharges the inbank area of the Murray and Darling rivers. Murray and Darling River Flooding is typically characterised by relatively deep and faster flowing floodwater in the main channel of the river but can include shallower and slower moving floodwater in overbank areas
Local Catchment Flooding	Is experienced at the four urban centres during periods of heavy rain. Local catchment flooding is characterised by relatively shallow and slow-moving floodwater.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land in the two urban centres where they are not impacted by the Extreme Flood.

APPENDIX A

COMMUNITY SURVEY

Community Survey
WENTWORTH FLOOD STUDY

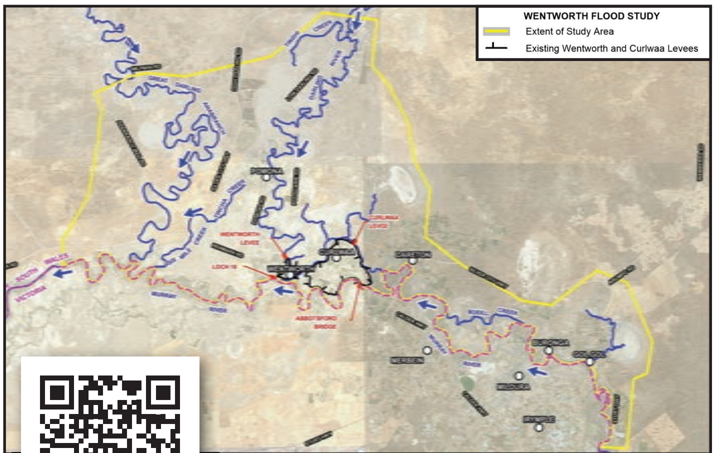
Wentworth Shire Council has engaged consultants to undertake a flood study (herein referred to as the Wentworth Flood Study).

The Wentworth Flood Study will define patterns of riverine-type flooding at Wentworth, Pomona, Curlwaa, Dareton, Buronga and Gol Gol.

The figure below shows the extent of the study area.

Aim of the Wentworth Flood Study

The Wentworth Flood Study aims to build community resilience towards flooding through informing better planning of development, emergency management and community awareness and is being undertaken by Council with funding assistance from the NSW Department of Climate Change, Energy, the Environment and Water. Council has established a Flood Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives to oversee the Wentworth Flood Study.



Scan the QR code to view the study area or complete the survey online.

Disclaimer: The attached Community Questionnaire has been provided to residents and business owners to assist the consultants in gathering this important information. All information provided will remain confidential and for use in this study only.

The Wentworth Flood Study is an important first step in the flood risk management process for this area and will be managed by Council according to the NSW Government's Flood Prone Land Policy.

The various stages of the Wentworth Flood Study are as follows:

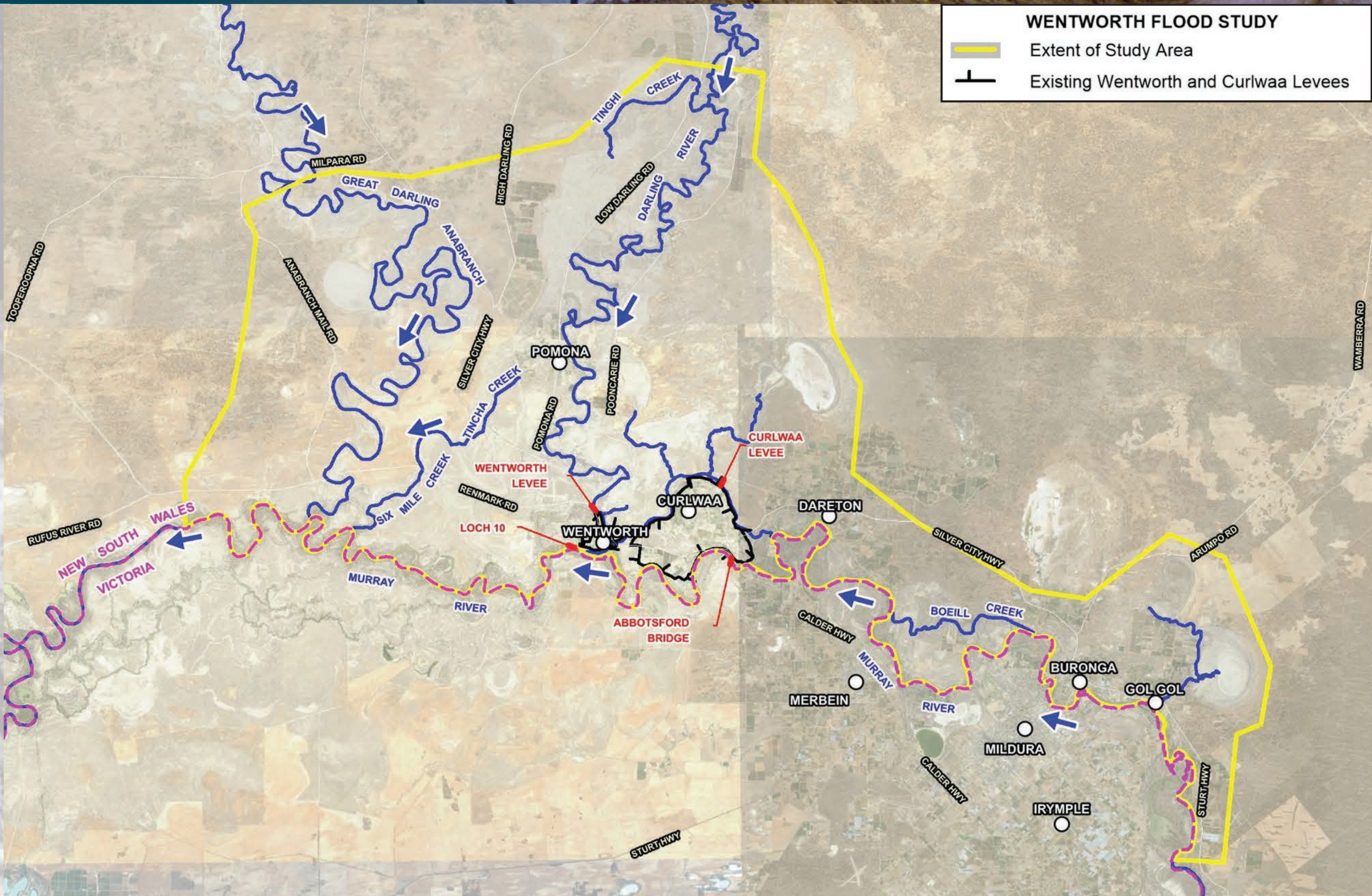
- Undertake survey of the existing drainage system as required, as well as the collection of data on historic flooding.
- Preparation of computer models of the watercourses to determine flooding patterns, flood levels, flow velocities and depths of inundation.
- Preparation of a flood study report which will document the findings of the investigation. The draft flood study report will be placed on public exhibition following completion of the investigation seeking community feedback on its findings.

Following the completion of the Wentworth Flood Study, Wentworth Shire Council may be eligible for further funding from the NSW Government to undertake a Flood Risk Management Study and prepare a Flood Risk Management Plan which will assist Council in refining strategic plans for mitigating and managing the effects of the existing, future and continuing flood risk at Wentworth, Pomona, Curlwaa, Dareton, Buronga and Gol Gol.

An important first step in the preparation of the Wentworth Flood Study is to identify the availability of information on historic flooding in the study area.

Survey closing Friday 15 April 2024.
For further information, contact George Kenende, Acting Director Health & Planning via phone (03) 5027 5027 or email council@wentworth.nsw.gov.au

Wentworth Flood Study



Wentworth Flood Study

Community Survey to define patterns of riverine-type flooding in Wentworth Shire

This questionnaire is part of the Wentworth Flood Study, which is currently being prepared by Wentworth Shire Council with the financial support of the NSW Department of Climate Change, Energy, the Environment and Water. Your responses to the questionnaire will help us understand historical flood impacts and determine the flood issues that are important to you.

Survey closing Friday 15 April 2024.
For further information, contact George Kenende, Acting Director Health & Planning via phone (03) 5027 5027 or email council@wentworth.nsw.gov.au

Your Details:	
Name *(optional)*	
Address	
Phone number *(optional)*	
Email *(optional)*	

What type of property do you live in/own?

☐ Residential ☐ Industrial ☐ Commercial ☐ Vacant Land

☐ Other (please specify):

What is the occupier status of this property

☐ Owner Occupied ☐ Rental Property ☐ Business

☐ Other (please specify):

How long have you lived, worked or owned property in the area?

a) At this address:

☐ 0-5 years ☐ 5-10 years ☐ 10-20 years ☐ More than 20 years

b) In the general area?

☐ 0-5 years ☐ 5-10 years ☐ 10-20 years ☐ More than 20 years

Continued overleaf

Wentworth
SHIRE COUNCIL

Wentworth Flood Study

Community Survey to define patterns of riverine-type flooding in Wentworth Shire

Have you been affected by flooding? When and where were you affected?
This answer is not particularly in relation to water inundation to property.

- ☐ August 1956
- ☐ October 1974
- ☐ October 1990
- ☐ December 2022
- ☐ Never
- ☐ Other (please specify):

How were you affected by the above flood/s indicated?

- ☐ Roadway was cut by water
- ☐ Front/back yard was flooded
- ☐ House/business was flooded
- ☐ Isolated from town/ essential services

Please provide a detailed description of your experience.

Please add any additional comments, information or suggestions that you think may assist the flood study.

Do you have any photos or videos of the floods you have indicated?
Please send a copy to wentworth@lyallandassociates.com.au

APPENDIX B

DETAILS OF AVAILABLE DATA

TABLE OF CONTENTS

ANNEXURES

LIST OF FIGURES
(BOUND IN VOLUME 2)

B1 COLLECTION OF MISCELLANEOUS DATA

B1.1 Aerial Photography

Aerial photography covering the study area was provided by Council. This included aerial photography that was captured of the Murray and Darling River floodplains in the vicinity of Wenworth on 3 December 2022 when both rivers were in flood.

B1.2 Airborne Laser Scanning Survey

Table B1.1 sets out the details of the LiDAR survey data that are available for the study area, while **Figure B1.1**, sheet 1 shows the plan extent of each data set that were used for the purpose of undertaking the present study. The data comprising the data set were captured in accordance with the International Committee on Surveying and Mapping guidelines for digital elevation data with a 95% confidence interval on horizontal accuracy of ±800 mm and a vertical accuracy of ±300 mm.

TABLE B1.1
LiDAR SURVEY DATA SPECIFICATIONS

Data Set	Date of Capture	Data Provider
Bunnerungee201907	July 2019	Geoscience Australia
Bunnerungee202002	February 2020	
Bunnerungee202012	December 2020	
LakeVictoria202012	December 2020	
Lindsay202012	December 2020	
LowerDarling2013	May 2013	
Mildura2019sep10	September 2019	
Mildura202012	December 2020	
Nowingi202102	February 2021	
Para201907	July 2019	
Para202012	December 2020	
Robinvale202101	January 2021	
Wentworth201907	July 2019	
Wentworth202002	February 2020	
Wentworth202012	December 2020	

Photogrammetric survey data that covers the outer extents of the floodplain were also obtained from Geoscience Australia's online portal. The photogrammetric survey data has a horizontal accuracy of ±1.25 m and a vertical accuracy of ±0.9 m.

B1.3 Drainage and Flood Mitigation Assets

Figure B1.1 (13 sheets) shows the alignment of the existing stormwater drainage network in the study area, details of which were contained in Council's GIS stormwater drainage asset database. Council also provided a GIS database of the existing bridges and major culverts that are present in the Wentworth Shire LGA.

Council provided copies of plans relating to recent residential subdivisions that have been constructed in the study area.

Mildura Rural City Council provided details of temporary and permanent levees that were constructed on the left (southern) side of the Murray River prior to the arrival of the December 2022 flood peak.

TfNSW provided a database of bridge and culvert structures that are located along the arterial road that are located in the study area.

B1.4 Field Survey Data

Council provided surveyed elevation data along the centrelines of roads throughout the LGA which were used to validate the LiDAR survey data (refer LiDAR Validation Survey on **Figure B1.1**). It is noted that the LiDAR survey data were generally found to be within +/-50 mm of the surveyed elevations.

DCCEEW provided bathymetric survey data of an approximately 650 km long reach of the Murray River between Red Cliffs in NSW and Murray Bridge in South Australia, as well a 16 km reach of the Great Darling Anabranch immediately upstream of its confluence with the Murray River. The bathymetric survey data generally comprised cross sections at 100 m spacings in the vicinity of Wentworth. A DEM of bathymetric survey of the Darling River Weir Pool was also provided by DCCEEW.

Council provided a copy of detailed survey that was undertaken along the crest of the Western, Eastern and Hospital Levee's at Wentworth that was undertaken in March 2017 by PWA.

Figure B1.1 (Sheet 12) shows the extent of drone-based LiDAR survey data that were captured by Council in the vicinity of the Wentworth Aerodrome in February 2024.

B1.5 Rainfall Data

Figure B1.1, sheet 1 shows the BoM operated daily-read and All Weather Station (**AWS**) rain gauges that are located in the vicinity of the study area, while **Table B1.2** sets out the details of the latter.

TABLE B1.2
SUMMARY OF AVAILABLE AWS RAIN GAUGE DATA(1)

Gauge Number	Gauge Name	Gauge Type	Site Commence	Site Cease
47,111	Wentworth (Nulla)	BoM AWS	June 2017	Ongoing
76,031	Mildura Airport	BoM AWS	1946	Ongoing

1. Refer **Figure B1.1**, sheet 1 for location

B1.6 Stream Flow Data

Stream flow data from the ten key stream gauges that are located on the Murray River, Darling River and Great Darling Anabranch were obtained from their respective operators' online databases, previous flooding investigations and archival data that was provided by Advisian. The location of the stream gauges is shown on **Figure B1.1**, while their dates of operation are set out in **Table B1.3** over the page.

TABLE B1.3
DETAILS OF AVAILABLE STREAM GAUGES[1]

Gauge Number	Gauge Name	Site Established	Commencement Date of Telemetered Data	Status	Gauge Operator[2]
414203	Murray River at Euston	January 1930	September 1975	Open	VIC
414207	Murray River at Colignan	June 1960	December 1975	Open	VIC
414202	Murray River at Mildura	September 1864	-	Closed in 1931	VIC
425010	Murray River at Lock 10 Wentworth	August 1872	January 1987	Open	NSW
A4260505	River Murray at Lock 9 Downstream	January 1922	October 1957	Open	SA
A4260507	River Murray at Lock 8 Downstream	January 1931	December 1970	Open	SA
A4260509	River Murray at Lock 7 Downstream	January 1930	October 1961	Open	SA
425007	Darling River at Burtundy	March 1940	March 1940	Open	NSW
425005	Darling River at Pooncarie	March 1885	January 1913	Open	NSW
425011	Great Darling Anabranch at Bulpunga	November 1954	November 1954	Open	NSW
425054	Great Darling Anabranch Tara Downs	November 2013	November 2013	Open	NSW

1. Refer **Figure B1.1** for location of stream gauge.
2. VIC stream gauges operated by the Victorian Department of Environment, Land, Water and Planning, NSW stream gauges operated by WaterNSW and SA stream gauges operated by SA – Department of Environment and Water.

Annexures B1 to **B7** of this Appendix set out the annual maximum peak height and flow data for the Euston, Colignan, Mildura, Lock 10, Burtundy, Pooncarie and Bulpunga stream gauges, while **Figure B1.2** shows the availability of continuous annual maximum peak flows at each of the stream gauges that have been relied upon for undertaking the present study. **Annexures B1** to **B7** also set out the source of the data.

It is noted that visual independence checks of the annual series of data that were obtained from the gauge operators were undertaken to ensure that they were representative of the largest flood in a given year, and not part of the rising or receding limb of a flood in the prior/subsequent year.

B1.7 Flood Mark Survey

Council provided 1,182 surveyed points that were captured over the period 7 October 2022 to 15 December 2022 so as to identify low points and monitor flood levels. Council also provided an additional 9,716 surveyed points that were captured over the period 11 November 2022 to 23 January 2023 so as to identify low points and monitor flood levels.

Surveyed flood levels recorded intermittently between 10 November 2022 and 15 December 2022 at ten temporary flood markers that were established on the Murray and Darling River floodplains were provided by Council. Council records did not include flood levels at the temporary flood markers after 15 December 2022, noting that the peak of the flood occurred on Sunday 18 December 2022.

Surveyed flood levels recorded intermittently between 30 September 2022 and 3 February 2023 at 19 temporary flood markers that were established on the left (southern) bank of the Murray River were provided by Mildura Rural City Council.

Advisian, 2021 contains flood marks from floods that occurred in 1870 (three off), 1956 (35 off), 1974 (three off), 1975 (four off) and 1990 (one off) (refer **Annexure B8** of this Appendix for extracts from Advisian, 2021). GHD et al, 1986 also contains a long section of the Murray River extending downstream of the Murray and Murrumbidgee Rivers confluence to Wentworth showing water surface profiles for the 1956 and 1974 floods (refer **Annexure B9** for a copy).

NSW SES provided a geodatabase file containing 12 GB of flood intelligence that they captured during the December 2022 flood event.

B1.8 Photographic Record

Annexure B10 of this Appendix contains a series of aerial photographs that have been taken from GHD et al, 1986 showing the flooding that was experienced along the Murray River at the time of the 1956 flood.

Photographs were provided by Council at the commencement of the study showing riverine type flooding on the Murray and Darling River floodplains in the vicinity of Wentworth on 30 November 2022, copies of which are contained in **Annexure B11** of this Appendix.

Several photographs showing the configuration of the bridge/road crossing of the Murray River at Mildura were obtained from the internet, copies of which are contained in **Annexure B12** of this Appendix.

B1.9 Murray River Locks

Both WaterNSW and DCCEEW provided details of the locks that are located along the Murray River in the vicinity of the study area, which included the operating procedures of Locks 10 and 11.

B2 BRIEF OVERVIEW OF PREVIOUS REPORTS

B2.1 The River Murray Flood Problem (Harrison, 1957)

Harrison, 1957 provides a detailed description of flooding along the Murray River with particular reference to the 1956 flood, including a large amount of technical data. The report notes that the following:

> *"… it is important here to note that during floods the major part of the flow of the river leaves the main stream below Tocumwal, forms a huge temporary lake of some 4 million acre feet capacity along the course of the Edward and Wakool Rivers part Deniliquin and Moulamein, and rejoins the river at Wakool Junction 75 miles by river from Swan Hill. This huge lake forms in itself a flood control reservoir and this considerably reduces flooding that would otherwise occur at Euston, Mildura, Wentworth and the South Australian river floods."*

Harrison, 1957 notes that reasonable records are available for floods that occurred in 1870, 1890, 1917, 1931, 1955 and 1956, and that except in the South Australian section of the river where the 1956 flood was higher than previously recorded, the 1870 flood was the highest at most places along the Murray River.

Harrison, 1957 notes that in the Darling River, flood intensities reach their peak at Bourke, but are reduced as the flood travels downstream by natural storage, large effluents such as Talyawalka Creek and the Great Darling Anabranch and may large lakes until by the time the flood reaches its peak at Burtundy, the intensity at Bourke has been reduced by about half. While Harrison, 1957 notes that the frequency of river floods at Wentworth is affected by flood flows in the Darling River, it also notes that the flood peaks in the two rivers do not synchronise owing to the incidence of rainfall in the headwaters.

Of interest, Harrison, 1957 states that the flood in the Great Darling Anabranch reportedly reached an intensity of 25,000 cubic feet per second (or 708 m^3/s) which is generally consistent with the extrapolation of WaterNSW Rating Table 178 (refer **Figure 2.13** of the Main Report), while on the Darling River at Burtundy it reportedly reached 32,250 cubic feet per second (or 913 m^3/s) which is not consistent with WaterNSW Rating Table 26 (refer **Figure 2.12** of the Main Report). **Plates B2.1** and **B2.22** over the page show the discharge hydrographs that are presented in Harrison, 1957 at the Burtundy and Bulpunga stream gauges for the 1956 flood. For the purpose of the present study, the peak flow of 913 m^3/s quoted in Harrison, 1957 has been adopted, noting that subsequent studies have also adopted this value.

Harrison, 1957 notes that breakaways above Wentworth in the vicinity of Pomona were diverting large volumes of water from the Darling River during the 1956 flood which returned to the Murray River below Wentworth.

B2.2 Murray River Flood Plain Management Study (GHD et al, 1986)

The principal objectives of Gutteridge Haskins & Davey Pty Ltd (**GHD**) et al, 1986 were to identify flooding problems along the reach of the Murray River extending from Lake Hume to the South Australian border and to recommend a programme of detailed studies of these problems on a priority basis.

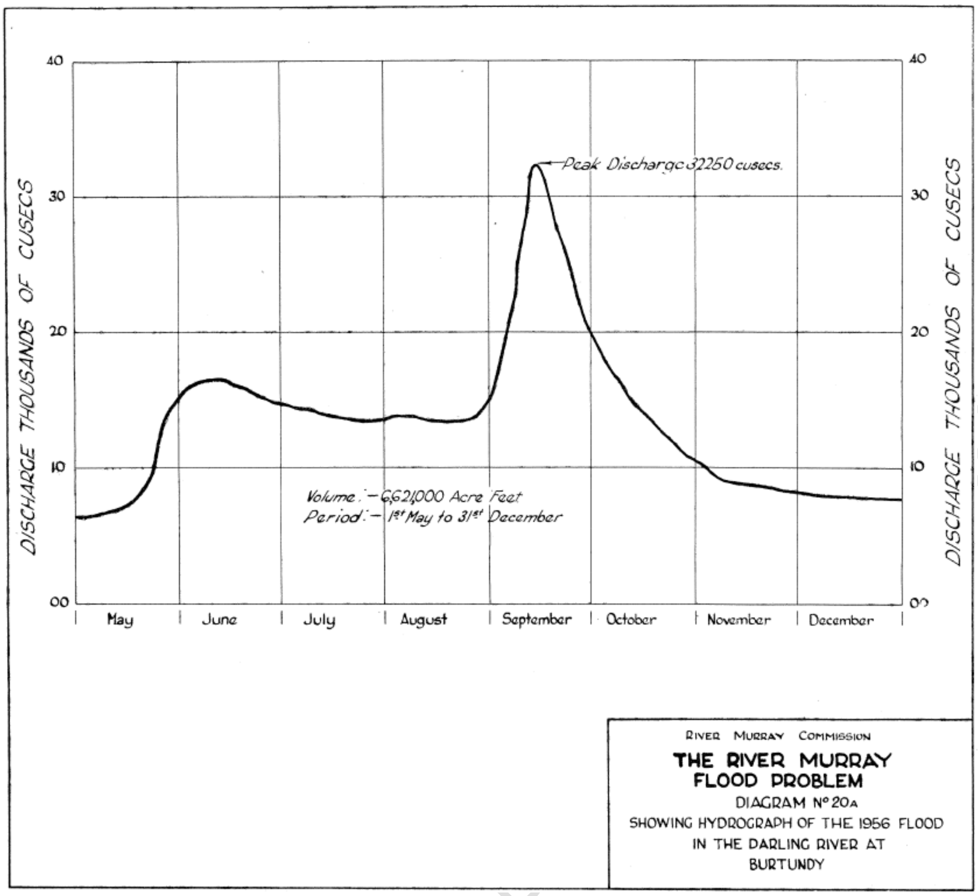


Plate B2.1 – 1956 flood discharge hydrograph at Burtundy stream gauge (Source: Harrison, 1957)

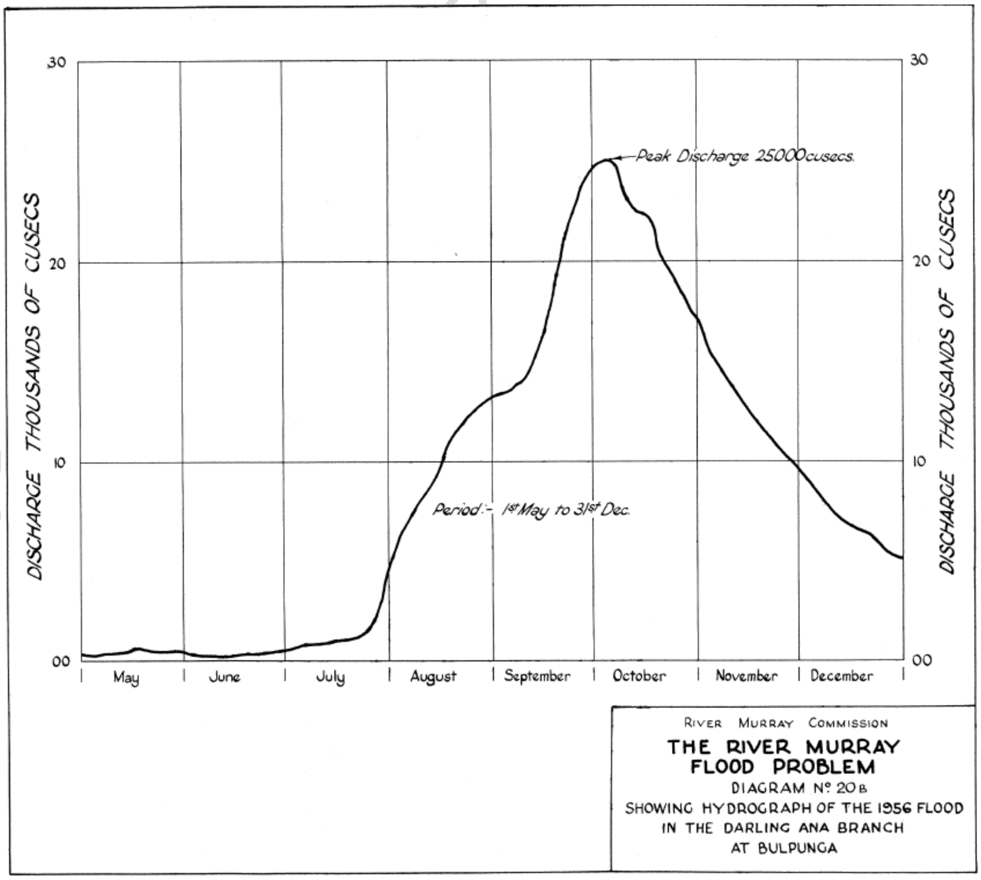


Plate B2.2 – 1956 flood discharge hydrograph at Bulpunga stream gauge (Source: Harrison, 1957)

Figures 4.1 in GHD et al, 1986 nominates the 1870 flood as the highest to have occurred on the Murray River, followed by floods that occurred in 1956, 1917, 1931, 1975 and 1974 (at Mildura). GHD, et al, 1986 states that the 1870 flood was above normal river level for about seven months, while the 1956 flood that was 150 mm lower lasted for about 4 months. **Table B2.1** sets out the nominated peak flows at Euston and Mildura for the six historic flood events.

TABLE B2.1
HISTORIC AND DESIGN PEAK FLOWS AT EUSTON AND MILDURA STREAM GAUGES(1)

Flood Event		Euston		Mildura	
		Peak Flow			
		(ML/d)	(m^3/s)	(ML/d)	(m^3/s)
Historic	1870	-	-	367,000	4,248
	1956	301,800	3,493	308,000	3,565
	1917	-	-	200,000	2,315
	1931	248,100	2,872	209,800	2,428
	1974	197,700	2,288	183,400	2,123
	1975	203,800	2,359	185,000	2,141
Design	1%	327,000	3,785	308,000	3,565
	2%	262,000	3,032	245,000	2,836
	5%	189,000	2,188	176,600	2,044

1. Source: GHD et al, 1986

GHD et al, 1986 noted that based on the findings of a then recent study that had been commissioned by the Rural Water Commission of Victoria (**RWC**), the 1956 flood had been assigned an AEP of 1% (refer **Table B2.1** above for 5%, 2% and 1% AEP peak flows).

Annexure B9 of this Appendix contains a copy of Figure 4.3 of GHD et al, 1986 showing water surface profiles along the reach of the Murray River extending from its confluence with the Murrumbidgee River to Wentworth for the 1956 and 1974 floods. Also included on Figure 4.3 are peak flood levels at the locks that are located downstream of Wentworth for the two historic flood events.

As previously mentioned, **Annexure B11** of this Appendix contains a series of aerial photographs that have been taken from GHD et al, 1986 showing the flooding that was experienced along the Murray River at the time of the 1956 flood.

While more relevant to the next phase of the flood risk management process, GHD et al, 1986 sets out the following flood risk management measures for the four urban centres that are located along the Murray River in the Wentworth Shire:

Gol Gol

- Carry out an investigation to define the exact extent of flooding
- Confine future development to within the zoned village area and on either flood free land or accessible filled land

<u>Buronga</u>

- Define extent of flood liable land
- Encourage development to be within the zoned village area
- Require floor levels to be above the RWC designated flood level
- Require all residences in floodplain to have flood free access subject to consideration by the WRC of effects on regional flow patterns
- Require levees to be subject to Council and WRC approval

<u>Dareton</u>

- Define extent of flood liable land.
- Confine development to village area and to flood free land
- Require floor levels to be above RWC designated flood level
- Require all residences in floodplain to have flood free access subject to consideration by the WRC of effects on regional flow patterns

<u>Wentworth</u>

- Consider feasibility of closing two gaps in levee
- Carry our inspection of levee to assess need for upgrading
- Consider fitting all drainage outlets with screw down gates
- Assess feasibility of installing permanent drainage pumps
- Investigate joint probability of Murray/Darling flooding and effect on adopted flood levels
- Continue with levee maintenance
- Limit village zoning area to that protected by levees
- Promote flood awareness amongst residents
- Maintain flood emergency resources

GHD et al, 1986 states that the Wentworth levees were built in response to the 1956 flood and later strengthened in 1975 to ensure the crest along their entire length was above the 1956 flood level.

B2.3 Gol Gol to Abotsford Bridge Flood Study (DWR, 1990)

The Gol Gol to Abotsford Bridge Flood Study was prepared by DWR on behalf of Wentworth Shire Council and was focussed on the villages of Gol Gol, Buronga and Dareton. DWR, 1990 states that the 1870 flood was 0.2 m higher than the 1956 flood at Mildura and had a rate of rise of 0.9 m/month, as opposed to 1.3 m/month of the 1956 flood.

DWR, 1990 adopted the same flood frequency analysis derived peak flows that were derived by RWC and subsequently presented in GHD et al, 1986 (refer **Table B2.1**).

A cross sectional based HEC-2 model was developed as part of DWR, 1990 which was then calibrated to the 1956 flood, noting that it was deemed at the time to approximate a 1% AEP flood. The model was then used to assess the impact that various levees and bridge crossings have had on flood behaviour, as well as conditions that would have arisen if the 1870 flood had occurred under 1990 floodplain conditions.

B2.4 Murray River - Gol Gol to Abbotsford Bridge Floodplain Management Study (Kinhill Engineers, 1995a)

The structure of the HEC-2 model that was originally developed as part of DWR, 1990 was updated as part of Kinhill Engineers, 1995a. While the updated HEC-2 model was calibrated to the 1956 flood, it was found that in order to calibrate to the 1975 flood it was necessary to develop a second HEC-2 model which incorporated a different set of Manning's n values. Peak flood levels were derived for events with AEPs of 10%, 5%, 2%, 1% and 0.5%. The results of the updated flood modelling were used to describe flood behaviour at the villages of Gol Gol, Buronga and Dareton.

B2.5 Murray River - Gol Gol to Abbotsford Bridge Floodplain Management Plan (Kinhill Engineers, 1995b)

Kinhill Engineering set out a number of recommend flood risk management measures which broadly comprised the following :

- Development within floodway and high hazard areas should not be permitted, and that river set back should be set to only permit development in low hazard areas
- The then current flood standard of providing 750 mm freeboard to the 1% AEP flood be maintained
- Council endeavour to require flood free access for new development up to the 1% AEP flood, but where deemed not feasible, then access to be no lower than the 5% AEP flood.
- A public education program be designed and implemented by Council
- A register of all existing levees should be prepared and licencing should be sought for all unlicenced levees. Maintenance should also be carried out by the owners of all existing levees

Kinhill Engineering, 1995b also includes copies of separate flood studies that were undertaken in relation to a then proposed development at Lot 567 River Drive, Buronga and the then proposed Alcheringa Reserve levee bank at Gol Gol.

B2.6 Rehabilitation of Wentworth Levee - Investigation & Design (WRCS, 1997)

Water Resources Consulting Services (**WRCS**) completed an Environmental Impact Statement for the proposed levee rehabilitation works at Wentworth. The levee rehabilitation works were prompted by an audit of the levee that was conducted in 1992 by NSW Public Works Department (**PWD**).

The proposed works included rehabilitation, upgrading and extensions. The aim of the works was to provide improved flood protection and cater for future urban expansion. Sections of Cadell Street, Perry Street and near the Wharf were of particular focus.

A MIKE-11 one dimensional hydrodynamic computer model was developed to simulate flood behaviour. The model extended 8.3km upstream and 9.2km downstream of Lock 10 on the Murray River, 2.4km upstream of Tuckers Creek Bridge, and 2.7km upstream of Darling River Bridge. Overland flowpaths through Thegoa Lagoon, Thegoa Lagoon breakout and Tuckers Creek breakout were incorporated as separate branches within the model network.

Calibration of the model was based on matching the peak of the 1956 flood at Lock 10, while also considering the distribution of reported flows between the Murray River, Darling River and Tuckers Creek.

WRCS, 1997 states that the highest computed peak 1% AEP flood level and flow velocity in the vicinity of the levee banks was RL 34.75 m AHD and 1.0 m/s, respectively. WRCS, 1997 also states that Council had resolved to adopt a crest level design for the levee to the flood of record, which approximates to the 1% AEP flood plus one metre freeboard.

WRCS, 1997 found that a levee bank built 1 m higher than the flood level for the 1% AEP event would come close to being overtopped by a 0.2% AEP event.

As set out in **Sections B2.9** and **B2.10** of this Appendix, PWA identified that the Hebel panels and associated steel installation brackets which are required for the section of concrete retaining wall behind No. 5-7 Perry Street had at the time not been purchased by Council. Is if further noted that a site inspection that was undertaken in November 2025 identified that there were no brackets fitted to the concrete retaining wall, indicating that these additional measures were still yet to be installed by Council.

B2.7 Wentworth Shire Council Stormwater Management Plan (DPWS, 2007)

Department of Public Works and Services (**DPWS**), 2007 represents an update to an original stormwater management plan that was prepared in 2001 (**SMP, 2001**) and includes updated aims, objectives and work programs for the period 2007 to 2012. DPWS, 2007 noted that a questionnaire was mailed to all householders within the Wentworth, Dareton, Buronga, and Gol Gol in February 2001. An Issues Report was prepared to provide stakeholders with an informed insight into current stormwater issues within each of the stormwater catchments. The report facilitated development of SMP, 2001 by the stormwater planners, based on sound understanding of values and issues as identified through stakeholder consultation.

DPWS, 2007 provides a detailed description of the operating environment, the planning framework and the proposed strategy for managing stormwater runoff at the four urban centres over a 5-year period, noting that these included a range of both structural and non-structural measures.

B2.8 Wentworth Floodplain Risk Management Study (Worley Parsons, 2011)

The stated aims and objectives of Worley Parsons, 2011:

- *"Provide information on flood behaviour and flood hazard, so that community aspirations for future land use can be assessed;*
- *Use the flood model established as part of the Flood Study to assess various options for the development of areas within the floodplain, in terms of impact on existing flood levels and flood hazard;*
- *Provide a framework for revisions to planning instruments such as Local Environmental Plans (LEPs) and Council's policy for development on the floodplains of the Murray and Darling Rivers, so that land use controls are consistent with flood risk and flood hazard; and,*
- *Identify and evaluate emergency response measures for floodplain communities to ensure the safety of residents;*
- *Facilitate the preparation of a Floodplain Risk Management Plan for Wentworth Shire."*

Worley Parsons, 2011 relied on design flood behaviour that was defined as part of an earlier draft version of the Advisian, 2021 (refer **Section B2.10** of this Appendix for details) which was dated June 2010 (Worley Parsons, 2010).

Worley Parsons, 2011 recommended that a Floodplain Risk Management Plan be prepared for Wentworth that incorporates the following:

- *"Inclusion of mapping for Murray River and Darling River floodway zones across the study area into Council's Local Environmental Plan (LEP)*
- *Preparation of a Development Control Plan (DCP) for floodprone land, for inclusion within Council's existing Policy Register. The DCP should contain specific conditions attached to the identified development areas shown in Figure 8.*
- *The relevant clauses in Council's LEP should also be updated to reflect the latest standard clauses for flood prone land suggested by DECCW.*
- *Inclusion of warning times for flooding of SES Operational Sectors relative to known flood levels at upstream flood level gauges within the Wentworth Local Flood Plan (refer Table 7).*
- *Calculations undertaken for this investigation have established that at up to 4 days warning time can be provided based on flood levels recorded at Euston (Murray River) and up to two weeks according to flood levels recorded at Burtundy (Darling River).*
- *Development of a Community Education and Flood Awareness program involving the preparation and distribution of a community information brochure, preparation of a poster display to be posted at community notice boards and convening an annual information session."*

No structural floodplain risk management options were recommended as part of Worley Parsons, 2011.

B2.9 Visual Audit of Wentworth Levee (NSW Public Works Advisory, 2017)

PWA undertook a visual audit of the Eastern and Western levees in June 2017. The aim of the inspection was to enable determination of the following:

- whether the levee is being maintained in accordance with the appropriate Operation and Maintenance Manual/Asset Management Plan or other appropriate maintenance schedule;
- the level of deterioration of the levee since its refurbishment in 2000/2001; and
- if additional investigations are required to confirm the conditions of the levee.

It is noted that visual audits of the two levees were also undertaken by PWA in 2011 and 2016, the findings of which are also documented in PWA, 2017.

The visual audit identified the following issues, noting that these needed to be read as an addition to those previously identified issues that had not been addressed at the time of the 2017 audit:

1. *There are still saplings located on the levee batters that require removal before further growth leads to more expensive repairs.*
2. *If Council has topsoil to spare from other projects, the sections of levee on crown land and council reserves could use some more topsoil on the batters. When applying dump onto batters and level out with a grader. Note: when spreading the topsoil, do not cut into the levee with the grader, this is purely a spreading "on top of batter" exercise. 100mm thickness minimum is recommended.*
3. *Providing there are no stormwater drains that will be affected, mulch added on top of freshly topsoiled batters is recommended to reduce the runoff velocity, hence reducing erosion.*

4. *A crest level survey has been undertaken as part of the audit. Sections of the levee have eroded to levels less than the design crest level. This reduces the protection to the town. Raise the low levels as per the completed report back to design levels.*
5. *In conjunction with the above issue, the wearing course requires thickening back to 100mm after 15 years of weathering since the upgrade in 2000/01. This will mainly apply to where the levee crosses Council reserves and Crown Land. Where landholders are not maintaining the levee crest it may be appropriate to offer 100mm covering of DGB20 or similar.*
6. *Where access is restricted to sections of the levee by way of signage on the levee crest or by gates with private locks, it is recommended that the signage be removed and replaced with a rural 3m gate. The signage can then be attached to the gate and the gate padlocked with a master keyed padlock. Emergency Services and Council can then have access to all parts of the levee for maintenance and during a flood event without having to damage existing infrastructure.*
7. *Ant nests that have been in existence since the 2011 audit should be excavated and repaired. All new nests should be exterminated before excessive damage is caused to the levee structure. Exterminating ants is a very important maintenance issue. Left alone great unseen damage can be achieved, drastically increasing the likelihood of a breach.*
8. *Any water service passing through the levee is required to meet the following minimum requirements.*
   a) *the pipeline is to be located in the top 500 of the levee crest (in the freeboard) and to be no deeper than 100mm on the batters (in the topsoil layer).*
   b) *a stop valve on the inside of the levee structure is required to prevent water passing through the pipe if the pump is removed prior to a flood event.*
9. *While long grass / weeds on levee embankments serve the purpose of bank stabilisation they inhibit the ability to identify potential defects and perform maintenance. Landholders need to be reminded that to correctly maintain their section of levee that slashing / mowing to a moderate height is required.*
10. *It would be advisable to firstly select a location (or locations) inside the levee structures to store stockpiles of clay material to be used to close roadways etc. during a major flood event. Then from the nominated borrow pits to the east of town stockpile sufficient material at each of the strategic locations. Thought must be given to where to locate the material so it is not stolen or used by council for any other purpose.*
11. *As Council have been doing in the past, it is important that stormwater drains continue to be checked, maintained and cleaned at regular intervals.*
12. *The hebel panels and brackets for the wall in Perry St have still not been purchased. It is recommended they are purchased / constructed and stored to be prepared for a major flood event.*

B2.10 Wentworth Levee Owner's Manual [DRAFT rev1] (NSW Public Works Advisory, 2018)

PWA prepared a draft Levee Owner's Manual in 2018 as a Quality Assurance document that provides general assistance to suitably trained and experienced operation staff, managed by Council, to operate and maintain the existing the Wentworth town levees, inclusive of their ancillary and auxiliary structures, equipment, materials, etc.

The manual contains a brief description of the three levees, noting that it states that the design flood level is RL 34.7 m AHD and the three levees incorporate 1 m of freeboard.[1] The manual sets out the inspection and maintenance regime for the three levees, as well as the operations that should be conducted in advance, during and after a flood event.

Appendix F of the manual contains a guide to the installation of the Hebel wall arrangement at Wharf Street on the Western Levee. The guide in Appendix F also states that additional Hebel panels (and steel brackets for installation) are required to be purchased to increase the height of the concrete retaining wall behind No. 5-7 Perry Street, noting further that this is to raise this section of levee to be compliant with 1 m freeboard as per the design.

B2.11 Wentworth Flood Study (Advisian, 2021)

An updated flood study for Wentworth extending downstream from Gol Gol on the Murray River and Upstream from Pomona on the Darling River has undergone multiple revisions dating back as far as June 2010, with the latest draft which was prepared by Advisian (previously Worley Parsons, which was previously Patterson Britton) dated July 2021.

Advisian, 2021 undertook a flood frequency analysis for the Euston stream gauge for the following two scenarios:

- **Scenario 1** – Based on the Euston gauge record for the period 1930 to 2017
- **Scenario 2** – Based on an extended Euston gauge record which included the Mildura gauge record for the period 1870 to 1929.

Each scenario was run through FLIKE, with the LP3 distribution found to best fit the data. **Table B2.2** over the page sets out the results of the flood frequency analysis, noting that Advisian, 2021 recommended that the results of Scenario 1 be adopted for floods up to 2% AEP in magnitude, with the results of Scenario 2 be adopted for rarer floods.

Advisian, 2021 also undertook a flood frequency analysis for the Burtundy stream gauge for the following two scenarios:

- **Scenario 1** – Based on the Burtundy gauge record for the period 1941 to 2017
- **Scenario 2** – Based on the Burtundy gauge record for the period 1941 to 2017 plus one known larger flood (1890) added as censored data.

Each scenario was run through FLIKE, with the LP3 distribution found to best fit the data. **Table B2.2** sets out the results of the flood frequency analysis, noting that Advisian, 2021 recommended that the results of Scenario 2 be adopted for all floods up to the Extreme Flood.

Table B2.2 also includes the design peak flows which were derived for input to the upstream boundary of the hydraulic model on the Great Darling Anabranch, noting these were derived by factoring the ordinance of the discharge hydrographs that were recorded at the Bulpunga stream gauge for the 1974 (10% and 5% AEPs) and 1956 (2%, 1% and 0.5% AEPs) floods.

[1] Note that WRCS, 1997 states that the highest computed peak 1% AAP flood level in the vicinity of the levee banks was RL 34.75 m AHD.

TABLE B2.2
DESIGN PEAK FLOWS(1)
(m^3/s)

Design Flood Event (AEP)	Murray River		Darling River		Great Darling Anabranch
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	
10%	**1,638**	1,377	290	**298**	91
5%	**2,207**	1,929	382	**399**	106
2%	**3,012**	2,869	535	**571**	462
1%	3,654	**3,779**	680	**739**	**598**
0.5%	4,318	**4,899**	857	**949**	**795**
Extreme 3 x 1% AEP)	10,962	**11,337**	2,040	**2,217**	**1,794**

1. Source: Advisian, 2021

The RMA-2 (Resource Management Associates, USA) suite of software was employed as part of Advisian, 2021 to simulate flood behaviour along the Murray and Darling River systems. The model covered the floodplain of the Murray River from Gol Gol to downstream of the Great Darling Anabranch, and the floodplain of the Darling River from north of Pomona to its confluence with the Murray River. The model was calibrated to the 1956 flood and validated to the 1974 flood. It was then used to define flood behaviour for design floods with AEPs of 10%, 5%, 2%, 1% and 0.5%, as well as the Extreme Flood which was assumed to have a peak flow 3 times that of the 1% AEP.

Advisian, 2021 undertook a joint probability analysis based on the coincidence of the peak flow in the Murray and Darling rivers at the time of the 1956 flood. For example, records indicate that during the peak at Lock 10 along the Murray River at Wentworth, the flow in the Darling River at Burtundy corresponded to a 5% AEP flood, while the flow in the Murray River at Wentworth at the time of the peak in the Darling River corresponded to a 2% AEP flood.

To test the sensitivity of peak flood levels at Wentworth to different joint probability scenarios, two additional simulations were run adopting different combinations of events along the Murray and Darling Rivers. The key components of the two scenarios simulated, such as peak flow magnitudes and timing information that were assessed as part of Advisian, 2021 are set out in **Table B2.3**.

TABLE B2.3
ADOPTED JOINT PROBABILITY SCENARIOS(1)

Joint Probability Scenario	Murray River (Inflow 1)		Darling River (Inflow 2)		Great Darling Anabranch (Inflow 3)	
	AEP	Peak Flow (m^3/s)	AEP	Peak Flow (m^3/s)	AEP	Peak Flow (m^3/s)
Base Case (1% AEP)	1%	3,779	1%	739	1%	598
Scenario 1	1%	3,779	5%	399	5%	106
Scenario 2	5%	2,207	1%	739	1%	598

1. Source: Advisian, 2021

Simulation of Joint Probability Scenarios 1 and 2 demonstrated that flood levels near Wentworth and the confluence of the Murray and Darling Rivers are not highly sensitive to changes to peak flows along the Darling River. In this regard, the dominant flooding mechanism was confirmed to be the Murray River with changes along the Darling River likely to impact peak flood levels at Wentworth by less than 0.1 metres. For example, **Plate B2.3** over the page is an extract from Advisian, 2021 which shows that flood levels at Wentworth are significantly more sensitive to Murray River flooding, noting that this finding is supported by the very similar flood level hydrographs for the Base Case 1% AEP Event and Joint Probability Scenario 1.

B2.12 Visual Audit of Curlwaa Levee (NSW Public Works Advisory, 2022)

PWA undertook a visual audit of the Curlwaa Levee in April 2022. PWA, 2022 states that the Curlwaa Levee was originally constructed as a temporary levee at the time of the 1956 flood, with the aim of protecting the village of Curlwaa and surrounding orchards. It also states that Western Murray Irrigation owns and maintains the levee which comprises a series of grassed earth embankments with stormwater pipes/floodgates installed at various locations. From a review of Work-As-Executed drawings that were prepared in 1961, PWA, 2022 concluded that the Curlwaa Levee incorporates a freeboard to the 1956 flood of between 600-900 mm. PWA, 2022 also identified that there are no designated spillways along the Curlwaa Levee.

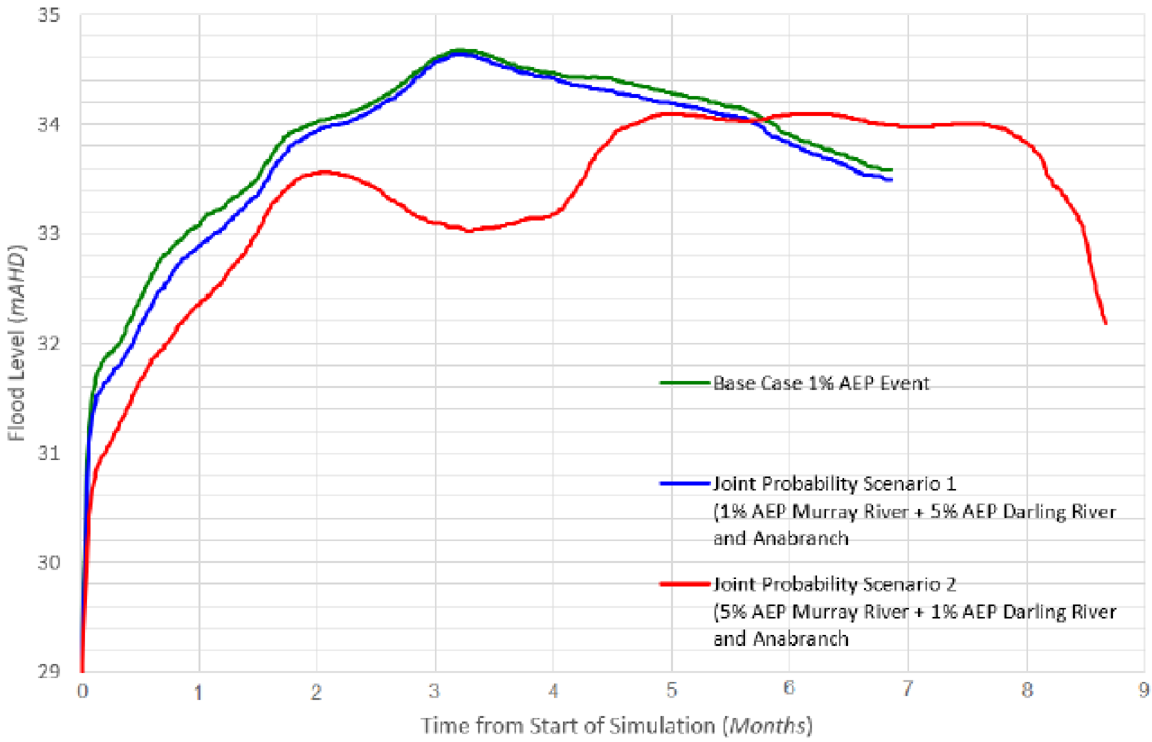


Plate B2.3 – Stage hydrographs at Wentworth for the Base Case 1% AEP Event and Joint Probability Scenario 1 and 2

PWA, 2022 found that the levee was generally in an unacceptable condition and required immediate remediation works, with the following issues given an **unacceptable** rating on the levees:

- Stormwater pipe to be fitted with floodgate
- Road and ramps used by public has lowered crest height
- Over-steep batters
- Permanent conglomeration due to ant nests

- Trees and shrubs present on levee bank
- Surface ruts/depressions/holes present in levee bank
- Access impeded by private land holder
- Privately-owned water supply infrastructure running through levee embankment

PWA, 2022 also identified the issues that have been assigned a **marginal** and **acceptable** rating at multiple locations on the levee.

B2.13 Wentworth Shire Local Flood Emergency Sub Plan (NSW SES, 2023)

NSW SES, 2023 covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding. NSW SES, 2023 provides a description of the historic flooding patterns in the vicinity of Wentworth and the effects of flooding on the community. Annex B of NSW SES, 2023 contains a detailed description of specific areas of risk in Wentworth Shire, these being Wentworth, Gol Gol, Buronga, Dareton and Pooncarie. It also assigns AEPs to historic floods as measured at the Lock 10 stream gauge (refer **Table B2.5** over the page).

Table B2.6 over the page sets out the Minor, Moderate and Major Flood Levels that are presented in Annex C of NSW SES, 2023 for the various stream gauges that are located in the study area.

TABLE B2.5
HISTORIC FLOOD PEAKS AT LOCK 10 STREAM GAUGE[(1)]

Year	Rank	Peak Flood Level (m AHD)	% AEP
1956	1	34.56	1.0
1931	2	34.23	2.6
1974	3	33.83	4.2
1975	4	33.72	5.8
1939	5	33.29	7.4
1973	6	33.19	7.4
1981	7	33.18	10.6
1990	8	33.03	12.2
1964	9	32.92	13.8
1989	10	32.31	15.4
1970	11	31.97	17.0
1983	12	31.89	18.6
1984	13	31.58	20.3
1978	14	31.14	21.9
1976	15	31.10	23.5
1988	16	30.53	25.1

1. Source: NSW SES, 2023

TABLE B2.6
FLOOD CLASSIFICATIONS AND CORRESPONDING GAUGE HEIGHTS FOR WENTWORTH SHIRE STREAM GAUGES[1, 2]

River System	Stream Gauge Name	Stream Gauge No.	Flood Classification		
			Minor	Moderate	Major
Murray	Euston Weir	414991	9.1	9.8	10.3
	Mildura	414202	36.0	37.5	38.5
	Lock 10	425992	7.3 [32.1]	7.9 [32.7]	9.1 [33.9]
Darling	Burtundy	425007	6.1	-	7.7
	Pooncarie	425005	6.8	7.6	8.7

1. Source: NSW SES, 2023
2. Unless otherwise stated, gauge heights are in metres
3. Gauge heights in [ ] are to m AHD

B3 REFERENCES

Advisian, 2021. ***"Wentworth Flood Study"*** [Draft report]

Harrison, 1957. ***"Report on the River Murray Flood Problem"***

Department of Water Resources, 1990. ***"Flood Study Report – Wentworth Shire – Gol Gol to Abbotsford Bridge"***

GHD et al (Gutteridge Haskins & Davey, Cameron McNamara and Laurie Montgomerie & Pettit), 1986. ***"Murray River Flood Plain Management Study – Summary Report"***

Kinhill Engineers, 1995a. ***"Floodplain Management Study – Murray River Gol Gol Bridge to Abbotsford Bridge"***

Kinhill Engineers, 1995b. "***Floodplain Management Plan –Gol Gol to Abbotsford Bridge (NSW only)***"

DPWS (NSW Department of Public Works and Services), 2007. ***"Wenworth Shire Council – Stormwater Management Plan"***

PWA (NSW Public Works Advisory), 2017. ***"Visual Audit of Wentworth Levee"***

PWA (NSW Public Works Advisory), 2018. ***"Wentworth Levee Owner's Manual"***

PWA (NSW Public Works Advisory), 2022. ***"Visual Audit of Curlwaa Levee"***

NSW SES (NSW State Emergency Service), 2023. ***" Wentworth Shire Local Flood Emergency Sub Plan"***

Worley Parsons, 2010. ***"Wentworth Flood Study – Extending Downstream from Gol Gol on the Murray River and Downstream from Pomona on the Darling River"*** [Draft report superseded by Advisian, 2021]

Worley Parsons, 2011. ***"Wentworth Floodplain Risk Management Study – Extending Downstream from Gol Gol on the Murray River and Downstream from Pomona on the Darling River"*** [Draft Report]

WRCS (Water Resources Consulting Services), 1997. ***"Rehabilitation of Wentworth Levee - Investigation & Design"***

ANNEXURE B1

**MURRAY RIVER AT EUSTON
STREAM GAUGE DATA (GS 414203)**

TABLE B1-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT EUSTON STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1870	10.77	GHD, 1986	-	-
1917	10.08			
1931	10.27		2,871	Victoria DECCA Website
1932	-	-	1,075	
1933			631	
1934			976	
1935			858	
1936			1,115	
1937			285	
1938			137	
1939			1,955	
1940			396	
1941			278	
1942			881	
1943			477	
1944			135	
1945			263	
1946			724	
1947			676	
1948			422	
1949			656	
1950			633	
1951			1,275	
1952			1,828	
1953			947	
1954			398	
1955			2,007	
1956			3,493	
1957			788	

TABLE B1-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT EUSTON STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1958	-	-	1,240	Victoria DECCA Website
1959			274	
1960			1,224	
1961			316	
1962			304	
1963			395	
1964			1,542	
1965			349	
1966			394	
1967			418	
1968			467	
1969			467	
1970			1,002	
1971			555	
1972			243	
1973			1,777	
1974	9.83	GHD, 1986	2,289	
1975	9.87		2,367	BoM Water Data Online
1976	3.68	BoM Water Data Online	258	
1977	3.65		257	
1978	6.07		596	
1979	5.96		580	
1980	3.17		224	
1981	9.31		1,752	
1982	1.98		109	
1983	6.96		746	
1984	6.59		692	
1985	4.53		374	
1986	10.08		562	

TABLE B1-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT EUSTON STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1987	4.94	BoM Water Data Online	431	BoM Water Data Online
1988	5.04		439	
1989	7.87		1,008	
1990	8.71		1,358	
1991	6.61		702	
1992	8.98		1,502	
1993	9.56		1,973	
1994	3.12		211	
1995	7.35		846	
1996	8.06		1,073	
1997	2.78		183	
1998	3.17		220	
1999	3.36		239	
2000	6.05		585	
2001	2.45		151	
2002	2.38		146	
2003	3.28		235	
2004	2.52		163	
2005	3.07		214	
2006	2.03		122	
2007	1.81		111	
2008	1.62		93	
2009	2.26		114	
2010	5.2		438	
2011	7.42		819	
2012	5.91		557	
2013	3.98		317	
2014	3.68		287	
2015	2.95		207	

TABLE B1-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT EUSTON STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
2016	9.06	BoM Water Data Online	1,316	BoM Water Data Online
2017	3.3		238	
2018	2.85		195	
2019	2.85		203	
2020	2.62		184	
2021	4.97		433	
2022	10.26		2,374	
2023	6.68		663	
2024	3.97		301	

ANNEXURE B2

MURRAY RIVER AT COLIGNAN STREAM GAUGE DATA (GS 414207)

TABLE B2-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT COLIGNAN STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1960	-	-	1,180	Victoria DECCA Website
1961			311	
1962			311	
1963			411	
1964			1,282	
1965			349	
1966			406	
1967			423	
1968			473	
1969			455	
1970			1,013	
1971			582	
1972			234	
1973			1,450	
1974			2,325	
1975	8.53	BoM Water Data Online	1,806	BoM Water Data Online
1976	7.67		250	
1977	3.98		244	
1978	6.04		537	
1979	5.99		528	
1980	3.57		222	
1981	8.36		1,405	
1982	2.43		113	
1983	6.67		646	
1984	6.47		608	
1985	4.81		368	
1986	5.87		511	
1987	5.22		419	
1988	5.28		427	

TABLE B2-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT COLIGNAN STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1989	7.41	BoM Water Data Online	868	BoM Water Data Online
1990	8.01		1,143	
1991	6.44		602	
1992	8.15		1,243	
1993	8.49		1,542	
1994	3.52		195	
1995	6.97		720	
1996	7.54		923	
1997	3.22		187	
1998	3.51		216	
1999	3.68		234	
2000	6.05		537	
2001	2.84		156	
2002	2.7		143	
2003	3.68		234	
2004	2.89		161	
2005	3.4		206	
2006	2.48		125	
2007	2.31		110	
2008	1.98		84	
2009	2.48		113	
2010	6.14		430	
2011	7.12		763	
2012	6.03		534	
2013	4.36		294	
2014	3.99		268	
2015	3.36		202	
2016	8.24		1,182	
2017	3.77		241	

TABLE B2-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT COLIGNAN STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
2018	3.29	BoM Water Data Online	196	BoM Water Data Online
2019	3.3		197	
2020	3.09		178	
2021	5.23		412	
2022	8.96		2,411	
2023	8.61		629	
2024	4.26		289	

ANNEXURE B3
MURRAY RIVER AT MILDURA
STREAM GAUGE DATA (GS 414202)

TABLE B3-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT MILDURA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1865	33.09		660	
1866	33.68		498	
1867	37.74	Archive Data	1,620	
1868	32.87		579	
1869	33.4		451	
1870	39.37	GHD, 1986	4236	
1871	36.35	Archive Data	1,204	
1872			848	
1873			905	
1874			827	
1875			1,074	
1876			534	
1877			300	
1878			732	Archive Data
1879	-	-	905	
1880			803	
1881			403	
1882			588	
1883			679	
1884			335	
1885			520	
1886			490	
1887			961	
1888	33.36		1493	
1889	37.52		868	
1890	35.96	Archive Data	1,273	
1891	37.28		660	
1892	34.84		972	

TABLE B3-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT MILDURA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1893	36.14	Archive Data	1,528	Archive Data
1894	37.74		903	
1895	35.1		382	
1896	32.89		498	
1897	33.7		475	
1898	33.53		509	
1899	33.73		764	
1900	35.38		498	
1901	33.8		185	
1902	30.81		475	
1903	33.53		509	
1904	33.83		775	
1905	35.2		1,400	
1906	37.36		660	
1907	32.96		417	
1908	33.07		1,458	
1909	37.49		706	
1910	34.88		683	
1911	37.74		556	
1912	34.02		382	
1913	32.82		139	
1914	30.91		775	
1915	35.2		1,470	
1916	37.53		2,315	
1917	39.14		1,192	
1918	36.75		336	
1919	32.48		1,215	
1920	37.06		1,215	
1921	37.07		498	

TABLE B3-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT MILDURA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1922	33.66	Archive Data	1,146	Archive Data
1923	36.63		833	
1924	35.45		833	
1925	34.43		903	
1926	35.77		370	
1927	32.77		521	
1928	32.83		313	
1929	-	-	-	-
1930				
1931	38.17	GHD, 1986	2,428	GHD, 1986
1932	-	-	-	-
1933				
1934				
1935				
1936				
1937				
1938				
1939				
1940				
1941				
1942				
1943				
1944				
1945				
1946				
1947				
1948				
1949				
1950				

TABLE B3-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT MILDURA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1951	-	-	-	-
1952				
1953				
1954				
1955	38.1	GHD, 1986	1,793	GHD, 1986
1956	-	-	3,565	GHD, 1986
1957			-	-
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974	38.43	GHD, 1986	2,123	GHD, 1986
1975	38.53	GHD, 1986	2,141	GHD, 1986

ANNEXURE B4
MURRAY RIVER AT LOCK 10
STREAM GAUGE DATA (GS 425010)

TABLE B4-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT LOCK 10 STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1987	29.710	BoM Water Data Online	415.5	BoM Water Data Online
1988	30.510		578.9	
1989	32.289		1052.1	
1990	33.010		1381.7	
1991	30.770		638.3	
1992	32.689		1216.1	
1993	33.320		1628.4	
1994	28.470		201.4	
1995	31.370		787.0	
1996	31.950		941.0	
1997	28.350		177.5	
1998	29.730		419.4	
1999	28.730		247.6	
2000	30.830		652.7	
2001	28.720		246.0	
2002	28.000		124.5	
2003	28.510		210.0	
2004	28.060		132.3	
2005	28.329		173.6	
2006	27.950		118.4	
2007	28.092		136.6	
2008	28.076		134.4	
2009	28.020		127.0	
2010	31.049		632.7	
2011	32.282		946.4	
2012	32.201		665.1	
2013	29.084		305.5	
2014	28.790		259.7	
2015	28.407		202.5	

TABLE B4-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
MURRAY RIVER AT LOCK 10 STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
2016	32.662	BoM Water Data Online	-	BoM Water Data Online
2017	28.538		-	
2018	28.198		-	
2019	28.291		-	
2020	28.242		-	
2021	29.760		425.5	
2022	34.143		2294.3	
2023	33.885		2029.8	
2024	28.886		-	

ANNEXURE B5

DARLING RIVER AT BURTUNDY
STREAM GAUGE DATA (GS 425007)

TABLE B5-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT BURTUNDY STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1941	5.66	BoM Water Data Online	182	BoM Water Data Online
1942	5.08		157	
1943	4.80		145	
1944	3.70		99	
1945	4.42		129	
1946	3.61		96	
1947	5.56		177	
1948	5.19		162	
1949	5.46		173	
1950	8.53		396	
1951	5.37		148	
1952	6.07		183	
1953	5.77		167	
1954	5.30		125	
1955	6.03		180	
1956	9.61		913	Harrison, 1957
1957	1.22		22	BoM Water Data Online
1958	-	-	101	Advisian, 2021
1959			181	
1960			124	
1961			3	
1962			166	
1963			166	
1964			154	
1965			41	
1966			55	
1967			21	
1968			40	
1969			49	

TABLE B5-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT BURTUNDY STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1970	0.95	BoM Water Data Online	12	BoM Water Data Online
1971	7.75		261	
1972	3.69		80	
1973	4.50		104	
1974	8.48		374	
1975	6.19		170	
1976	9.72		689	
1977	6.91		198	
1978	6.64		186	
1979	0.95		10	
1980	2.66		49	
1981	0.77		3	
1982	2.15		37	
1983	7.39		231	
1984	6.70		189	
1985	0.79		4	
1986	1.37		20	
1987	1.02		12	
1988	5.71		142	
1989	6.80		194	
1990	7.68		256	
1991	3.51		74	
1992	1.30		22	
1993	1.31		22	
1994	1.68		30	
1995	2.24		42	
1996	5.53		144	
1997	4.42		102	
1998	7.69		251	

TABLE B5-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT BURTUNDY STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1999	4.32	BoM Water Data Online	99	BoM Water Data Online
2000	2.38		45	
2001	6.10		164	
2002	0.70		5	
2003	0.74		2	
2004	2.53		49	
2005	0.85		5	
2006	0.79		3	
2007	0.74		1	
2008	2.27		43	
2009	1.03		12	
2010	5.68		140	
2011	7.41		231	
2012	7.41		231	
2013	4.20		86	
2014	2.17		4	
2015	-	-	-	-
2016	1.27	BoM Water Data Online	21	BoM Water Data Online
2017	2.93		59	
2018	0.74		1	
2019	0.54		1	
2020	1.75		24	
2021	2.01		36	
2022	6.12		163	
2023	8.27		296	
2024	2.26		41	

ANNEXURE B6
DARLING RIVER AT POONCARIE
STREAM GAUGE DATA (GS 425005)

TABLE B6-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT POONCARIE STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1913	5.92	BoM Water Data Online	152	BoM Water Data Online
1914	3.3		66	
1915	2.31		36	
1916	6.30		165	
1917	6.76		180	
1918	6.76		180	
1919	1.45		16	
1920	6.91		185	
1921	7.54		206	
1922	6.55		173	
1923	2.85		52	
1924	5.66		144	
1925	6.10		158	
1926	5.08		124	
1927	4.47		103	
1928	5.64		143	
1929	4.95		120	
1930	4.55		105	
1931	6.63		176	
1932	5.56		140	
1933	5.77		147	
1934	5.94		153	
1935	5.56		140	
1936	3.81		81	
1937	5.51		138	
1938	4.17		92	
1939	5.00		121	
1940	3.81		81	
1941	6.25		163	

TABLE B6-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT POONCARIE STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1942	5.59	BoM Water Data Online	141	BoM Water Data Online
1943	5.31		132	
1944	4.19		93	
1945	4.90		118	
1946	4.19		93	
1947	6.15		160	
1948	5.74		146	
1949	5.99		155	
1950	7.79		216	
1951	7.86		219	
1952	6.71		179	
1953	6.33		166	
1954	6.02		155	
1955	6.50		172	
1956	8.20		232	
1957	-	-	-	-
1958				
1959				
1960				
1961				
1962				
1963	6.40	BoM Water Data Online	168	BoM Water Data Online
1964	-	-	-	-
1965				
1966	3.10	BoM Water Data Online	60	BoM Water Data Online
1967	-	-	-	-
1968				
1969				
1970				

TABLE B6-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT POONCARIE STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1971	-	-	-	-
1972				
1973				
1974	7.95	BoM Water Data Online	222	BoM Water Data Online
1975	6.67		177	
1976	8.39		238	
1977	7.05		190	
1978	6.88		184	
1979	6.46		170	
1980	3.11		60	
1981	2.84		52	
1982	3.72		78	
1983	7.50		206	
1984	6.97		187	
1985	5.78		147	
1986	2.31		37	
1987	-	-	-	
1988				
1989	7.12	BoM Water Data Online	193	BoM Water Data Online
1990	7.72		214	
1991	4.21		94	
1992	-	-	-	-
1993	2.14	BoM Water Data Online	63	BoM Water Data Online
1994	-	-	-	-
1995				
1996				
1997				
1998				
1999				

TABLE B6-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT POONCARIE STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
2000	-	-	-	-
2001				
2002				
2003	1.71	BoM Water Data Online	2	BoM Water Data Online
2004	3.16		70	
2005	2.01		4	
2006	1.91		2	
2007	1.90		2	
2008	2.84		47	
2009	2.21		14	
2010	6.60		172	
2011	7.58		246	
2012	7.9		338	
2013	4.67		101	
2014	3.05		42	
2015	1.87		3	
2016	2.57		22	
2017	3.57		62	
2018	1.73		2	
2019	1.7		2	
2020	3.20		27	
2021	6.07		152	
2022	7.29		219	
2023	7.81		326	
2024	3.10		44	

ANNEXURE B7
DARLING ANABRANCH AT BULPUNGA
STREAM GAUGE DATA (GS 425011)

TABLE B7-1
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT BULPUNGA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Discharge Data
1955	2.44	BoM Water Data Online	20	WaterNSW Rating Table 178
1956	6.30		700	Visual Extrapolation of WaterNSW Rating Table 178
1957	2.03		105	WaterNSW Rating Table 178
1958	-	-	-	
1959	2.58	BoM Water Data Online	22	
1960	0.33		0	
1961	-	-	-	
1962	2.46	BoM Water Data Online	20	
1963	2.57		22	
1964	-	-	-	
1965	2.29	BoM Water Data Online	17	
1966	1.96		12	
1967	2.34		18	
1968	2.39		19	
1969	2.57		22	
1970	2.26		17	
1971	2.52		21	
1972	2.16		15	
1973	2.64		24	
1974	3.99		110	
1975	1.91		11	
1976	5.49		382	
1977	1.42		8	
1978	2.36		18	
1979	2.54		22	
1980	2.34		18	
1981	2.59		23	
1982	2.39		19	
1983	2.52		21	

TABLE B7-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT BULPUNGA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Gauge Height Data
1984	2.50	BoM Water Data Online	21	WaterNSW Rating Table 178
1985	2.21		0.946	BoM Water Data Online
1986	2.36		6.146	
1987	2.41		6.583	
1988	2.61		8.456	
1989	2.76		4.65	
1990	3.98		113.964	
1991	2.34		37.449	
1992	1.12		1.387	
1993	2.42		1.655	
1994	2.22		1.57	
1995	1.84		0	
1996	2.44		6.514	
1997	2.46		6.02	
1998	2.67		5.04	
1999	2.50		5.04	
2000	2.46		4.989	
2001	2.56		5.012	
2002	2.44		4.955	
2003	0.53		0	
2004	0.53		0	
2005	0.53		0	
2006	0.52		0	
2007	0.53		0	
2008	0.52		0	
2009	0.58		0	
2010	2.37		15.774	
2011	1.17		12.669	
2012	2.63		21.425	

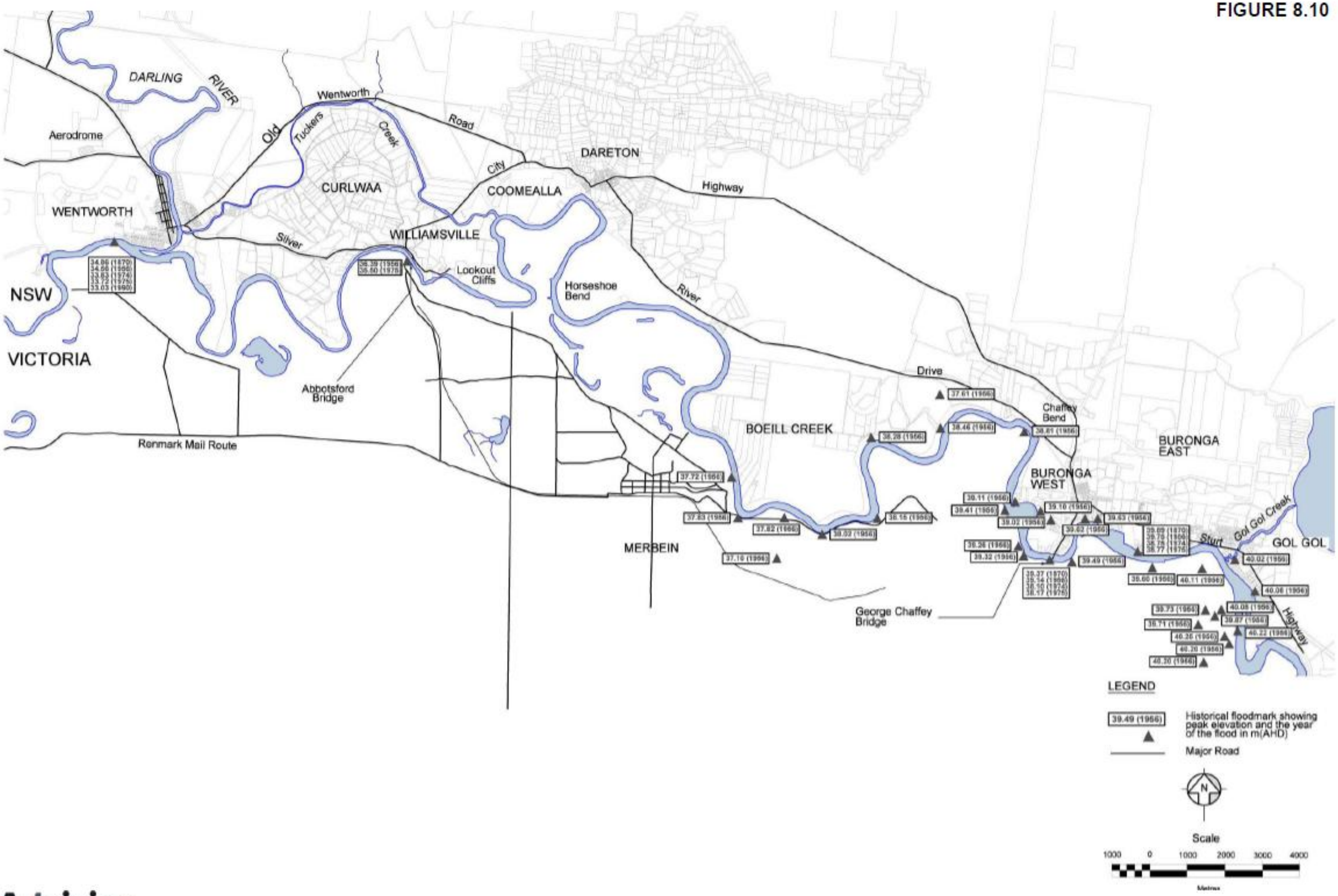
TABLE B7-1 (Cont'd)
RECORDED PEAK HEIGHT AND DISCHARGE DATA IN DATE ORDER
DARLING RIVER AT BULPUNGA STREAM GAUGE

Year	Gauge Height (m)	Source of Gauge Height Data	Discharge (m^3/s)	Source of Gauge Height Data
2013	1.78	BoM Water Data Online	7.875	BoM Water Data Online
2014	0.59		1.259	
2015	0.62		0.174	
2016	0.06		0	
2017	2.01		10.262	
2018	0.06		0	
2019	0.06		0	
2020	0.06		0	
2021	1.72		8.529	
2022	1.81		11.136	
2023	4.58		122.204	
2024	1.30		6.06	

ANNEXURE B8

EXTRACT FROM ADVISIAN, 2021

FIGURE 8.10



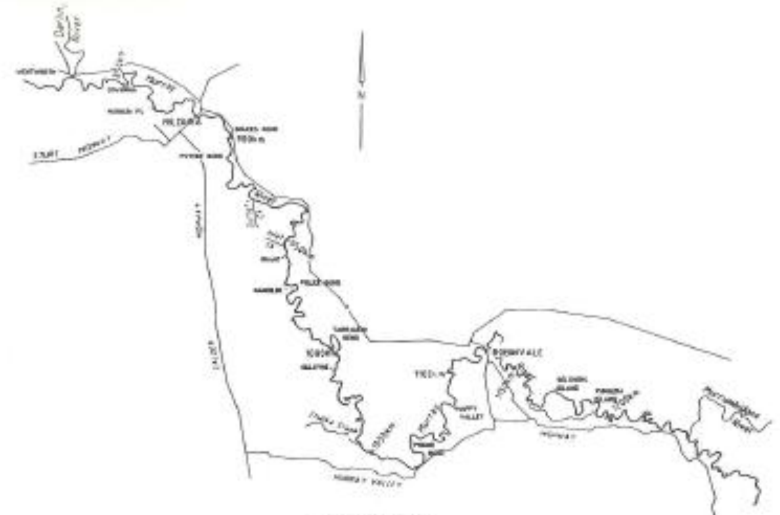
Advisian

Rp301015-03729 – Wentworth Flood Study
fg301015-03729rg200701-Fig 8.10_Historic Flood Marks (Murray River)

LOCATION OF HISTORIC FLOOD MARKS ALONG THE MURRAY RIVER

ANNEXURE B9

EXTRACT FROM GHD ET AL, 1986



LOCALITY PLAN

NOTES

1. Flood level information was obtained from the following sources:-

(a) 1975 Flood Levels - R.W.C. Plan No. [illegible] (Sheets 1-[illegible]) and R.W.C. Plan No. 136092.

(b) 1956 Flood Levels - R.W.C. Plan No. [illegible] and Plan No. [illegible]

2. 1956 and 1975 flood levels were also obtained at Locks 6, 7, 8, and 9 along the Murray River from a point 18km west of the South Australian border to Wentworth. These levels are not shown on this longitudinal section but are as follows:-

Location	River R.D (km)	1956 Flood Level (m A.H.D.)	1975 Flood Level (m A.H.D.)
Lock No.6	635.3	22.63	20.57
S.A./Vict. border	652.9	-	-
Lock No. 7	702.9	26.33	25.72
Lock No. 8	732.0	28.08	27.39
Lock No. 9	771.6	30.76	29.98

3. River Running Distances can be obtained from the following plans:-

(a) South Australian Border to Wentworth - R.W.C. Plan No. 147364

(b) Wentworth to Murrumbidgee River - R.W.C. Plan No. 146579 (Sheets 1-10)

(c) The Murray River Running distances shown on the above plans were established using the method indicated in the note below "Determination of Murray River Distances".

4. Statistical analysis at Mildura and Euston has indicated that the August, 1956 flood is equivalent to the "1% probability flood" between Mildura and the Murrumbidgee River. It can also be assumed that the 1956 flood is equivalent to the 1% flood between Mildura and the South Australian border. This is the flood prescribed by Sec. 378 of the Drainage of Land Act, 1975 for flood plain management purposes. The 1% flood is regarded as having a probability of occurrence of 1% in any one year, i.e. on average it will occur once in 100 years.

5. The August, 1956 (ie. 1% flood profile) is based on observed 1956 flood level information. Accordingly, this profile applies to 1956 conditions.

6. Statistical analysis at Mildura and Euston has indicated that the December, 1975 flood has a 4% probability of occurrence.

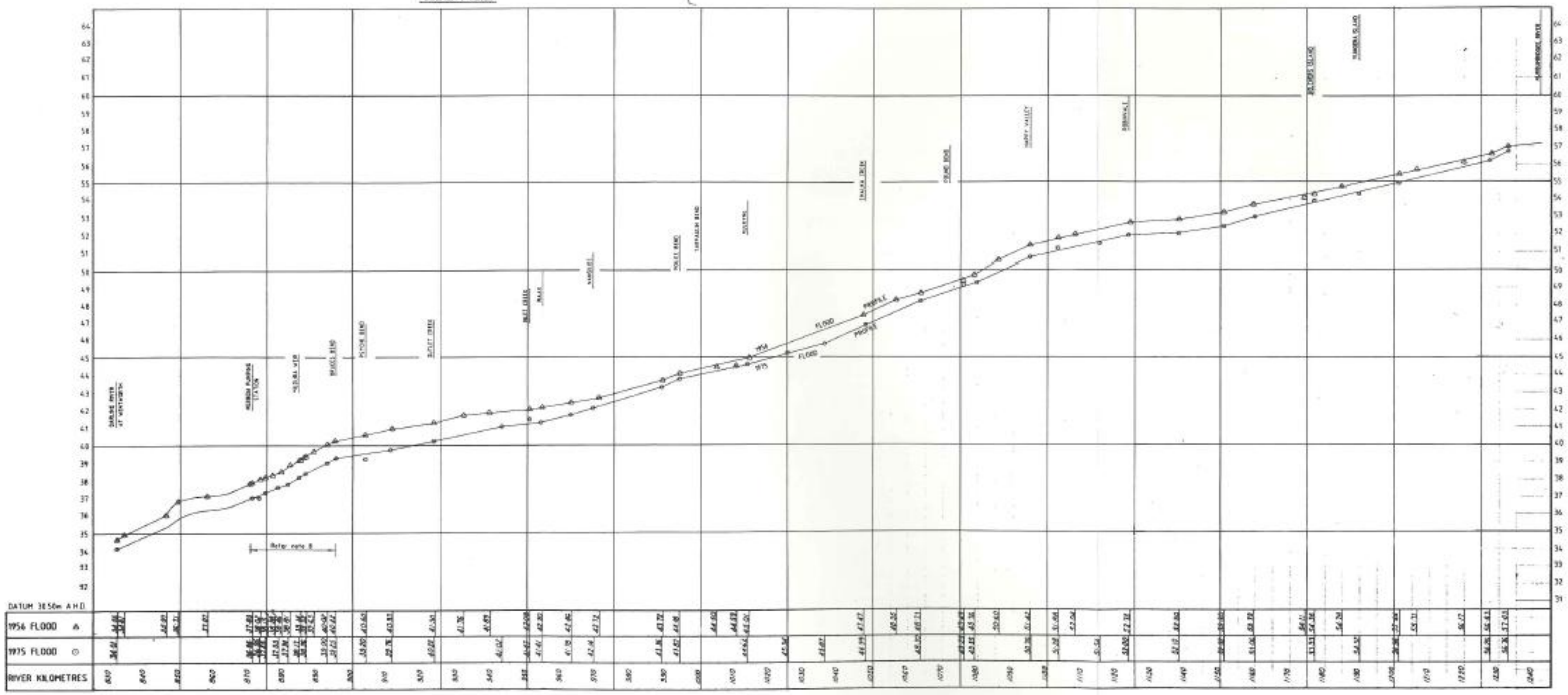
7. All flood levels are shown in metres to Australian Height Datum.

8. Between River Running Distances 870 and 896 the following R.W.C. Plans provide more information:-

(a) Longitudinal Sections of 1956, 1974 and 1975 Flood - Plan No. 136092.

(b) Designation Plan No. 135095 (Sheets 1-21) - Mildura.

(c) Proclamation Plan No. 147052 (Sheets 1-21) - Mildura.



SCALES

VERTICAL

HORIZONTAL & LOCALITY

NOTE:
THESE PROFILES ARE REPRODUCED AT FULL SCALE IN THE FLOOD ATLAS.

MURRAY RIVER FLOOD PLAIN MANAGEMENT STUDY	
WENTWORTH TO MURRUMBIDGEE RIVER FLOOD PROFILES (RWC)	GHD-CM-LMP
	FIGURE 4.3

ANNEXURE B10

PHOTOGRAPHS SHOWING FLOODING THAT WAS EXPERIENCED AT TIME OF 1956 FLOOD

Plate B10.1 – 1956 Flood. Mildura (Source: GHD et al, 1986)

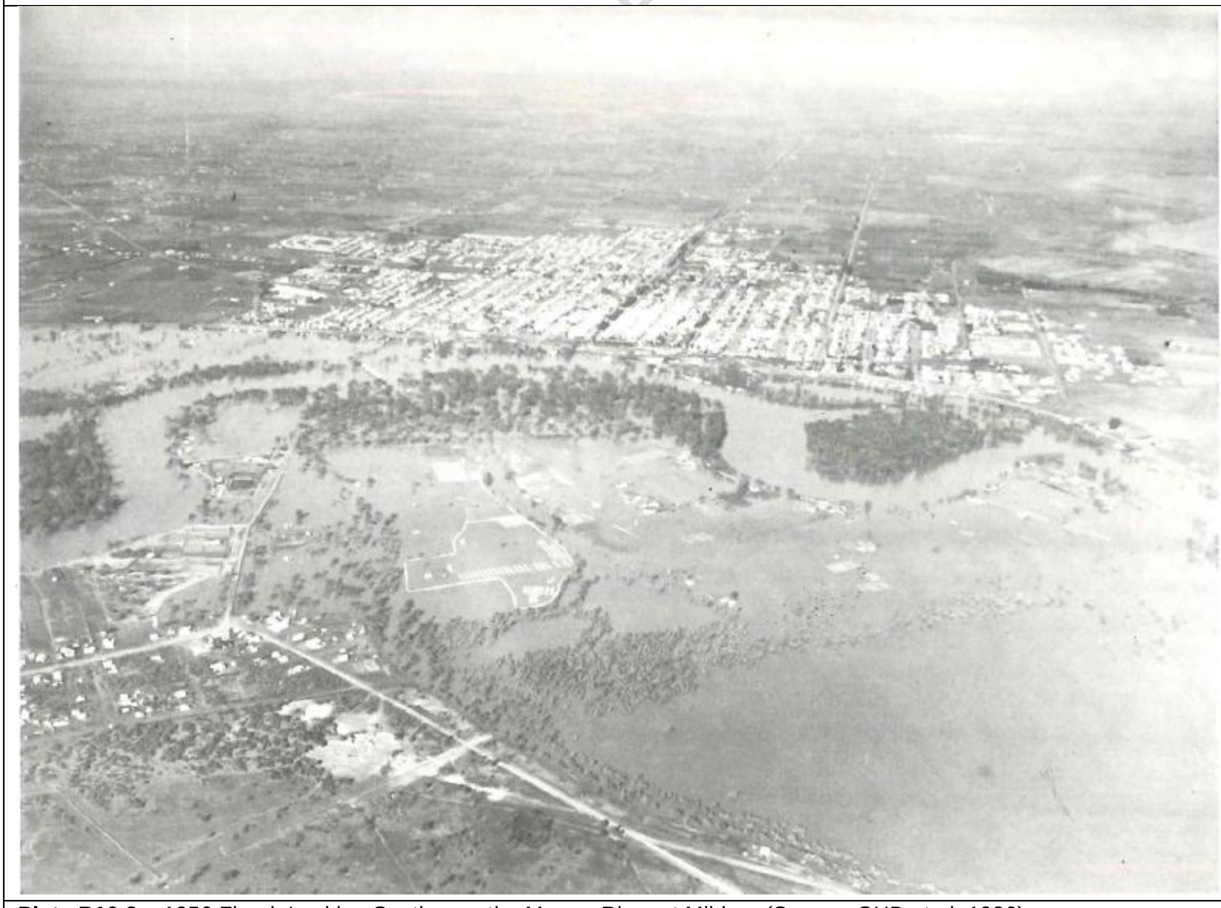


Plate B10.2 – 1956 Flood. Looking South over the Murray River at Mildura (Source: GHD et al, 1986)

Plate B10.3 – 1956 Flood. Looking upstream past Mildura (Source: GHD et al, 1986)

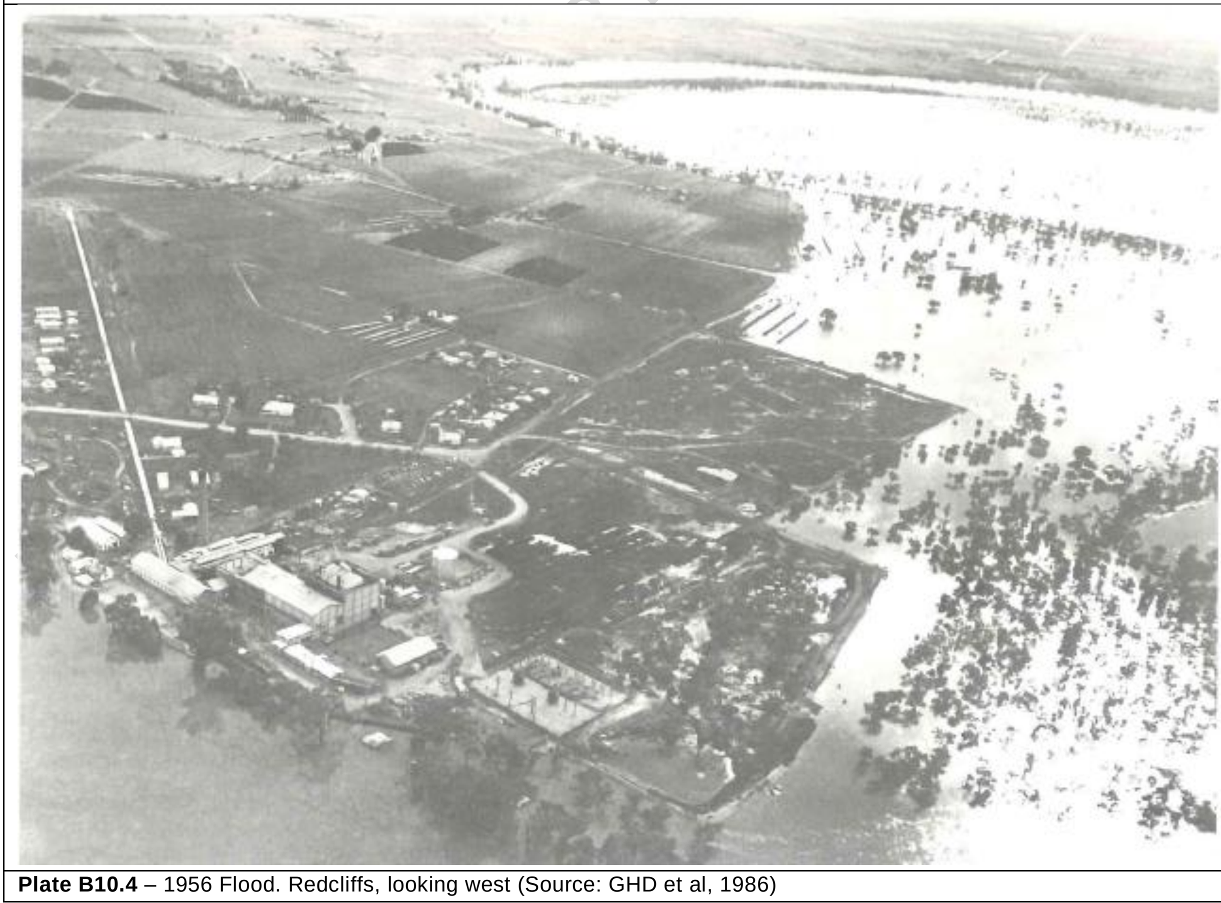


Plate B10.4 – 1956 Flood. Redcliffs, looking west (Source: GHD et al, 1986)

Plate B10.5 – 1956 Flood. Looking downstream past Merbein (Source: GHD et al, 1986)

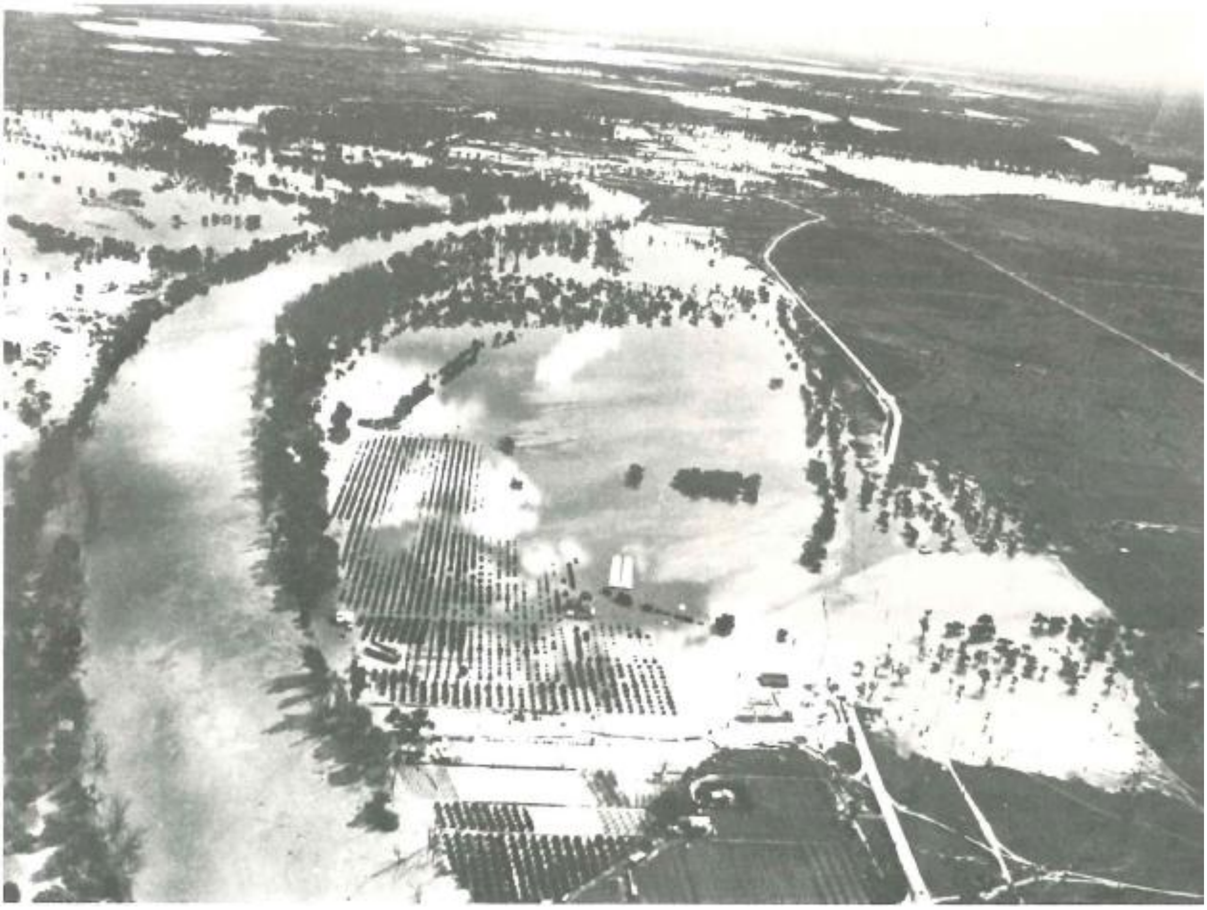


Plate B10.6 – 1956 Flood. Looking downstream over Gol Gol (Source: GHD et al, 1986)

Plate B10.7 – 1956 Flood. Looking downstream over Abbotsford Bridge (between Mildura and Wentworth) (Source: GHD et al, 1986)

Plate B10.8 – 1956 Flood. Looking downstream over Wentworth. Darling River in foreground (Source: GHD et al, 1986)

Plate B10.9 – 1956 Flood. Looking south towards Tucker's Creek Bridge, Silver City Highway (Source: GHD et al, 1986)

Plate B10.10 – 1956 Flood. Looking downstream along Darling River at Wentworth. Murray River in background (Source: Advisian, 2021)

Plate B10.11 – 1956 Flood. Looking north-west over Wentworth from near confluence of Murray and Darling Rivers (Source: Advisian, 2021)

Plate B10.12 – 1956 Flood. Looking north-west towards the hospital, Darling River and Wentworth (Source: Advisian, 2021)

ANNEXURE B11

PHOTOGRAPHS SHOWING FLOODING THAT WAS EXPERIENCED AT TIME OF 2022 FLOOD


30 Nov 2022 at 2:46:40 pm
59 Darling St
Wentworth NSW 2648
Australia


30 Nov 2022 at 2:46:42 pm
59 Darling St
Wentworth NSW 2648
Australia


30 Nov 2022 at 2:46:55 pm
59 Darling St
Wentworth NSW 2648
Australia
STOP


30 Nov 2022 at 2:47:33 pm
Wharf St
Wentworth NSW 2648
Australia
Port of Wentworth


30 Nov 2022 at 2:49:22 pm
Wharf St
Wentworth NSW 2648
Australia
Port of Wentworth
WSC


30 Nov 2022 at 2:49:53 pm
Wharf St
Wentworth NSW 2648
Australia
Port of Wentworth


30 Nov 2022 at 2:50:17 pm
Wharf St
Wentworth NSW 2648
Australia
Port of Wentworth


30 Nov 2022 at 2:52:57 pm
Silver City Highway
Wentworth NSW 2648
Australia


30 Nov 2022 at 2:53:50 pm
Silver City Highway
Wentworth NSW 2648
Australia


30 Nov 2022 at 2:54:21 pm
Silver City Highway
Wentworth NSW 2648
Australia


30 Nov 2022 at 2:55:22 pm
Silver City Highway
Wentworth NSW 2648
Australia
Wentworth Region


30 Nov 2022 at 2:57:41 pm
2978–2998 Silver City Highway
Wentworth NSW 2648
Australia
ADOPT-A-ROAD
LITTER REMOVAL
WENTWORTH
ROTARY CLUB


30 Nov 2022 at 3:03:21 pm
2414–2418 Silver City Highway
Curlwaa NSW 2648
Australia


30 Nov 2022 at 3:04:11 pm
2414–2418 Silver City Highway
Curlwaa NSW 2648
Australia


30 Nov 2022 at 3:06:23 pm
2401–2419 Silver City Highway
Curlwaa NSW 2648
Australia


30 Nov 2022 at 3:06:50 pm
2401–2419 Silver City Highway
Curlwaa NSW 2648
Australia


30 Nov 2022 at 3:07:42 pm
2421–2433 Silver City Highway
Curlwaa NSW 2648
Australia

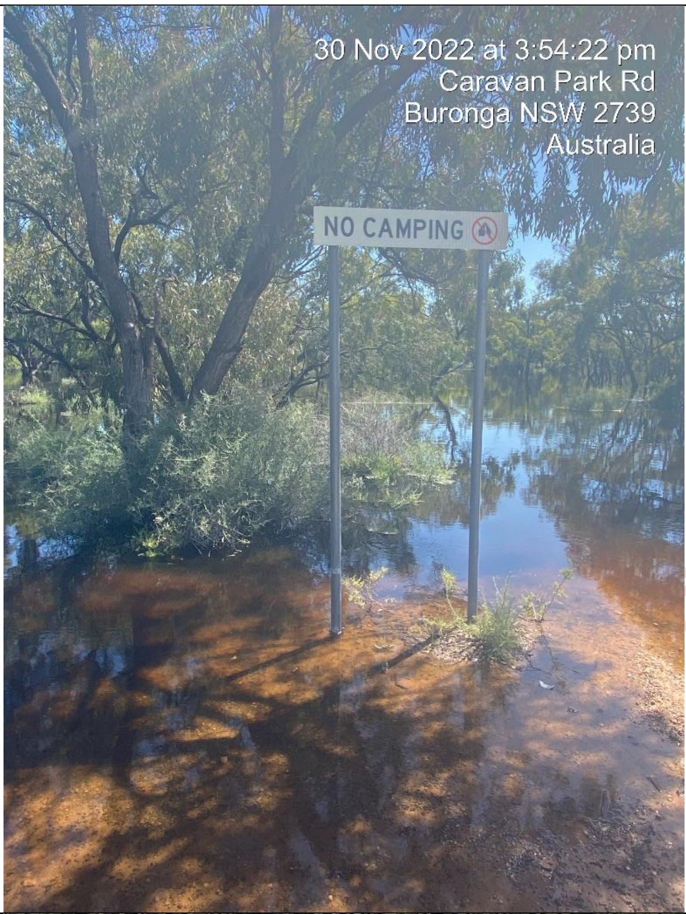

30 Nov 2022 at 3:11:02 pm
2369 Silver City Highway
Curlwaa NSW 2648
Australia


30 Nov 2022 at 3:18:49 pm
8 Kookaburra Dr
Dareton NSW 2717
Australia


30 Nov 2022 at 3:36:39 pm
63–153 Carramar Dr
Gol Gol NSW 2738
Australia


30 Nov 2022 at 3:42:41 pm
Ferdi Way
Gol Gol NSW 2738
Australia


30 Nov 2022 at 3:45:37 pm
Ferdi Way
Gol Gol NSW 2738
Australia


30 Nov 2022 at 3:54:22 pm
Caravan Park Rd
Buronga NSW 2739
Australia
NO CAMPING


30 Nov 2022 at 3:54:32 pm
Caravan Park Rd
Buronga NSW 2739
Australia
NGA RIVERSIDE


30 Nov 2022 at 3:54:56 pm
Caravan Park Rd
Buronga NSW 2739
Australia


30 Nov 2022 at 3:54:49 pm
Caravan Park Rd
Buronga NSW 2739
Australia


30 Nov 2022 at 3:59:47 pm
14 River Dr
Buronga NSW 2739
Australia
LOW CLEARANCE ON SIDE ROAD 3.3 m


30 Nov 2022 at 3:59:26 pm
14 River Dr
Buronga NSW 2739
Australia
12 RIVER DRIVE


30 Nov 2022 at 4:00:25 pm
14 River Dr
Buronga NSW 2739
Australia


30 Nov 2022 at 4:07:37 pm
143 Hugh King Drive
Mildura VIC 3500
Australia


30 Nov 2022 at 4:07:13 pm
143 Hugh King Drive
Mildura VIC 3500
Australia


30 Nov 2022 at 4:07:14 pm
143 Hugh King Drive
Mildura VIC 3500
Australia


30 Nov 2022 at 4:08:46 pm
143 Hugh King Drive
Mildura VIC 3500
Australia


30 Nov 2022 at 4:09:23 pm
143 Hugh King Drive
Mildura VIC 3500
Australia
1956
FLOOD LEVEL


30 Nov 2022 at 4:10:32 pm
147 Hugh King Drive
Mildura VIC 3500
Australia
Mildura Rowing Club Lawns
WARNING
INFORMATION
REGULATIONS

GOL GOL AND BURONGA

Plate B11.1 – Gol Gol Creek Regulator a few weeks before the peak [*Photo taken on 29/11/2022 at 12:25 hours*]

Plate B11.2 – Gol Gol Creek coming up to Sturt Highway a few week before the peak [*Photo taken on 29/11/2022 at 12:27 hours*]

Plate B11.3 – Gol Gol Creek close to flooding Sturt Highway [*Photo taken on 29/11/2022 at 12:28 hours*]

GOL GOL AND BURONGA

Plate B11.4 – Looking east along West Road, Buronga [*Photo taken on 14/12/2022 at 16:33 hours*]

Plate B11.5 – Property on River Drive with inundated yard [*Photo taken on 14/12/2022 at 16:37 hours*]

GOL GOL AND BURONGA

Plate B11.6 – Looking east along the rear of residential properties that are located on River Drive [*Photo taken on 14/12/2022 at 16:42 hours*]

Plate B11.7 – Looking east along residential property near Carbone Court [*Photo taken on 14/12/2022 at 16:44 hours*]

Plate B11.8 – Property on Murray Street elevated [*Photo taken on 15/12/2022 at 10:30 hours*]

GOL GOL AND BURONGA

Plate B11.9 – Property on Murray Street inundated [*Photo taken on 15/12/2022 at 10:38 hours*]

Plate B11.10 – Looking south-east along the rear of residential property on Murray Street [*Photo taken on 15/12/2022 at 10:57 hours*]

GOL GOL AND BURONGA

Plate B11.11 – Looking north-west along the rear of properties along Murray Street [*Photo taken on 15/12/2022 at 10:57 hours*]

Plate B11.12 – Looking north-west along the side of property on Wilga Road South [*Photo taken on 15/12/2022 at 11:23 hours*]

Plate B11.13 – Looking north-west at flooding on the corner of Wilga Road South and Murray Street [*Photo taken on 15/12/2022 at 11:35 hours*]

GOL GOL AND BURONGA

Plate B11.14 – Looking east along the rear of residential property on Carramar Drive [*Photo taken on 15/12/2022 at 12:21 hours*]

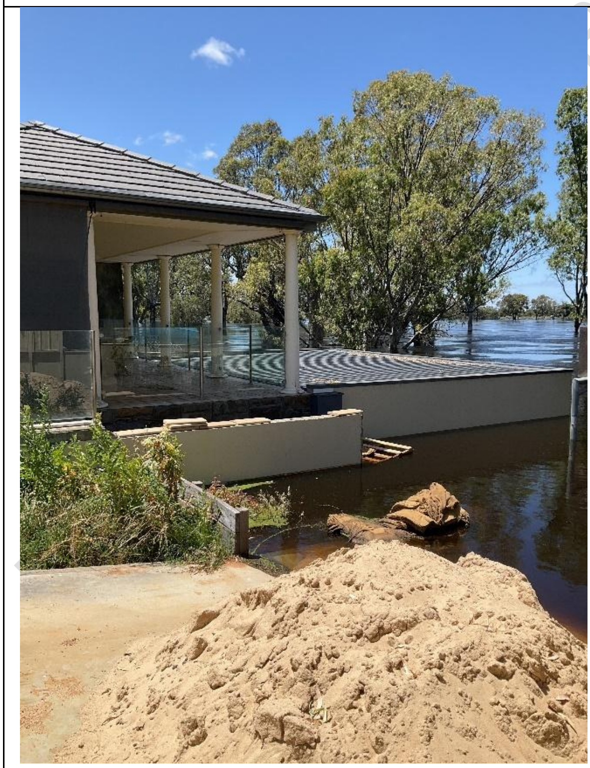


Plate B11.15 – Looking east along the rear of residential property on Carramar Drive [*Photo taken on 15/12/2022 at 12:28 hours*]

Plate B11.16 – Looking south along the rear of residential property on Carramar Drive [*Photo taken on 15/12/2022 at 12:30 hours*]

GOL GOL AND BURONGA

	
Plate B11.17 – Looking east along the rear of residential property on Carramar [*Photo taken on 15/12/2022 at 12:34 hours*]	**Plate B11.18** – Looking south at the extent of water approaching properties on Carramar Drive [*Photo taken on 15/12/2022 at 12:46 hours*]
	
Plate B11.19 – Looking south along the rear of residential property on Carramar Drive [*Photo taken on 15/12/2022 at 13:09 hours*]	**Plate B11.20** – Looking south along the rear of residential property on Carramar Drive [*Photo taken on 15/12/2022 at 13:24 hours*]

GOL GOL AND BURONGA

Plate B11.21 – Property on Punt Road protected by levee [*Photo taken on 15/12/2022 at 14:07 hours*]

Plate B11.22 – Looking south at a levee near Sturt Highway [*Photo taken on 15/12/2022 at 14:23 hours*]

Plate B11.23 – Looking south along a levee near Sturt Highway [*Photo taken on 15/12/2022 at 14:24 hours*]

GOL GOL AND BURONGA

Plate B11.24 – Property on Sturt Highway [*Photo taken on 15/12/2022 at 14:31 hours*]

Plate B11.25 – Looking west along a levee behind a property near Sturt Highway [*Photo taken on 15/12/2022 at 14:31 hours*]

GOL GOL AND BURONGA

Plate B11.26 – Looking east along a levee behind property near Sturt Highway [*Photo taken on 15/12/2022 at 14:32 hours*]

Plate B11.27 – Looking west along a levee behind property near Sturt Highway [*Photo taken on 15/12/2022 at 14:52 hours*]

GOL GOL AND BURONGA

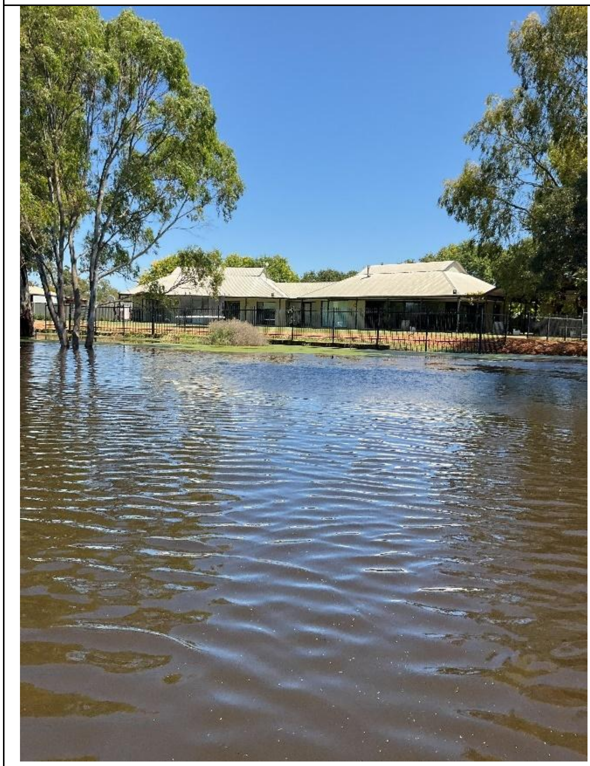


Plate B11.28 – Looking north at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:39 hours*]

Plate B11.29 – Looking north at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:39 hours*]

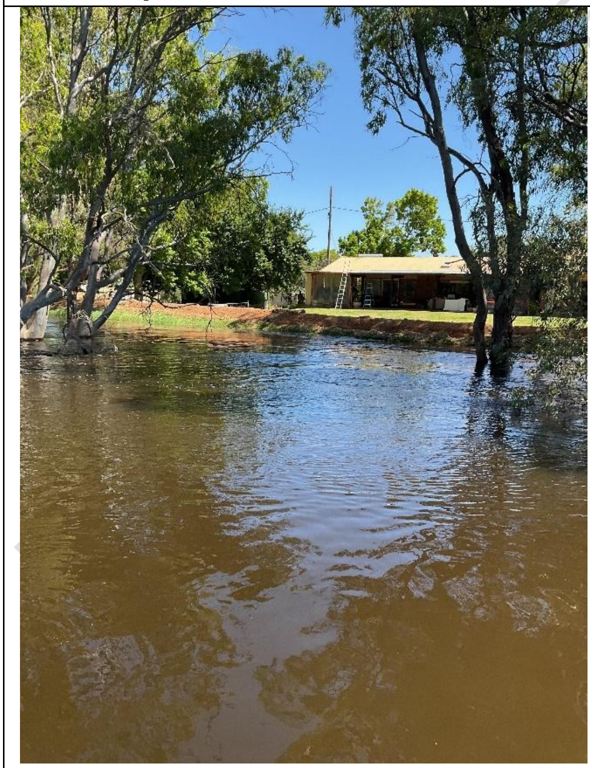


Plate B11.30 – Looking north at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:40 hours*]

Plate B11.31 – Looking north at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:41 hours*]

GOL GOL AND BURONGA

Plate B11.32 – Looking north at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:43 hours*]

Plate B11.33 – Looking east at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:39 hours*]

Plate B11.34 –Looking east at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:45 hours*]

Plate B11.35 – Looking east at a levee near Pitman Avenue West [*Photo taken on 16/12/2022 at 11:47 hours*]

DARETON

Plate B11.36 – Looking south along an inundated Kookaburra Drive [*Photo taken on 01/12/2022 at 09:51 hours*]

Plate B11.37 – Looking north at Coomealla Golf Club [*Photo taken on 17/12/2022 at 13:08 hours*]

DARETON

Plate B11.38 – Looking south-west at an inundated storage shed near Coomealla Golf Club [*Photo taken on 01/12/2022 at 13:20 hours*]

Plate B11.39 – Looking north at an inundated residential property at the end of Twin Isle Drive [*Photo taken on 17/12/2022 at 13:28 hours*]

Plate B11.40 – Looking north at an inundated shed at the end of Twin Isle Drive [*Photo taken on 17/12/2022 at 13:38 hours*]

DARETON

Plate B11.41 – Looking south-west at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 13:54 hours*]

Plate B11.42 – Looking south east at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 14:09 hours*]

DARETON

Plate B11.43 – Looking south-west at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 14:24 hours*]

Plate B11.44 – Looking south at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 14:26 hours*]

Plate B11.45 – Looking south at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 14:26 hours*]

Plate B11.46 – Looking west at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 14:26 hours*]

DARETON

Plate B11.47 – Looking south-west at a residential property near Ryans Road [*Photo taken on 17/12/2022 at 14:24 hours*]

CURLWAA

Plate B11.48 – Looking south-west at the Curlwaa levee north of Box Tree Lane [*Photo taken on 19/11/2022 at 09:06 hours*]

Plate B11.49 – Looking-west at the Curlwaa levee north of Box Tree Lane [*Photo taken on 19/11/2022 at 09:06 hours*]

Plate B11.50 – Looking east at the Curlwaa levee north of Box Tree Lane [*Photo taken on 19/11/2022 at 10:58 hours*]

Plate B11.51 – Looking south west at the Curlwaa levee north of Box Tree Lane [*Photo taken on 24/11/2022 at 15:55 hours*]

CURLWAA

Plate B11.52 – Looking west at the Curlwaa levee near the intersection of Delta Road and Silver City Highway [*Photo taken on 24/11/2022 at 16:59 hours*]

Plate B11.53 – Looking west along a levee near Murray Road [*Photo taken on 14/12/2022 at 15:34 hours*]

CURLWAA

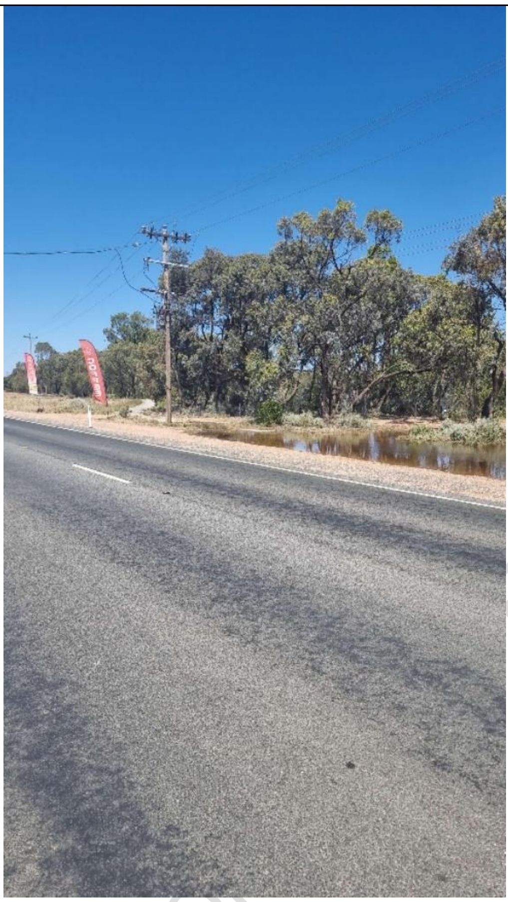


Plate B11.54 – Looking east along Silver City Highway near its intersection with Manly Road [*Photo taken on 15/12/2022 at 15:28 hours*]

Plate B11.55 – Looking south near the intersection of Silver City Highway and Manly Road [*Photo taken on 15/12/2022 at 15:28 hours*]

WENTWORTH

Plate B11.56 – Looking north east along the western side of the airport levee [*Photo taken on 18/11/2022 at 11:16 hours*]

Plate B11.57 – Looking south near the western side of the airport levee [*Photo taken on 18/11/2022 at 11:16 hours*]

Plate B11.58 – Looking east at Renmark Road in vicinity of the airport [*Photo taken on 21/11/2022 at 10:21 hours*]

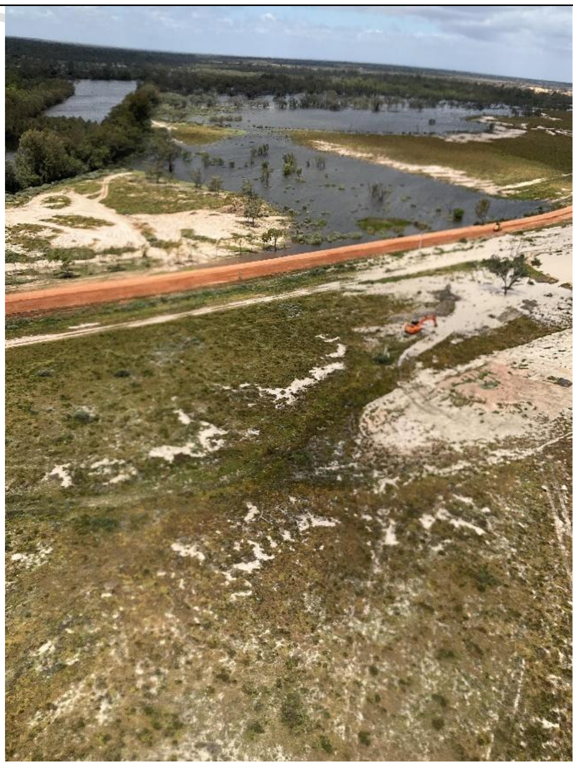


Plate B11.59 – Looking west at Renmark Road in vicinity of the airport [*Photo taken on 21/11/2022 at 12:01 hours*]

WENTWORTH

Plate B11.60 – Looking north along the western Wentworth levee near the western side of Liftspan Bridge [*Photo taken on 25/11/2022 at 06:10 hours*]

Plate B11.61 – Looking south along the western Wentworth levee near the western side of Liftspan Bridge [*Photo taken on 25/11/2022 at 06:11 hours*]

WENTWORTH

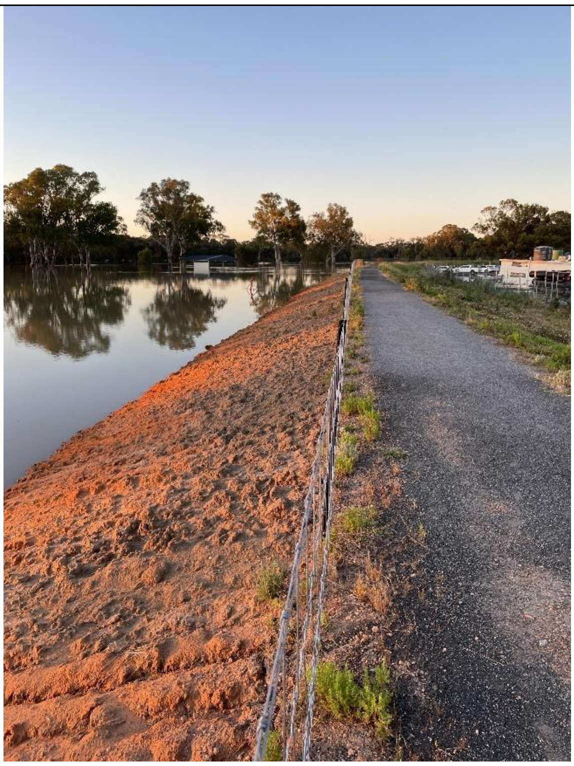


Plate B11.62 – Looking south west along the western Wentworth levee south of John Edge Lane [*Photo taken on 25/11/2022 at 06:25 hours*]

Plate B11.63 – Looking north at the Hospital levee east of the hospital [*Photo taken on 30/11/2022 at 09:18 hours*]

Plate B11.64 – Looking west along the north-western side of the Hospital levee [*Photo taken on 30/11/2022 at 09:24 hours*]

WENTWORTH

Plate B11.65 – Looking west at the western side of the Hospital levee [*Photo taken on 30/11/2022 at 09:25 hours*]

Plate B11.66 – Looking north along the western Wentworth levee east of Rotary Park [*Photo taken on 12/12/2022 at 16:28 hours*]

WENTWORTH

Plate B11675 – Looking west along the western Wentworth levee north of the golf course [*Photo taken on 13/12/2022 at 06:50 hours*]

Plate B11.68 – Looking west at the western Wentworth levee south of the Liftspan Bridge [*Photo taken on 18/12/2022 at 14:43 hours*]

Plate B11.69 – Water level reaching roughly 32 cm below a 1956 flood marker near Junction Park [*Photo taken on 18/12/2022 at 16:30 hours*]

WENTWORTH

Plate B11.70 – Looking south west at the airport levee [*Photo taken on 20/12/2022 at 12:16 hours*]

Plate B11.72 – Looking north-west at the western Wentworth levee near the eastern end of Cadell Street [*Photo taken on 20/12/2022 at 12:49 hours*]

Plate B11.73 – Looking down at Wentworth Health Service [*Photo taken on 20/12/2022 at 12:50 hours*]

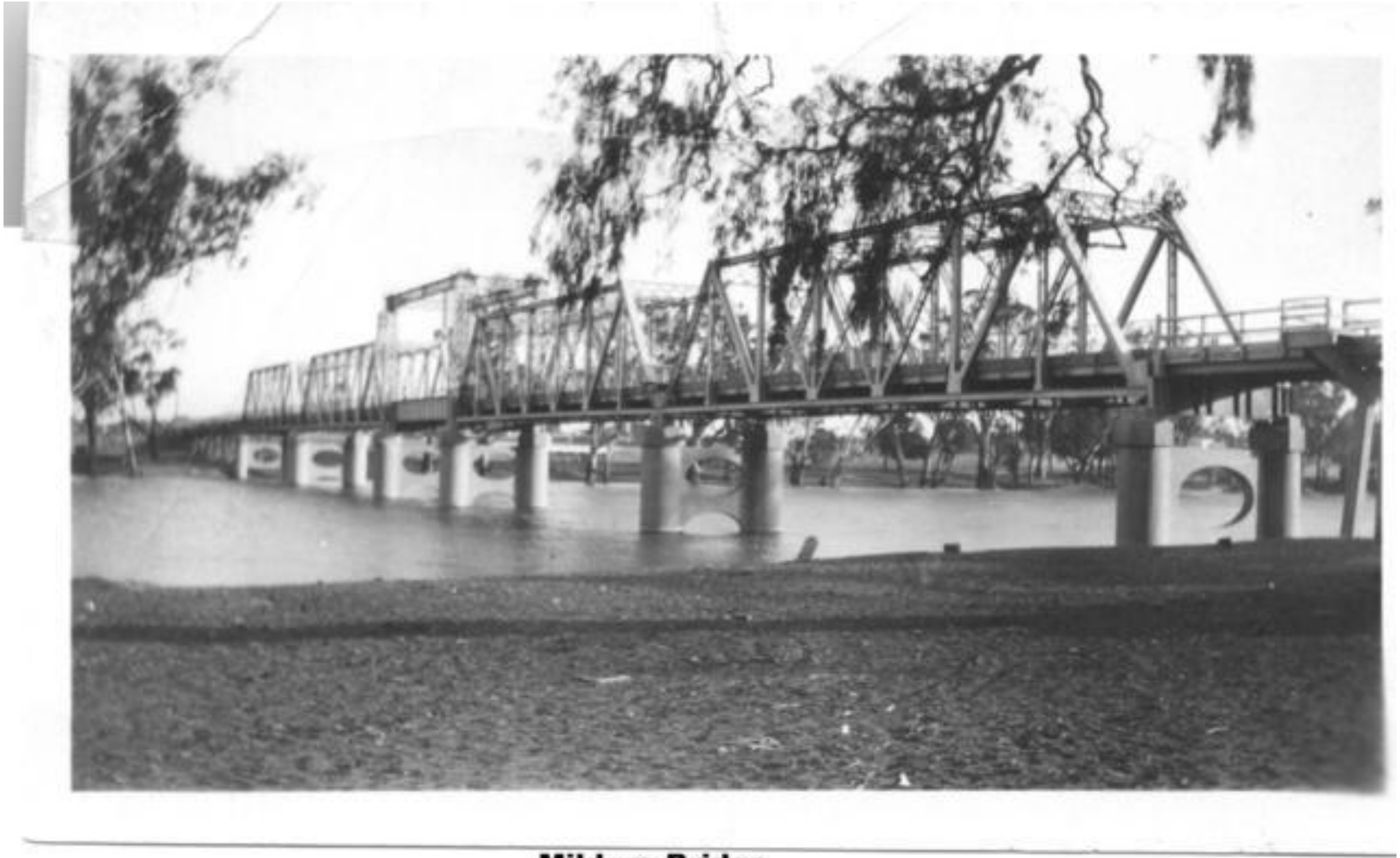
Plate B11.74 – Looking north along the Darling River, north of the Liftspan Bridge [*Photo taken on 20/12/2022 at 12:50 hours*]

WENTWORTH

Plate B11.75 – Looking north along the Darling River, north of the Liftspan Bridge [*Photo taken on 20/12/2022 at 12:51 hours*]

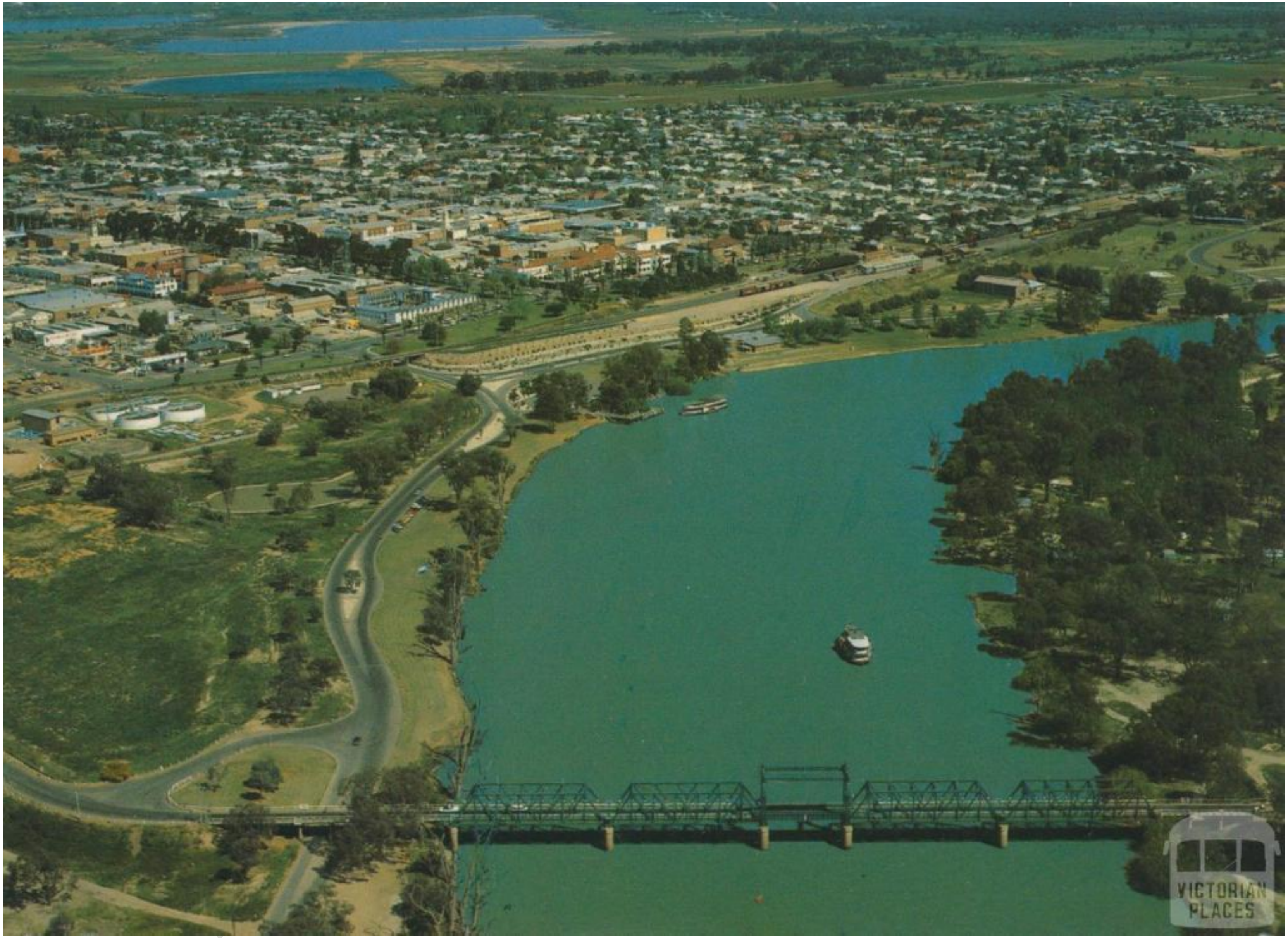
ANNEXURE B12

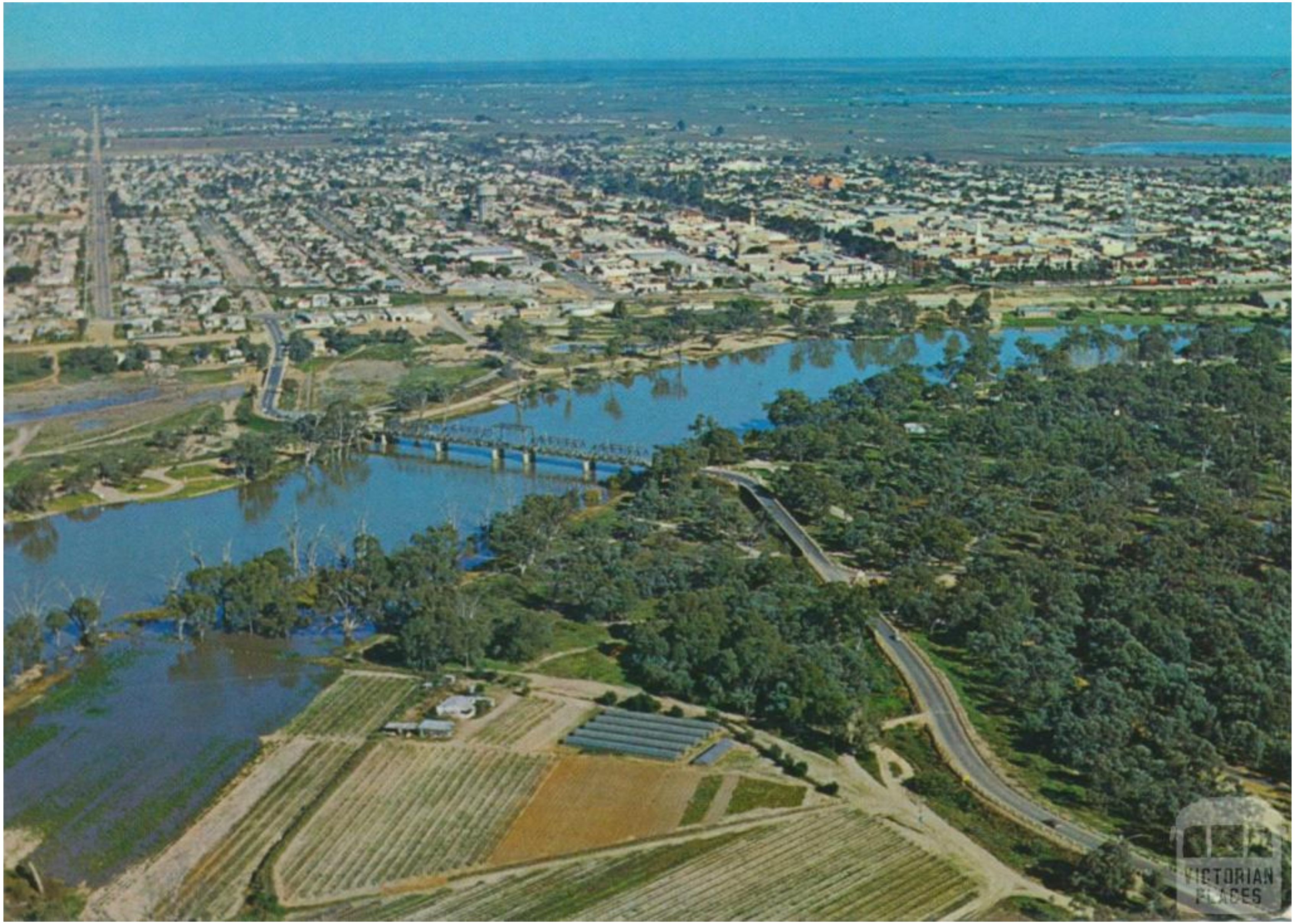
PHOTOGRAPHS SHOWING MURRY RIVER BRIDGE CROSSING AT MILDURA



Mildura Bridge


BURONGA
22 JULY 1956


VICTORIAN
PLACES


VICTORIAN
PLACES

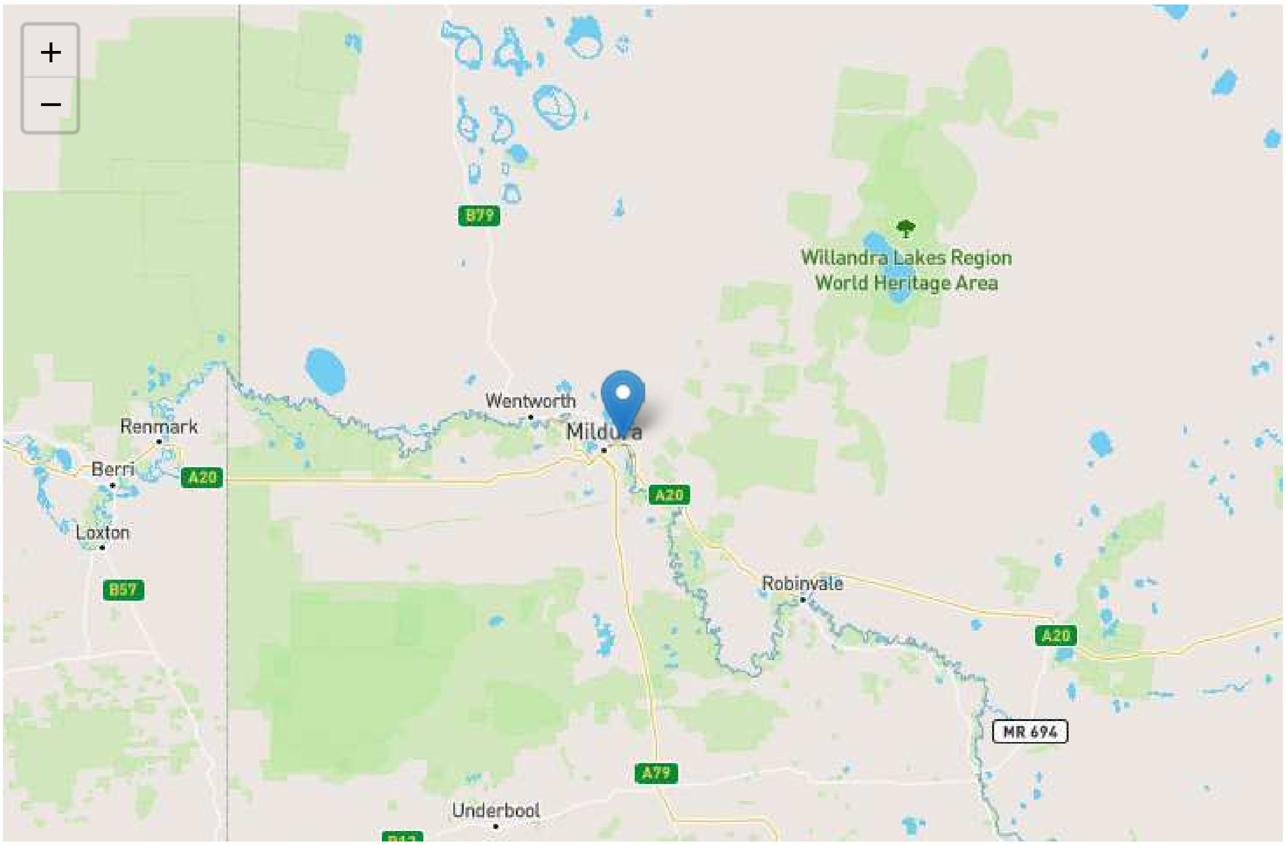
APPENDIX C

DESIGN INPUT DATA FROM ARR DATA HUB

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	142.208
Latitude	-34.169
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

Division	Murray-Darling Basin
River Number	16
River Name	Upper Mallee

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Semi-arid	0.254	0.247	0.403	0.351	0.0013	0.302	0.058	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	19883.0
Storm Initial Losses (mm)	NaN
Storm Continuing Losses (mm/h)	NaN

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.168823&longitude=142.207592&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	15 July 2025 02:11PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.3 (0.091)	1.0 (0.044)	0.8 (0.027)	0.6 (0.017)	1.3 (0.028)	1.8 (0.032)
90 (1.5)	1.3 (0.080)	1.2 (0.046)	1.1 (0.033)	1.0 (0.025)	1.8 (0.033)	2.3 (0.037)
120 (2.0)	2.1 (0.116)	1.6 (0.057)	1.3 (0.036)	1.0 (0.022)	1.6 (0.028)	2.1 (0.030)
180 (3.0)	1.7 (0.085)	2.3 (0.075)	2.7 (0.069)	3.1 (0.063)	4.4 (0.069)	5.3 (0.070)
360 (6.0)	0.5 (0.020)	1.3 (0.035)	1.9 (0.039)	2.4 (0.041)	3.3 (0.045)	4.0 (0.046)
720 (12.0)	0.0 (0.000)	0.4 (0.008)	0.6 (0.011)	0.9 (0.013)	2.0 (0.023)	2.8 (0.028)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.002)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	6.9 (0.473)	9.4 (0.409)	11.0 (0.375)	12.6 (0.346)	12.9 (0.273)	13.0 (0.232)
90 (1.5)	7.8 (0.475)	11.9 (0.462)	14.6 (0.442)	17.2 (0.420)	19.3 (0.365)	20.9 (0.331)
120 (2.0)	11.7 (0.652)	14.0 (0.501)	15.6 (0.435)	17.1 (0.385)	18.7 (0.327)	19.9 (0.292)
180 (3.0)	9.9 (0.489)	12.5 (0.399)	14.2 (0.356)	15.9 (0.322)	21.5 (0.340)	25.7 (0.342)
360 (6.0)	5.5 (0.221)	10.2 (0.268)	13.2 (0.276)	16.2 (0.276)	20.3 (0.273)	23.4 (0.267)
720 (12.0)	1.2 (0.038)	5.1 (0.112)	7.7 (0.136)	10.2 (0.149)	14.5 (0.169)	17.7 (0.177)
1080 (18.0)	0.0 (0.001)	3.6 (0.072)	6.0 (0.097)	8.4 (0.111)	10.2 (0.110)	11.5 (0.107)
1440 (24.0)	0.0 (0.000)	2.1 (0.038)	3.4 (0.052)	4.8 (0.060)	4.1 (0.042)	3.6 (0.032)
2160 (36.0)	0.0 (0.000)	1.1 (0.019)	1.8 (0.026)	2.5 (0.030)	2.0 (0.019)	1.6 (0.014)
2880 (48.0)	0.0 (0.000)	0.4 (0.006)	0.6 (0.008)	0.8 (0.009)	0.5 (0.005)	0.3 (0.003)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	19.8 (1.365)	22.9 (0.997)	24.9 (0.845)	26.8 (0.735)	29.2 (0.620)	30.9 (0.551)
90 (1.5)	15.2 (0.925)	21.7 (0.840)	26.0 (0.785)	30.1 (0.734)	31.0 (0.586)	31.7 (0.502)
120 (2.0)	18.9 (1.056)	24.2 (0.863)	27.7 (0.772)	31.0 (0.699)	40.2 (0.705)	47.2 (0.693)
180 (3.0)	17.5 (0.862)	22.2 (0.708)	25.3 (0.634)	28.3 (0.575)	37.1 (0.587)	43.7 (0.582)
360 (6.0)	14.3 (0.570)	20.9 (0.551)	25.3 (0.529)	29.6 (0.505)	43.9 (0.592)	54.6 (0.624)
720 (12.0)	6.7 (0.218)	13.9 (0.304)	18.7 (0.328)	23.2 (0.338)	26.7 (0.311)	29.3 (0.293)
1080 (18.0)	1.9 (0.056)	9.9 (0.195)	15.1 (0.242)	20.1 (0.268)	25.1 (0.271)	28.8 (0.269)
1440 (24.0)	4.9 (0.132)	8.6 (0.160)	11.1 (0.167)	13.5 (0.170)	17.4 (0.178)	20.3 (0.181)
2160 (36.0)	2.0 (0.051)	8.2 (0.139)	12.2 (0.170)	16.1 (0.189)	15.1 (0.145)	14.4 (0.121)
2880 (48.0)	0.0 (0.001)	7.8 (0.127)	12.9 (0.172)	17.9 (0.201)	17.9 (0.166)	17.9 (0.145)
4320 (72.0)	0.0 (0.000)	1.5 (0.024)	2.6 (0.032)	3.6 (0.038)	4.8 (0.043)	5.8 (0.045)

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Climate Change Factors

Rainfall Factors

SSP1-2.6

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	1.22	1.2	1.18	1.17	1.15	1.15	1.14	1.13	1.12	1.11
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	1.29	1.26	1.24	1.22	1.2	1.19	1.18	1.17	1.16	1.15
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	1.59	1.53	1.49	1.44	1.4	1.38	1.35	1.33	1.3	1.29

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.04**	**1.04**	**1.04**	**1.04**
2040	1.04	1.04	1.05	1.05
2050	**1.04**	**1.05**	**1.06**	**1.07**
2060	1.05	1.06	1.07	1.08
2070	1.05	1.07	1.08	1.1
2080	1.05	1.07	1.09	1.11
2090	**1.05**	**1.07**	**1.11**	**1.13**
2100	1.04	1.08	1.12	1.15

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.08**	**1.08**	**1.08**	**1.09**
2040	1.09	1.1	1.1	1.11
2050	**1.1**	**1.11**	**1.13**	**1.14**
2060	1.1	1.13	1.15	1.18
2070	1.1	1.14	1.18	1.21

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2080	1.1	1.16	1.21	1.25
2090	**1.1**	**1.17**	**1.24**	**1.3**
2100	1.1	1.17	1.27	1.33

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	15.1	15.3	14.6	15.0	15.3	14.4
90 (1.5)	17.4	15.8	15.5	16.5	15.3	13.2
120 (2.0)	19.2	16.4	15.5	16.0	15.0	12.2
180 (3.0)	22.0	16.1	15.1	15.9	14.5	10.5
360 (6.0)	27.1	19.5	18.1	18.2	15.8	11.2
720 (12.0)	29.1	22.2	20.6	20.4	17.7	12.6
1080 (18.0)	30.9	24.5	23.4	22.8	19.9	16.1
1440 (24.0)	32.2	26.3	25.2	24.3	21.8	18.8
2160 (36.0)	32.6	27.6	26.6	26.1	24.8	23.6
2880 (48.0)	32.9	28.2	27.8	28.4	27.5	26.4
4320 (72.0)	33.1	28.5	28.1	29.1	28.5	27.0

Layer Info

Time Accessed	15 July 2025 02:11PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/6055a8f9-6a4a-45c2-be19-3275ca847bf5.txt)

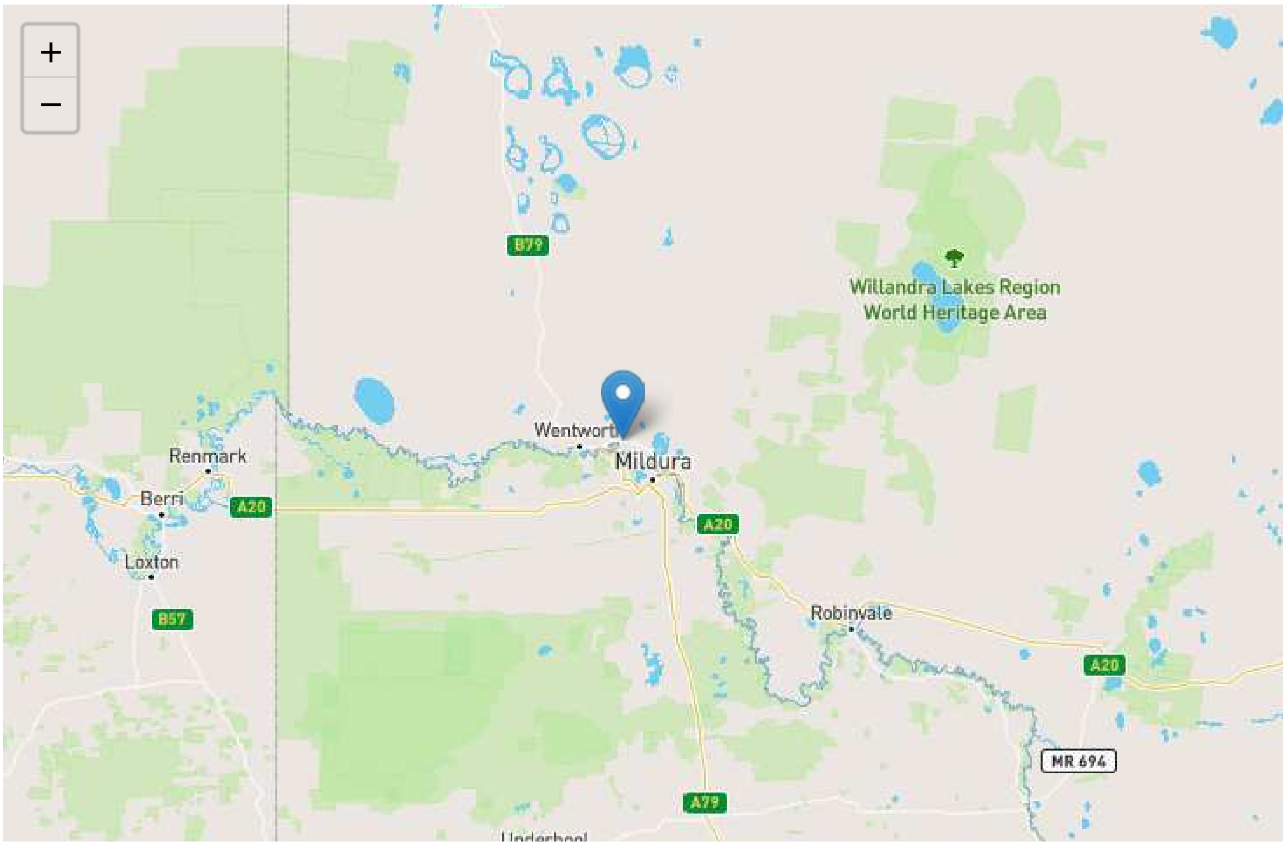
Download JSON (downloads/31261a75-e135-4567-9ade-22b6dcbc267c.json)

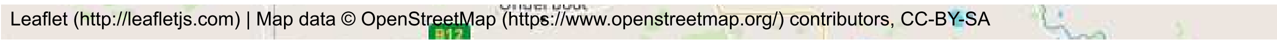
Generating PDF... (downloads/5f4137d2-c15f-4ea2-9f9b-8cf2eaaf88b2.pdf)

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	142.053
Latitude	-34.093
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show





Data

River Region

Division	Murray-Darling Basin
River Number	16
River Name	Upper Mallee

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Semi-arid	0.254	0.247	0.403	0.351	0.0013	0.302	0.058	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	20469.0
Storm Initial Losses (mm)	NaN
Storm Continuing Losses (mm/h)	NaN

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.092829&longitude=142.053195&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	15 July 2025 02:33PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.6 (0.106)	1.2 (0.052)	1.0 (0.033)	0.8 (0.020)	1.5 (0.030)	2.0 (0.035)
90 (1.5)	1.7 (0.104)	1.4 (0.054)	1.2 (0.036)	1.0 (0.024)	1.7 (0.032)	2.2 (0.034)
120 (2.0)	2.4 (0.133)	2.0 (0.070)	1.7 (0.047)	1.4 (0.032)	1.6 (0.028)	1.8 (0.025)
180 (3.0)	1.8 (0.086)	2.4 (0.076)	2.8 (0.070)	3.2 (0.064)	3.5 (0.053)	3.6 (0.047)
360 (6.0)	0.5 (0.021)	1.6 (0.041)	2.3 (0.047)	3.0 (0.049)	3.6 (0.047)	4.0 (0.045)
720 (12.0)	0.0 (0.000)	0.6 (0.012)	0.9 (0.016)	1.3 (0.018)	3.0 (0.034)	4.3 (0.042)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.2 (0.003)	0.4 (0.004)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.002)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	10.9 (0.744)	12.3 (0.528)	13.2 (0.440)	14.0 (0.378)	13.6 (0.284)	13.3 (0.232)
90 (1.5)	10.6 (0.637)	13.7 (0.521)	15.7 (0.467)	17.7 (0.423)	18.1 (0.335)	18.4 (0.285)
120 (2.0)	11.3 (0.627)	13.9 (0.490)	15.6 (0.428)	17.3 (0.382)	18.3 (0.314)	19.1 (0.275)
180 (3.0)	8.9 (0.433)	12.1 (0.380)	14.2 (0.350)	16.3 (0.323)	21.5 (0.333)	25.4 (0.330)
360 (6.0)	5.2 (0.204)	10.1 (0.262)	13.4 (0.275)	16.5 (0.277)	20.8 (0.274)	24.0 (0.268)
720 (12.0)	1.1 (0.035)	5.8 (0.124)	8.9 (0.153)	11.9 (0.169)	16.3 (0.185)	19.6 (0.190)
1080 (18.0)	0.1 (0.002)	4.0 (0.078)	6.6 (0.103)	9.1 (0.118)	10.6 (0.111)	11.7 (0.106)
1440 (24.0)	0.0 (0.000)	2.2 (0.040)	3.7 (0.054)	5.0 (0.062)	5.2 (0.052)	5.4 (0.046)
2160 (36.0)	0.0 (0.000)	1.0 (0.017)	1.7 (0.023)	2.3 (0.026)	1.9 (0.017)	1.5 (0.013)
2880 (48.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.005)	0.5 (0.005)	0.4 (0.004)	0.4 (0.003)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	22.9 (1.567)	24.8 (1.068)	26.1 (0.871)	27.2 (0.733)	29.5 (0.614)	31.1 (0.543)
90 (1.5)	17.4 (1.047)	24.6 (0.938)	29.4 (0.872)	34.0 (0.812)	32.5 (0.601)	31.4 (0.486)
120 (2.0)	18.6 (1.030)	25.6 (0.902)	30.3 (0.830)	34.7 (0.768)	37.1 (0.637)	38.9 (0.560)
180 (3.0)	16.8 (0.823)	22.6 (0.710)	26.4 (0.650)	30.1 (0.599)	39.2 (0.607)	46.1 (0.599)
360 (6.0)	14.4 (0.569)	21.5 (0.556)	26.1 (0.535)	30.5 (0.511)	44.0 (0.578)	54.0 (0.601)
720 (12.0)	6.0 (0.192)	15.3 (0.330)	21.5 (0.371)	27.4 (0.390)	35.0 (0.397)	40.6 (0.394)
1080 (18.0)	4.0 (0.116)	11.2 (0.218)	16.0 (0.251)	20.5 (0.267)	27.6 (0.290)	32.9 (0.297)
1440 (24.0)	6.8 (0.182)	9.9 (0.180)	11.9 (0.175)	13.8 (0.170)	18.2 (0.182)	21.5 (0.186)
2160 (36.0)	2.8 (0.069)	7.8 (0.130)	11.0 (0.150)	14.2 (0.162)	13.9 (0.130)	13.8 (0.112)
2880 (48.0)	2.9 (0.068)	7.5 (0.119)	10.5 (0.136)	13.3 (0.146)	15.9 (0.143)	17.9 (0.141)
4320 (72.0)	0.0 (0.000)	1.8 (0.027)	3.0 (0.037)	4.1 (0.043)	5.0 (0.043)	5.7 (0.043)

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Climate Change Factors

Rainfall Factors

SSP1-2.6

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	**1.22**	**1.2**	**1.18**	**1.17**	**1.15**	**1.15**	**1.14**	**1.13**	**1.12**	**1.11**
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	**1.23**	**1.21**	**1.2**	**1.18**	**1.17**	**1.16**	**1.15**	**1.14**	**1.13**	**1.12**
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	**1.27**	**1.24**	**1.23**	**1.21**	**1.19**	**1.18**	**1.17**	**1.16**	**1.15**	**1.14**
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	**1.4**	**1.36**	**1.34**	**1.31**	**1.28**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	**1.29**	**1.26**	**1.24**	**1.22**	**1.2**	**1.19**	**1.18**	**1.17**	**1.16**	**1.15**
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	**1.59**	**1.53**	**1.49**	**1.44**	**1.4**	**1.38**	**1.35**	**1.33**	**1.3**	**1.29**

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.04**	**1.04**	**1.04**	**1.04**
2040	1.04	1.04	1.05	1.05
2050	**1.04**	**1.05**	**1.06**	**1.07**
2060	1.05	1.06	1.07	1.08
2070	1.05	1.07	1.08	1.1
2080	1.05	1.07	1.09	1.11
2090	**1.05**	**1.07**	**1.11**	**1.13**
2100	1.04	1.08	1.12	1.15

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.08**	**1.08**	**1.08**	**1.09**
2040	1.09	1.1	1.1	1.11
2050	**1.1**	**1.11**	**1.13**	**1.14**
2060	1.1	1.13	1.15	1.18
2070	1.1	1.14	1.18	1.21

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2080	1.1	1.16	1.21	1.25
2090	**1.1**	**1.17**	**1.24**	**1.3**
2100	1.1	1.17	1.27	1.33

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	15.1	15.3	14.6	15.0	15.3	14.4
90 (1.5)	17.4	15.8	15.5	16.5	15.3	13.2
120 (2.0)	19.2	16.4	15.5	16.0	15.0	12.2
180 (3.0)	22.0	16.1	15.1	15.9	14.5	10.5
360 (6.0)	27.1	19.5	18.1	18.2	15.8	11.2
720 (12.0)	29.1	22.2	20.6	20.4	17.7	12.6
1080 (18.0)	30.9	24.5	23.4	22.8	19.9	16.1
1440 (24.0)	32.2	26.3	25.2	24.3	21.8	18.8
2160 (36.0)	32.6	27.6	26.6	26.1	24.8	23.6
2880 (48.0)	32.9	28.2	27.8	28.4	27.5	26.4
4320 (72.0)	33.1	28.5	28.1	29.1	28.5	27.0

Layer Info

Time Accessed	15 July 2025 02:33PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/6808e4c0-11b6-4586-8edc-b3f0ff6a4942.txt)

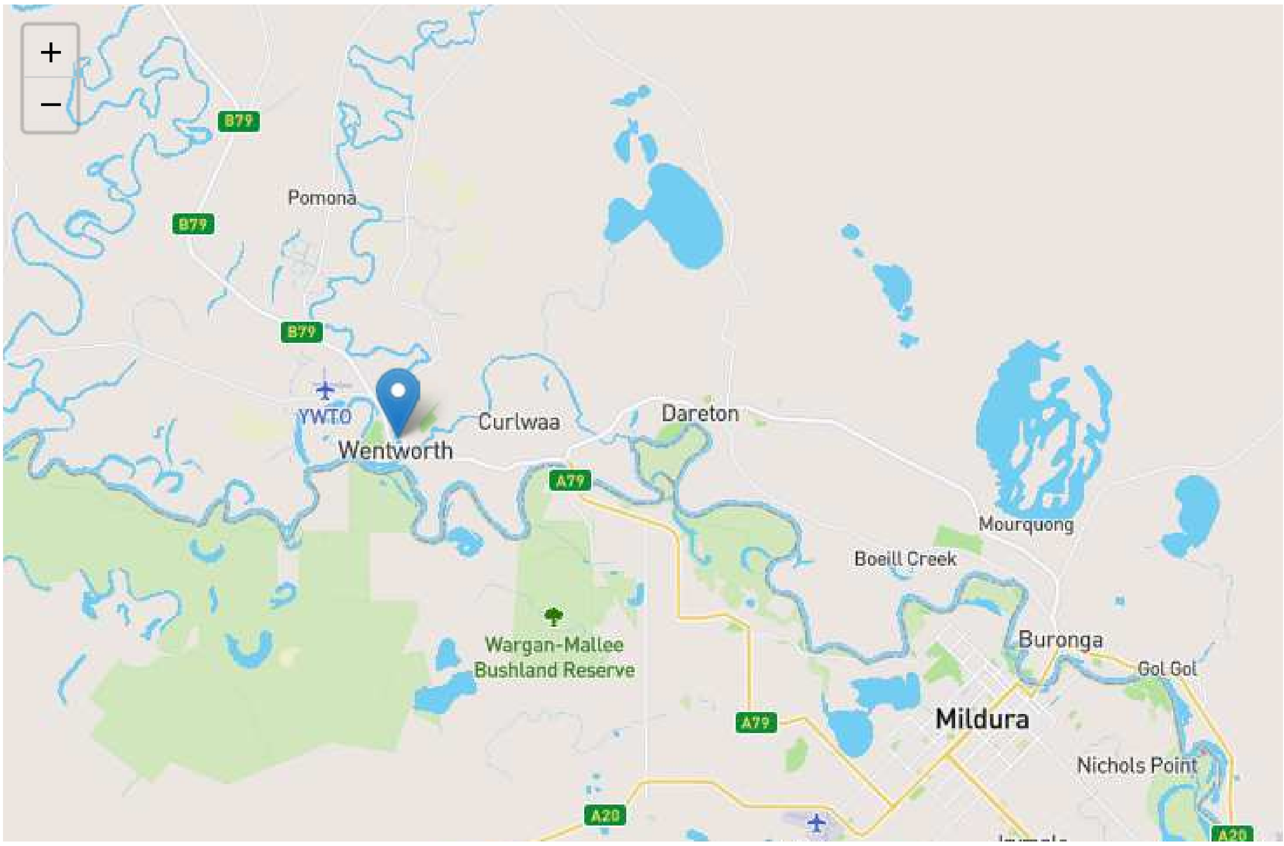
Download JSON (downloads/0fed346c-ac2c-42aa-bb29-db7122c29c4c.json)

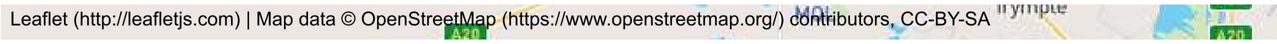
Generating PDF... (downloads/3b1b2086-8135-4600-bb83-7a68213c2079.pdf)

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	141.92
Latitude	-34.104
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show





Data

River Region

Division	Murray-Darling Basin
River Number	26
River Name	Darling River

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Semi-arid	0.254	0.247	0.403	0.351	0.0013	0.302	0.058	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	22348.0
Storm Initial Losses (mm)	NaN
Storm Continuing Losses (mm/h)	NaN

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.103845&longitude=141.920229&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	15 July 2025 02:08PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.6 (0.112)	1.2 (0.054)	1.0 (0.034)	0.8 (0.021)	1.4 (0.030)	1.9 (0.034)
90 (1.5)	1.7 (0.103)	1.4 (0.053)	1.1 (0.035)	0.9 (0.023)	1.6 (0.030)	2.1 (0.033)
120 (2.0)	2.4 (0.135)	1.9 (0.069)	1.6 (0.046)	1.3 (0.030)	1.7 (0.030)	2.0 (0.029)
180 (3.0)	1.7 (0.085)	2.2 (0.069)	2.5 (0.062)	2.8 (0.056)	3.4 (0.054)	3.9 (0.052)
360 (6.0)	0.5 (0.020)	1.7 (0.044)	2.4 (0.051)	3.2 (0.054)	3.8 (0.051)	4.2 (0.048)
720 (12.0)	0.0 (0.000)	0.5 (0.011)	0.8 (0.014)	1.1 (0.016)	2.9 (0.034)	4.2 (0.042)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.001)	0.3 (0.003)	0.5 (0.004)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.001)	0.1 (0.001)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.004)	0.0 (0.001)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	11.0 (0.763)	12.3 (0.538)	13.2 (0.448)	14.1 (0.383)	13.4 (0.284)	12.9 (0.230)
90 (1.5)	10.3 (0.628)	13.2 (0.510)	15.1 (0.456)	17.0 (0.413)	17.7 (0.334)	18.2 (0.289)
120 (2.0)	11.3 (0.635)	13.6 (0.486)	15.1 (0.421)	16.6 (0.372)	18.3 (0.320)	19.6 (0.288)
180 (3.0)	9.0 (0.446)	12.0 (0.383)	14.0 (0.351)	15.9 (0.323)	21.1 (0.333)	24.9 (0.331)
360 (6.0)	5.0 (0.201)	9.9 (0.263)	13.2 (0.277)	16.4 (0.280)	20.6 (0.277)	23.8 (0.271)
720 (12.0)	1.2 (0.038)	5.5 (0.121)	8.3 (0.147)	11.1 (0.161)	15.9 (0.186)	19.6 (0.195)
1080 (18.0)	0.1 (0.002)	3.7 (0.073)	6.1 (0.098)	8.3 (0.112)	10.3 (0.111)	11.8 (0.110)
1440 (24.0)	0.0 (0.000)	2.1 (0.040)	3.6 (0.054)	4.9 (0.062)	5.3 (0.055)	5.6 (0.050)
2160 (36.0)	0.0 (0.000)	1.2 (0.020)	1.9 (0.027)	2.7 (0.031)	2.1 (0.020)	1.7 (0.014)
2880 (48.0)	0.0 (0.000)	0.2 (0.003)	0.3 (0.005)	0.5 (0.005)	0.4 (0.004)	0.3 (0.003)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	22.6 (1.566)	24.5 (1.068)	25.7 (0.872)	26.9 (0.735)	29.1 (0.616)	30.7 (0.545)
90 (1.5)	17.1 (1.048)	24.9 (0.965)	30.1 (0.907)	35.1 (0.852)	32.6 (0.614)	30.7 (0.485)
120 (2.0)	18.6 (1.044)	24.9 (0.888)	29.0 (0.808)	33.0 (0.742)	35.8 (0.626)	38.0 (0.557)
180 (3.0)	16.2 (0.805)	22.2 (0.710)	26.3 (0.657)	30.1 (0.610)	38.5 (0.608)	44.8 (0.595)
360 (6.0)	14.0 (0.566)	22.1 (0.586)	27.5 (0.577)	32.7 (0.559)	45.3 (0.610)	54.7 (0.623)
720 (12.0)	5.9 (0.195)	13.7 (0.303)	18.9 (0.335)	23.9 (0.348)	32.9 (0.382)	39.6 (0.393)
1080 (18.0)	3.6 (0.108)	10.7 (0.215)	15.4 (0.249)	19.9 (0.266)	26.5 (0.285)	31.4 (0.291)
1440 (24.0)	7.1 (0.195)	10.1 (0.190)	12.1 (0.184)	14.0 (0.177)	18.5 (0.189)	21.8 (0.193)
2160 (36.0)	3.1 (0.078)	8.3 (0.143)	11.7 (0.164)	15.0 (0.176)	15.2 (0.146)	15.4 (0.128)
2880 (48.0)	3.8 (0.092)	7.8 (0.129)	10.4 (0.140)	13.0 (0.146)	15.0 (0.138)	16.6 (0.134)
4320 (72.0)	0.0 (0.000)	1.6 (0.026)	2.7 (0.035)	3.8 (0.040)	4.7 (0.041)	5.4 (0.042)

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Climate Change Factors

Rainfall Factors

SSP1-2.6

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.21	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.11	1.11
2050	**1.22**	**1.2**	**1.18**	**1.17**	**1.15**	**1.15**	**1.14**	**1.13**	**1.12**	**1.11**
2060	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2070	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2080	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2090	**1.23**	**1.21**	**1.2**	**1.18**	**1.17**	**1.16**	**1.15**	**1.14**	**1.13**	**1.12**
2100	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	**1.27**	**1.24**	**1.23**	**1.21**	**1.19**	**1.18**	**1.17**	**1.16**	**1.15**	**1.14**
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	**1.4**	**1.36**	**1.34**	**1.31**	**1.28**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

SSP3-7.0

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.12**	**1.12**	**1.11**	**1.1**	**1.1**
2040	1.23	1.21	1.2	1.18	1.17	1.16	1.15	1.14	1.13	1.12
2050	**1.29**	**1.26**	**1.24**	**1.22**	**1.2**	**1.19**	**1.18**	**1.17**	**1.16**	**1.15**
2060	1.35	1.32	1.3	1.27	1.25	1.23	1.22	1.2	1.19	1.18
2070	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2080	1.5	1.45	1.42	1.38	1.35	1.33	1.3	1.28	1.26	1.25
2090	**1.59**	**1.53**	**1.49**	**1.44**	**1.4**	**1.38**	**1.35**	**1.33**	**1.3**	**1.29**

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2100	1.66	1.59	1.55	1.5	1.45	1.42	1.39	1.37	1.34	1.32

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.04**	**1.04**	**1.04**	**1.04**
2040	1.04	1.04	1.05	1.05
2050	**1.04**	**1.05**	**1.06**	**1.07**
2060	1.05	1.06	1.07	1.08
2070	1.05	1.07	1.08	1.1
2080	1.05	1.07	1.09	1.11
2090	**1.05**	**1.07**	**1.11**	**1.13**
2100	1.04	1.08	1.12	1.15

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.08**	**1.08**	**1.08**	**1.09**
2040	1.09	1.1	1.1	1.11
2050	**1.1**	**1.11**	**1.13**	**1.14**
2060	1.1	1.13	1.15	1.18
2070	1.1	1.14	1.18	1.21

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2080	1.1	1.16	1.21	1.25
2090	**1.1**	**1.17**	**1.24**	**1.3**
2100	1.1	1.17	1.27	1.33

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	15.1	15.3	14.6	15.0	15.3	14.4
90 (1.5)	17.4	15.8	15.5	16.5	15.3	13.2
120 (2.0)	19.2	16.4	15.5	16.0	15.0	12.2
180 (3.0)	22.0	16.1	15.1	15.9	14.5	10.5
360 (6.0)	27.1	19.5	18.1	18.2	15.8	11.2
720 (12.0)	29.1	22.2	20.6	20.4	17.7	12.6
1080 (18.0)	30.9	24.5	23.4	22.8	19.9	16.1
1440 (24.0)	32.2	26.3	25.2	24.3	21.8	18.8
2160 (36.0)	32.6	27.6	26.6	26.1	24.8	23.6
2880 (48.0)	32.9	28.2	27.8	28.4	27.5	26.4
4320 (72.0)	33.1	28.5	28.1	29.1	28.5	27.0

Layer Info

Time Accessed	15 July 2025 02:08PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/6d5445df-623b-4391-a9f3-f342ed517a4e.txt)

Download JSON (downloads/a94cf682-2189-47b1-9bfe-3fd3d5798e77.json)

Generating PDF... (downloads/48466b11-af48-491e-a474-bd8833369945.pdf)

APPENDIX D

COMPLETED BLOCKAGE ASSESSMENT FORMS

TABLE D1

ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES AT GOL GOL AND BURONGA

ID[1]	Structure Details				Floating Debris																							Adopted Design Blockage B_{DES}%		
	Structure Type[2]	Width / Diameter (m)	Height (m)	No. of Barrels / Spans	L_{10}[3]	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Approximate Average Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP				> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
B_MOF_623	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
B_MOF_624	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_321	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.8	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_626	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_627	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
B_MOF_629	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_682	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.8	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_327	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_330	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_625	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_630	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_404	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_819	R Culvert	1.8	0.9	0	1.5	L	M	L	LML	Low	Low	Low	Medium	0%	0%	10%	2	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
B_MOF_313	C Culvert	0.15	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_522	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_811	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.4	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_632	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_696	C Culvert	0.375	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_695	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_631	C Culvert	0.375	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
B_MOF_809	C Culvert	0.6	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_810	C Culvert	0.9	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
B_MOF_813	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_814	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_812	C Culvert	0.75	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
B_MOF_33	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_808	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
B_MOF_1001	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_1002	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_628	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
B_MOF_319	C Culvert	0.225	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%

1. Note that the plan location of each structure can be identified in the GIS layers contained in the data handover for the present study.
2. C Culvert = Circular Pipe Culvert
3. L_{10} is the average length of the longest 10% of the debris that could arrive at the culvert.

TABLE D2
ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES AT DARETON

ID[1]	Structure Details				Floating Debris																							
	Structure Type[2]	Width / Diameter (m)	Height (m)	No. of Barrels / Spans	L_{10}[3]	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Approximate Average Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)			Adopted Design Blockage B_{DES}%		
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP				> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
D_MOF_162	C Culvert	0.575	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_163	R Culvert	0.3	0.3	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_164	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_166	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_167	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_169	R Culvert	0.3	0.3	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_161	R Culvert	0.6	0.5	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_88	C Culvert	0.45	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_89	C Culvert	0.375	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_171	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	3.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_170	C Culvert	0.825	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
D_MOF_156	C Culvert	0.525	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	2.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%

2. C Culvert = Circular Pipe Culvert

3. L_{10} is the average length of the longest 10% of the debris that could arrive at the culvert.

TABLE D3

ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES AT WENTWORTH

ID[1]	Structure Details				Floating Debris																					Adopted Design Blockage B_{DES}%		
	Structure Type[2]	Width / Diameter (m)	Height (m)	No. of Barrels / Spans	L_{10}[3]	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Approximate Average Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP				> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
W_MOF_411	C Culvert	0.375	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_447	C Culvert	0.75	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.4	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_448	C Culvert	0.75	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_450	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_441	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_442	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
W_MOF_443	C Culvert	0.9	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_444	C Culvert	0.9	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_451	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_446	C Culvert	0.9	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
W_MOF_18	C Culvert	0.6	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_452	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_445	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_455	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_481	R Culvert	1.2	0.3	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_485	R Culvert	1.2	0.6	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_489	R Culvert	0.45	0.3	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.4	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_490	R Culvert	1.2	0.45	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_491	R Culvert	1.2	0.6	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_492	R Culvert	0.45	0.3	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_494	R Culvert	1.2	0.6	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_495	R Culvert	0.45	0.3	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
W_MOF_502	R Culvert	1.2	0.6	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_503	C Culvert	0.6	0	2	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
W_MOF_482	C Culvert	0.3	0	0	1.5	L	M	L	LML	Low	Low	Low	Medium	25%	25%	50%	0.2	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%

1. Note that the plan location of each structure can be identified in the GIS layers contained in the data handover for the present study.

2. C Culvert = Circular Pipe Culvert

3. L_{10} is the average length of the longest 10% of the debris that could arrive at the culvert.

APPENDIX E

GOL GOL AND BURONGA TUFLOW MODEL RESULTS
(BOUND IN VOLUME 2)

APPENDIX F

DARETON TUFLOW MODEL RESULTS
(BOUND IN VOLUME 2)

APPENDIX G

WENTWORTH TUFLOW MODEL RESULTS
(BOUND IN VOLUME 2)

APPENDIX H

FLOOD DAMAGES

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FIGURES
(BOUND IN VOLUME 2)

H1. INTRODUCTION AND SCOPE

H1.1 Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and residential building structures and contents as well as damages to infrastructure services such as electricity and water supply.

Intangible damages resulting from flooding includes a number of various factors that can have a significant effect on the community. Such factors may include:

a) risk of injury or loss of life;

b) mental health impacts such as depression, anxiety and post-traumatic stress disorder; and

c) social and wellbeing impacts such as isolation, inconvenience, or disruption of family and social activities.

H1.2 Scope of Investigation

In the following sections, both tangible and intangible damages to residential, commercial and industrial properties, and public buildings have been estimated resulting from flooding in the study area. For the present investigation, the procedures set out in *Flood Risk Management Guideline MM01 – Flood Risk Management Measures* (DPE, 2023) and the associated *NSW Flood Risk Management Tool DT01* (***FRM Tool DT01***) were used to undertake an assessment of both the tangible and intangible damages resulting from flooding in the study area.

The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there are no data available to allow a quantitative assessment of damages to be made to this category.

H1.3 Terminology

Definitions of the terms used in this Appendix are presented in **Section H7** which also summarises the value of Tangible Flood Damages.

H2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of flooding above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. The *FRM Tool DT01* was used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the updated flood study, a peak flood elevation was derived for each event at each property. The property flood levels were input to the *FRM Tool DT01* which also contained property characteristics and depth-damage relationships. The depth of flooding was computed as the difference between the interpolated flood level and the floor elevation at each property.

The floor levels of individual dwellings/buildings were assessed by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey. The type of structure and potential for property damage were also assessed during the visual inspection. If a property was not accessible to undertake a visual inspection, the height of the floor was assumed to be 150 mm above the adjacent natural surface level.

A series of depth-damages curves in the *FRM Tool DT01* were used to estimate the cost of tangible damages to residential, commercial, industrial and public properties. The spreadsheet model also includes procedures that were used to estimate intangible damages associated with:

a) risk of injury or loss of life correlated to the hazard vulnerability classification of flooding;

b) mental health costs correlated to the depth of above-floor inundation; and

c) social and wellbeing costs correlated to the frequency of above-floor inundation.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the values of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors to convert *potential damages* to *actual flood damages* experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

For the above reasons, the information contained in the spreadsheets used to prepare the estimates of flood damages for the study area should not be used to provide information on the depths of above-floor inundation of individual properties.

H3. SOURCES OF DATA

H3.1 General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e., of different frequencies, and then to integrate the area beneath the damage – frequency curve over the whole range of frequencies. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach is not possible in the study area as specific damage surveys have not been conducted following the historic flood events.
- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study. It was not used for the present investigation.
- The third way is to use generalised data that are considered to be suitable for broad regional studies. They are not considered to be suitable for use in specific areas unless none of the other approaches can be satisfactorily applied.
- The fourth way is to adapt or transpose data from other flood liable areas. The approach set out in DPE, 2023 and the *FRM Tool DT01* is based on data collected following major flooding in various urban centres across NSW and has been adopted for the present study.

H3.2 Property Data

The properties were divided into three categories: residential, commercial/industrial and public buildings.

For residential properties, the data used in the damages estimation included:

- the location/address of each property
- an assessment of the type of structure
- representative natural surface level of the allotment
- floor level of the residence

For commercial/industrial properties, the data used in the damages estimation included:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- natural surface level
- floor level

The property descriptions were used to classify the commercial/industrial developments into categories (i.e., high, medium or low value properties) which relate to the magnitude of likely flood damages.

The total number of residential properties, commercial / industrial and public buildings in the study area is shown in **Table H3.1**.

TABLE H3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties			
	Gol Gol	Buronga	Dareton	Wentworth
Residential	806	450	263	594
Commercial / Industrial	32	72	24	50
Public	12	14	26	23
Total	**850**	**536**	**313**	**667**

H3.3 Flood Levels Used in the Analysis

Damages were computed based on the design flood envelope levels that were determined from the hydraulic models that were developed as part of the present investigation. The design levels assume that the drainage system is operating at optimum capacity, with only the AEP neutral blockage factors applied to major hydraulic structures. They do not allow for any increase in levels resulting from wave action and significant debris build-ups at the location of major hydraulic structures, as well as other local hydraulic effects. These factors are usually taken into account by adding a factor of safety (freeboard) to the "nominal" flood level when assessing the "level of protection" against flooding of a particular property. Freeboard could also include an allowance for the future effects of climate change.

H4. RESIDENTIAL DAMAGES

H4.1 Damage Functions

The procedures identified in DPE, 2023 allow for the preparation of a depth versus damage relationship which incorporates structural damage, damage to contents, external damage, relocation costs and clean-up costs. In limited cases, the additional damage costs related to structural integrity due to building failure may also warrant consideration. Depth versus damage curves are computed for single and double storey residences.

The level of flood awareness and available warning time are taken into account by factors which are used to reduce "potential" damages to contents to "actual" damages. "Potential" damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean-up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (BoM and NSW SES).

Flooding in the study area is "flash flooding" in nature, with surcharge of the watercourses and various drainage lines occurring within three hours of the onset of flood producing rain. Consequently, there would be very limited time in advance of a flood event in which to warn residents located along the various flow paths and for them to take action to mitigate flood losses.

The actual damage to contents in an event can be reduced by actions taken during the warning time available in response to a flood threat. The actual to potential damage ratio is dependent on the effective warning time, likely duration of inundation of contents, flood awareness of the community, the likelihood of at least one resident being present at the time of the flood, the ability of the individual to lifts goods and the height to which goods would need to be raised. As there is minimal warning time available in the study area, the default actual to potential damage ratio of 0.9 was adopted for the present study.

H4.2 Total Residential Damages

H4.2.1 General

Table H4.1 over sets out the residential damages at the four urban centres relating to Murray and Darling River Flooding, while **Table H4.2** sets out similar information relating to local catchment flooding. **Figures H7.1**, **H7.2** and **H7.3** show the location and AEP at which individual dwellings first become above-floor inundated as a result of Murray and Darling River flooding at the urban centres of Gol Gol/Buronga, Dareton and Wentworth, respectively, while **Figures H7.4**, **H7.5** and **H7.6** show similar information relating to local catchment flooding.

H4.2.2 Murray and Darling River Flooding

The key findings of the flood damages assessment as it relates to Murray and Darling River flooding at the four urban centres are as follows:

Gol Gol

- A flood slightly smaller than 2% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, 22 dwellings would experience above-floor inundation, resulting in total flood damages of about $5.8 Million, of which about $3.3 Million would be attributable to structural damage, $0.5 Million to contents damage, $0.5 Million to external damage and $0.2 Million to intangibles.
- During an Extreme Flood event, 412 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $157 Million.

Buronga

- A flood slightly smaller than 5% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, 40 dwellings would experience above-floor inundation, resulting in total flood damages of about $12.8 Million, of which about $6.8 Million would be attributable to structural damage, $4.7 Million to contents damage, $0.9 Million to external damage and $0.5 Million to intangibles.
- During an Extreme Flood event, 134 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $52 Million.

Dareton

- Only one dwelling would be subject to above-floor inundation at Dareton, and only then during an Extreme Flood event

Wentworth

- A flood slightly smaller than 5% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, nine dwellings would experience above-floor inundation, resulting in total flood damages of about $1.8 Million, of which about $1.1 Million would be attributable to structural damage, $0.5 Million to contents damage, $0.2 Million to external damage and negligible intangible damages.
- Flood damages increase significantly at about the 0.2% AEP level of flooding due to overtopping of the Wentworth town levees.
- During an Extreme Flood event, 592 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $204 Million.

H4.2.3 Local Catchment Flooding

The key findings of the flood damages assessment as it relates to local catchment flooding at the four urban centres are as follows:

Gol Gol

- A flood slightly smaller than 20% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, three dwellings would experience above-floor inundation, resulting in total flood damages of about $0.8 Million.
- During a PMF event, 112 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $22 Million.

Buronga

- A flood slightly smaller than 1% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, two dwellings would experience above-floor inundation, resulting in total flood damages of about $0.3 Million.
- During a PMF event, 71 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $14 Million.

Dareton

- The 0.2% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- During a PMF event, 21 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $4.4 Million.

Wentworth

- The 2% AEP event was found to be the threshold at which dwellings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, two dwellings would experience above-floor inundation, resulting in total flood damages of about $0.6 Million.
- During an Extreme Flood event, 218 individual dwellings would experience above-floor inundation, resulting in total flood damages of about $44 Million.

TABLE H4.1
TOTAL RESIDENTIAL FLOOD DAMAGES
MURRAY AND DARLING RIVER FLOODING

Urban Centre	Design Flood Event	No. of Properties		Flood Damages ($ Million)				
		Flood Affected	Flooded Above Floor Level	Structural	Contents	External	Intangibles	Total
Gol Gol	20% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	2% AEP	17	10	1.5	0.8	0.2	0.1	2.6
	1% AEP	37	22	3.3	1.8	0.5	0.2	5.8
	0.5% AEP	127	61	8.4	4.4	1.3	0.4	14.5
	0.2% AEP	224	207	31.9	21.1	4.5	2.1	59.6
	Extreme	434	412	85.5	52.8	9.0	9.8	157.1
Buronga	20% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	6	3	0.4	0.2	0.1	0.0	0.7
	2% AEP	31	29	4.5	3.0	0.6	0.3	8.4
	1% AEP	43	40	6.8	4.7	0.9	0.4	12.8
	0.5% AEP	57	45	8.2	5.6	1.0	0.5	15.3
	0.2% AEP	84	74	13.8	8.4	1.6	0.9	24.7
	Extreme	137	134	27.7	16.9	2.9	4.5	52.0

Cont'd Over

TABLE H4.1 (Cont'd)
TOTAL RESIDENTIAL FLOOD DAMAGES
MURRAY AND DARLING RIVER FLOODING

Urban Centre	Design Flood Event	No. of Properties		Flood Damages ($ Million)				
		Flood Affected	Flooded Above Floor Level	Structural	Contents	External	Intangibles	Total
Dareton	20% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	2% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	1% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	0.5% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	0.2% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	Extreme	1	1	0.1	0.0	0.0	0.0	0.1
Wentworth	20% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	4	2	0.3	0.1	0.0	0.0	0.4
	2% AEP	10	4	0.6	0.3	0.1	0.0	1.0
	1% AEP	14	9	1.1	0.5	0.2	0.0	1.8
	0.5% AEP	19	12	1.5	0.8	0.3	0.1	2.7
	0.2% AEP	567	553	84.8	58.4	12.1	5.5	160.8
	Extreme	594	592	107.2	76.3	13.0	7.1	203.6

TABLE H4.2
TOTAL RESIDENTIAL FLOOD DAMAGES
LOCAL CATCHMENT FLOODING

Urban Centre	Design Flood Event	No. of Properties		Flood Damages ($ Million)				
		Flood Affected	Flooded Above Floor Level	Structural	Contents	External	Intangibles	Total
Gol Gol	20% AEP	6	1	0.0	0.0	0.0	0.0	0.0
	10% AEP	14	1	0.2	0.1	0.0	0.0	0.3
	5% AEP	23	1	0.3	0.1	0.0	0.0	0.4
	2% AEP	31	2	0.3	0.1	0.0	0.0	0.4
	1% AEP	50	3	0.6	0.1	0.1	0.0	0.8
	0.5% AEP	69	7	0.9	0.2	0.2	0.0	1.3
	0.2% AEP	86	10	1.3	0.3	0.2	0.0	1.8
	PMF	322	112	13.7	5.0	2.5	0.4	21.6
Buronga	20% AEP	0	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	2	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	6	0	0.0	0.0	0.0	0.0	0.0
	2% AEP	10	0	0.1	0.0	0.0	0.0	0.1
	1% AEP	27	2	0.3	0.0	0.0	0.0	0.3
	0.5% AEP	41	4	0.5	0.1	0.1	0.0	0.7
	0.2% AEP	49	11	0.9	0.2	0.2	0.0	1.3
	PMF	179	71	8.7	3.5	1.6	0.3	14.1

Cont'd Over

TABLE H4.2 (Cont'd)
TOTAL RESIDENTIAL FLOOD DAMAGES
LOCAL CATCHMENT FLOODING

Urban Centre	Design Flood Event	No. of Properties		Flood Damages ($ Million)				
		Flood Affected	Flooded Above Floor Level	Structural	Contents	External	Intangibles	Total
Dareton	20% AEP	1	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	4	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	6	0	0.0	0.0	0.0	0.0	0.0
	2% AEP	11	0	0.1	0.0	0.0	0.0	0.1
	1% AEP	16	0	0.1	0.0	0.0	0.0	0.1
	0.5% AEP	19	0	0.1	0.0	0.0	0.0	0.1
	0.2% AEP	25	1	0.1	0.0	0.0	0.0	0.1
	PMF	109	21	2.9	0.9	0.5	0.1	4.4
Wentworth	20% AEP	8	0	0.0	0.0	0.0	0.0	0.0
	10% AEP	9	0	0.0	0.0	0.0	0.0	0.0
	5% AEP	18	0	0.1	0.0	0.0	0.0	0.1
	2% AEP	33	1	0.2	0.0	0.0	0.0	0.2
	1% AEP	54	2	0.5	0.0	0.1	0.0	0.6
	0.5% AEP	68	5	0.5	0.0	0.1	0.0	0.6
	0.2% AEP	89	7	1.0	0.2	0.2	0.0	1.4
	PMF	414	218	27.3	11.1	4.8	0.8	44.0

H5. COMMERCIAL AND INDUSTRIAL DAMAGES

H5.1 Damage Functions

The procedures identified in DPE, 2023 allow for the preparation of a depth versus damage relationship for commercial and industrial buildings. The damage costs include the indirect costs associated with loss of trading and post-flood clean-up for commercial and industrial buildings.

Commercial and industrial property damages are highly variable, with the particular use and associated contents (rather than the structure) generally dominating the overall damage. The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise set out in **Table H5.1** below. Damages also depend on the floor area.

TABLE H5.1
ASSESSED COMMERCIAL AND INDUSTRIAL DAMAGE CATEGORIES

Proposed classification	Adjustment to average value curve	Representative uses
Low to medium	60% of average	Restaurants, cafes, offices, doctor's surgeries, retail/food outlets, butchers, bakeries, newsagencies, service stations, hardware
Medium/default	100%	Proposed as a representative average, where the particular use is not known
Medium to high	150% of average	Chemists, electrical goods, clothing stores, bottle shops, electronics

H5.2 Total Commercial and Industrial Damages

H5.2.1 General

Table H5.2 over sets out the estimated commercial and industrial damages at the four urban centres relating to Murray and Darling River Flooding, while **Table H5.2** sets out similar information relating to local catchment flooding. **Figures H7.1**, **H7.2** and **H7.3** show the location and AEP at which individual buildings first become above-floor inundated as a result of Murray and Darling River flooding at the urban centres of Gol Gol/Buronga, Dareton and Wentworth, respectively, while **Figures H7.4**, **H7.5** and **H7.6** show similar information relating to local catchment flooding.

H5.2.2 Murray and Darling River Flooding

The key findings of the flood damages assessment as it relates to Murray and Darling River flooding at the four urban centres are as follows:

<u>*Gol Gol*</u>

- A flood that has an AEP of between 5% and 2% was found to be the threshold at which commercial/industrial buildings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, 15 commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $14 Million.
- During an Extreme Flood event, 25 commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $31 Million.

<u>*Buronga*</u>

- The 2% AEP event was found to be the threshold at which commercial/industrial buildings first commence to be subject to above-floor inundation.

- At the 1% AEP level of flooding, three commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $0.4 Million.
- During an Extreme Flood event, 60 commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $95 Million.

Dareton

- No commercial/industrial buildings are subject to above-floor inundation over the full range of potential flooding.

Wentworth

- No commercial/industrial buildings are subject to above-floor inundation until such time as the Wentworth town levees are overtopped.
- At the 0.2% AEP level of flooding when the Wentworth town levees are overtopped, 48 commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $21 Million.
- During an Extreme Flood event, 50 commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $43 Million.

H5.2.3 Local Catchment Flooding

The key findings of the flood damages assessment as it relates to local catchment flooding at the four urban centres are as follows:

Gol Gol

- A flood smaller than PMF event was found to be the threshold at which commercial/industrial buildings first commence to be subject to above-floor inundation.
- During a PMF event, five commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $4 Million.

Buronga

- The 5% AEP event was found to be the threshold at which commercial/industrial buildings first commence to be subject to above-floor inundation.
- At the 1% AEP level of flooding, one commercial/industrial building would experience above-floor inundation, resulting in total flood damages of about $0.1 Million.
- During a PMF event, 18 commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $6 Million.

Dareton

- A flood smaller than PMF event was found to be the threshold at which commercial/industrial buildings first commence to be subject to above-floor inundation.
- During a PMF event, two commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $0.5 Million.

Wentworth

- A flood smaller than PMF event was found to be the threshold at which commercial/industrial buildings first commence to be subject to above-floor inundation.
- During a PMF event, seven commercial/industrial buildings would experience above-floor inundation, resulting in total flood damages of about $0.8 Million.

TABLE H5.2
COMMERCIAL / INDUSTRIAL FLOOD DAMAGES
MURRAY AND DARLING RIVER FLOODING

Urban Centre	Design Flood Event	No. of Properties		Total Damages[1] ($ Million)
		Flood Affected	Flooded Above Floor Level	
Gol Gol	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	14	13	10.5
	1% AEP	15	15	14.4
	0.5% AEP	20	15	17.6
	0.2% AEP	21	21	22.7
	Extreme	26	25	30.8
Buronga	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	1	1	0.2
	1% AEP	6	3	0.4
	0.5% AEP	28	12	4.2
	0.2% AEP	53	49	42.2
	Extreme	62	60	94.5
Dareton	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0
	1% AEP	0	0	0
	0.5% AEP	0	0	0
	0.2% AEP	0	0	0
	Extreme	0	0	0
Wentworth	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0
	1% AEP	0	0	0
	0.5% AEP	0	0	0
	0.2% AEP	50	48	21.3
	Extreme	50	50	43.1

1. Total damages are a combination of structural and internal flood damages

TABLE H5.3
COMMERCIAL / INDUSTRIAL FLOOD DAMAGES
LOCAL CATCHMENT FLOODING

Urban Centre	Design Flood Event	No. of Properties		Total Damages(1) ($ Million)
		Flood Affected	Flooded Above Floor Level	
Gol Gol	20% AEP	0	0	0
	10% AEP	1	0	0
	5% AEP	2	0	0
	2% AEP	2	0	0
	1% AEP	3	0	0
	0.5% AEP	4	0	0
	0.2% AEP	4	0	0
	PMF	18	5	3.5
Buronga	20% AEP	1	0	0
	10% AEP	4	0	0
	5% AEP	7	1	0
	2% AEP	8	1	0.1
	1% AEP	10	1	0.1
	0.5% AEP	14	1	0.1
	0.2% AEP	16	1	0.1
	PMF	41	18	5.8
Dareton	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0
	1% AEP	0	0	0
	0.5% AEP	1	0	0
	0.2% AEP	1	0	0
	PMF	7	2	0.5
Wentworth	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	2	0	0
	1% AEP	2	0	0
	0.5% AEP	2	0	0
	0.2% AEP	2	0	0
	PMF	25	7	0.8

1. Total damages are a combination of structural and internal flood damages

H6. DAMAGES TO PUBLIC BUILDINGS

H6.1 Damage Functions

The procedures identified in DPE, 2023 allow for the preparation of a depth versus damage relationship for public buildings. The damage costs include the indirect costs associated with post-flood clean-up for public buildings.

As part of the FRM tool DT01, depth versus damage relationship for public buildings have been classified for three categories which are schools, hospitals and other buildings, the latter of which comprises the following uses:

- Health (e.g. aged care, nursing home);
- Emergency Services (e.g. police station, fire station, ambulance station, NSE SES facilities etc.); and
- Government Buildings (e.g. courthouse, government administration buildings, diplomatic facilities, consulate facilities, major defence facilities, correctional facilities etc).

H6.2 Total Damages – Public Buildings

H6.2.1 General

Table I6.1 summarises the estimated public damages in the study area relating to Murray and Darling River Flooding, while **Table H6.2** summarises similar information relating to local catchment flooding. **Figures H8.1**, **H8.2** and **H8.3** show the location and AEP at which individual buildings first become above-floor inundated as a result of Murray and Darling River flooding at the urban centres of Gol Gol/Buronga, Dareton and Wentworth, respectively, while **Figures H8.4**, **H8.5** and **H8.6** show similar information relating to local catchment flooding.

H6.2.2 Murray and Darling River Flooding

The key findings of the flood damages assessment as it relates to Murray and Darling River flooding at the four urban centres are as follows:

Gol Gol

- A flood slightly smaller than 0.5% AEP event was found to be the threshold at which public buildings first commence to be subject to above-floor inundation.
- During an Extreme Flood event, 12 public buildings would experience above-floor inundation, resulting in total flood damages of about $3 Million.

Buronga

- The 0.2% AEP event was found to be the threshold at which public buildings first commence to be subject to above-floor inundation.
- During an Extreme Flood event, four public buildings would experience above-floor inundation, resulting in total flood damages of about $0.3 Million.

Dareton

- No public buildings are subject to above-floor inundation over the full range of potential flooding.

Wentworth

- No public buildings are subject to above-floor inundation until such time as the Wentworth town levees are overtopped.
- At the 0.2% AEP level of flooding when the Wentworth town levees are overtopped, 17 public buildings would experience above-floor inundation, resulting in total flood damages of about $3 Million.
- During an Extreme Flood event, 23 public buildings would experience above-floor inundation, resulting in total flood damages of about $10 Million.

H6.2.3 Local Catchment Flooding

The key findings of the flood damages assessment as it relates to local catchment flooding at the four urban centres are as follows:

Gol Gol

- A flood slightly smaller than PMF event was found to be the threshold at which public buildings first commence to be subject to above-floor inundation.
- While two public buildings would experience above-floor inundation in a PMF event, the resulting flood damages would be negligible.

Buronga

- The 1% AEP event was found to be the threshold at which public buildings first commence to be subject to above-floor inundation.
- While one public buildings would experience above-floor inundation in a 1% AEP flood event, the resulting flood damages would be negligible.
- While above-floor flooding would be limited to the same building in a PMF event, the total flood damages would only be about $0.1 Million

Dareton

- No public buildings are subject to above-floor inundation over the full range of potential flooding.

Wentworth

- A flood smaller than PMF event was found to be the threshold at which public buildings first commence to be subject to above-floor inundation.
- During a PMF event, five public buildings would experience above-floor inundation, resulting in total flood damages of about $0.2 Million.

TABLE H6.1
PUBLIC FLOOD DAMAGES
MURRAY AND DARLING RIVER FLOODING

Urban Centre	Design Flood Event	No. of Properties		Total Damages[(1)] ($ Million)
		Flood Affected	Flooded Above Floor Level	
Gol Gol	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0.0
	1% AEP	0	0	0.0
	0.5% AEP	5	2	0.1
	0.2% AEP	12	10	0.8
	Extreme	12	12	2.7
Buronga	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0.0
	1% AEP	0	0	0.0
	0.5% AEP	0	0	0.0
	0.2% AEP	1	1	0.0
	Extreme	4	4	0.3
Dareton	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0.0
	1% AEP	0	0	0.0
	0.5% AEP	0	0	0.0
	0.2% AEP	0	0	0.0
	Extreme	0	0	0.0
Wentworth	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0.0
	1% AEP	0	0	0.0
	0.5% AEP	0	0	0.0
	0.2% AEP	17	17	3.2
	Extreme	23	23	10.0

1. Total damages are a combination of structural and internal flood damages

TABLE H6.2
PUBLIC FLOOD DAMAGES
LOCAL CATCHMENT FLOODING

Urban Centre	Design Flood Event	No. of Properties		Total Damages[1] ($ Million)
		Flood Affected	Flooded Above Floor Level	
Gol Gol	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	1	0	0.0
	1% AEP	1	0	0.0
	0.5% AEP	1	0	0.0
	0.2% AEP	1	0	0.0
	PMF	7	2	0.0
Buronga	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	1	0	0
	2% AEP	1	0	0.0
	1% AEP	1	1	0.0
	0.5% AEP	1	1	0.0
	0.2% AEP	1	1	0.0
	PMF	5	1	0.1
Dareton	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0.0
	1% AEP	1	0	0.0
	0.5% AEP	1	0	0.0
	0.2% AEP	1	0	0.0
	PMF	4	0	0.0
Wentworth	20% AEP	0	0	0
	10% AEP	0	0	0
	5% AEP	0	0	0
	2% AEP	0	0	0.0
	1% AEP	1	0	0.0
	0.5% AEP	2	0	0.0
	0.2% AEP	3	0	0.0
	PMF	9	5	0.2

1. Total damages are a combination of structural and internal flood damages

H7. SUMMARY OF TANGIBLE DAMAGES

H7.1 Tangible Damages

Flood damages have been computed for a range of flood frequencies from 20% AEP up to the Extreme Flood/PMF. **Table H7.1** over the page summarises the total flood damages resulting from Murray and Darling River Flooding at the four urban centres, while **Table H7.2** sets out similar information relating to local catchment flooding.[1]

H7.2 Definition of Terms

Average Annual Damages (also termed "expected damages") are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent "*Net Present Value"* (**NPV**) of damages and used in the economic analysis of potential flood management measures.

A flood management scheme which has a design 1% AEP level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods then these damages represent the benefits of the scheme expressed on an average annual basis and converted to the NPV via the discount rate.

Using the procedures outlined in DPE, 2023 and NSW Treasury Guidelines, economic analyses were carried out assuming a 30 year economic life for projects and discount rates of 5% pa. (best estimate) and 7% and 3% pa (sensitivity analyses).

H7.3 Average Annual Damages

The average annual damages for all Murray and Darling River floods up to the Extreme Flood are shown below in **Table H7.3**, while similar information is shown in **Table H7.4** relating to local catchment flooding. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages.

H7.4 Net Present Value of Damages

The NPV of damages likely to be experienced for all Murray and Darling River floods up to the 5%AEP and 1% AEP, as well as the Extreme Flood, for a 30 year economic life and discount rates of 3, 5 and 7 per cent are shown in **Table H7.5**, while similar information is shown in **Table H7.6** relating to local catchment flooding.

One or more flood mitigation schemes costing up to the mid-range discount rate amounts could be economically justified if they eliminated damages in each urban centre for a given AEP event. While schemes costing more than these values would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

[1] Note that the total flood damages include a provision for damage to general public infrastructure which is assumed to equate to 10% of the total residential flood damages.

TABLE H7.1
TOTAL FLOOD DAMAGES
MURRAY AND DARLING RIVER FLOODING
$ MILLION

Urban Centre	Design Flood Event	Residential	Commercial/ Industrial	Public	General Public Infrastructure	Total
Gol Gol	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0	0	0	0	0
	2% AEP	2.6	10.5	0	0.3	13.4
	1% AEP	5.8	14.4	0	0.6	20.8
	0.5% AEP	14.5	17.6	0.1	1.5	33.7
	0.2% AEP	59.6	22.7	0.8	6.0	89.1
	Extreme	157.1	30.8	2.7	15.7	206.3
Buronga	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0.7	0	0	0.1	0.8
	2% AEP	8.4	0.2	0	0.8	9.4
	1% AEP	12.8	0.4	0	1.3	14.5
	0.5% AEP	15.3	4.2	0	1.5	21.0
	0.2% AEP	24.7	42.2	0	2.5	69.4
	Extreme	52.0	94.5	0.3	5.2	152.0
Dareton	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0	0	0	0	0
	2% AEP	0	0	0	0	0
	1% AEP	0	0	0	0	0
	0.5% AEP	0	0	0	0	0
	0.2% AEP	0	0	0	0	0
	Extreme	0.1	0	0	0.0	0.1
Wentworth	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0.4	0	0	0.0	0.4
	2% AEP	1.0	0	0	0.1	1.1
	1% AEP	1.8	0	0	0.2	2.0
	0.5% AEP	2.7	0	0	0.3	3.0
	0.2% AEP	160.8	21.3	3.2	16.1	201.4
	Extreme	203.6	43.1	10.0	20.4	277.1

TABLE H7.2
TOTAL FLOOD DAMAGES
LOCAL CATCHMENT FLOODING
$ MILLION

Urban Centre	Design Flood Event	Residential	Commercial/Industrial	Public	General Public Infrastructure	Total
Gol Gol	20% AEP	0	0	0	0	0
	10% AEP	0.3	0	0	0.0	0.3
	5% AEP	0.4	0	0	0.0	0.4
	2% AEP	0.4	0	0	0.0	0.4
	1% AEP	0.8	0	0	0.1	0.9
	0.5% AEP	1.3	0	0	0.1	1.4
	0.2% AEP	1.8	0	0	0.2	2.0
	PMF	21.6	3.5	0	2.2	27.3
Buronga	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0	0	0	0	0
	2% AEP	0.1	0.1	0	0.0	0.2
	1% AEP	0.3	0.1	0	0.0	0.4
	0.5% AEP	0.7	0.1	0	0.1	0.9
	0.2% AEP	1.3	0.1	0	0.1	1.5
	PMF	14.1	5.8	0.1	1.4	21.4
Dareton	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0	0	0	0	0
	2% AEP	0.1	0	0	0.0	0.1
	1% AEP	0.1	0	0	0.0	0.1
	0.5% AEP	0.1	0	0	0.0	0.1
	0.2% AEP	0.1	0	0	0.0	0.1
	PMF	4.4	0.5	0	0.4	5.3
Wentworth	20% AEP	0	0	0	0	0
	10% AEP	0	0	0	0	0
	5% AEP	0.1	0	0	0.0	0.1
	2% AEP	0.2	0	0	0.0	0.2
	1% AEP	0.6	0	0	0.1	0.7
	0.5% AEP	0.6	0	0	0.1	0.7
	0.2% AEP	1.4	0	0	0.1	1.5
	PMF	44.0	0.8	0.2	4.4	49.4

TABLE H7.3
AVERAGE ANNUAL DAMAGES
MURRAY AND DARLING RIVER FLOODING
$ MILLION

Urban Centre	Design Flood Event	Residential	Commercial/ Industrial	Public	General Public Infrastructure	Total	
						Contribution to AAD[1]	Cumulative AAD[2]
Gol Gol	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0	0	0	0	0	0
	2% AEP	0.04	0.16	0	0	0.20	0.20
	1% AEP	0.04	0.12	0	0	0.16	0.36
	0.5% AEP	0.05	0.08	0	0.01	0.14	0.50
	0.2% AEP	0.11	0.06	0	0.01	0.18	0.68
	Extreme	0.22	0.05	0	0.02	0.29	0.97
Buronga	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0.02	0	0	0	0.02	0.02
	2% AEP	0.14	0	0	0.01	0.15	0.17
	1% AEP	0.11	0	0	0.01	0.12	0.29
	0.5% AEP	0.07	0.01	0	0.01	0.09	0.38
	0.2% AEP	0.06	0.07	0	0.01	0.14	0.52
	Extreme	0.08	0.14	0	0.01	0.23	0.75

Cont'd Over

TABLE H7.3 (Cont'd)
AVERAGE ANNUAL DAMAGES
MURRAY AND DARLING RIVER FLOODING
$ MILLION

Urban Centre	Design Flood Event	Residential	Commercial/ Industrial	Public	General Public Infrastructure	Total Contribution to AAD[1]	Cumulative AAD[2]
Dareton	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0	0	0	0	0	0
	2% AEP	0	0	0	0	0	0
	1% AEP	0	0	0	0	0	0
	0.5% AEP	0	0	0	0	0	0
	0.2% AEP	0	0	0	0	0	0
	Extreme	0	0	0	0	0	0
Wentworth	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0.01	0	0	0	0.01	0.01
	2% AEP	0.02	0	0	0	0.02	0.03
	1% AEP	0.01	0	0	0	0.01	0.04
	0.5% AEP	0.01	0	0	0	0.01	0.05
	0.2% AEP	0.25	0.03	0	0.02	0.3	0.35
	Extreme	0.36	0.06	0.01	0.04	0.47	0.82

1. Represents the contribution to the total average annual damages for the specified design flood event
2. Represents the cumulative annual average damages for all floods up to the specified design flood event in magnitude.

TABLE H7.4
AVERAGE ANNUAL DAMAGES
LOCAL CATCHMENT FLOODING
$ MILLION

Urban Centre	Design Flood Event	Residential	Commercial/ Industrial	Public	General Public Infrastructure	Total	
						Contribution to AAD(1)	Cumulative AAD(2)
Gol Gol	20% AEP	0	0	0	0	0	0
	10% AEP	0.02	0	0	0	0.02	0.02
	5% AEP	0.02	0	0	0	0.02	0.04
	2% AEP	0.01	0	0	0	0.01	0.05
	1% AEP	0.01	0	0	0	0.01	0.06
	0.5% AEP	0.01	0	0	0	0.01	0.07
	0.2% AEP	0.00	0	0	0	0.00	0.07
	PMF	0.02	0	0	0	0.02	0.09
Buronga	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0	0	0	0	0	0
	2% AEP	0	0	0	0	0	0
	1% AEP	0	0	0	0	0	0
	0.5% AEP	0	0	0	0	0	0
	0.2% AEP	0	0	0	0	0	0
	PMF	0.02	0.01	0	0	0.03	0.03

Cont'd Over

TABLE H7.4 (Cont'd)
AVERAGE ANNUAL DAMAGES
LOCAL CATCHMENT FLOODING
$ MILLION

Urban Centre	Design Flood Event	Residential	Commercial/ Industrial	Public	General Public Infrastructure	Total	
						Contribution to AAD(1)	Cumulative AAD(2)
Dareton	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0	0	0	0	0	0
	2% AEP	0	0	0	0	0	0
	1% AEP	0	0	0	0	0	0
	0.5% AEP	0	0	0	0	0	0
	0.2% AEP	0	0	0	0	0	0
	PMF	0	0	0	0	0	0
Wentworth	20% AEP	0	0	0	0	0	0
	10% AEP	0	0	0	0	0	0
	5% AEP	0	0	0	0	0	0
	2% AEP	0	0	0	0	0	0
	1% AEP	0	0	0	0	0	0
	0.5% AEP	0	0	0	0	0	0
	0.2% AEP	0	0	0	0	0	0
	PMF	0.05	0	0	0	0.05	0.05

1. Represents the contribution to the total average annual damages for the specified design flood event
2. Represents the cumulative annual average damages for all floods up to the specified design flood event in magnitude.

TABLE H7.5
NET PRESENT VALUE OF DAMAGES
MURRAY AND DARLING RIVER FLOODING
$ MILLION

Urban Centre	Discount Rate (%)	All Floods up to 5% AEP	All Floods up to 1% AEP	All Floods up to Extreme Flood
Gol Gol	3	0	7.4	19.4
	5	0	5.8	15.2
	7	0	4.7	12.3
Buronga	3	0.4	5.9	14.6
	5	0.3	4.6	11.5
	7	0.2	3.8	9.3
Dareton	3	0	0	0
	5	0	0	0
	7	0	0	0
Wentworth	3	0.2	1.1	16.6
	5	0.2	0.8	13.0
	7	0.2	0.7	10.5

TABLE H7.6
NET PRESENT VALUE OF DAMAGES
LOCAL CATCHMENT FLOODING
$ MILLION

Urban Centre	Discount Rate (%)	All Floods up to 5% AEP	All Floods up to 1% AEP	All Floods up to PMF
Gol Gol	3	1.3	1.7	2.5
	5	1.0	1.3	1.9
	7	0.8	1.1	1.6
Buronga	3	0	0.2	0.7
	5	0	0.1	0.6
	7	0	0.1	0.5
Dareton	3	0.1	0.1	0.2
	5	0.1	0.1	0.2
	7	0	0.1	0.2
Wentworth	3	0.4	0.6	1.7
	5	0.3	0.4	1.3
	7	0.2	0.4	1.1

H8. REFERENCES

DPE (Department of Planning), 2023. *"**Flood Risk Management Guideline MM01 – Flood Risk Management Measures**"*

APPENDIX I

SUGGESTED WORDING FOR INCLUSION IN WENTWORTH SHIRE DEVELOPMENT CONTROL PLAN

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FIGURES
(BOUND IN VOLUME 2)

I1.1 Introduction

This section of the DCP sets out specific controls to guide development of flood liable land. The approach to managing future development that is subject to flooding supports the findings of a series of location specific flood risk management studies and plans that have been prepared as part of the NSW Government's program to mitigate the impact of major floods and reduce the associated hazards in the floodplain.

I1.2 Objectives in Relation to Flood Risk Management

a) To minimise the potential impact of development and other activity upon the aesthetic, recreational and ecological value of the waterway corridors.

b) To increase public awareness of the hazard and extent of land affected by all potential floods, including floods greater than the 1% Annual Exceedance Probability (**AEP**) flood and to ensure essential services and land uses are planned in recognition of all potential floods.

c) To inform the community of Council's controls and policy for the use and development of flood prone land.

d) To reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by potential floods.

e) To provide detailed controls for the assessment of applications lodged in accordance with the *Environmental Planning and Assessment Act 1979* on land affected by potential floods.

f) To provide different guidelines, for the use and development of land subject to all potential floods in the floodplain, which reflect the probability of the flood occurring and the potential hazard within different areas.

g) To apply a "merit-based approach" to all development decisions which takes account of social, economic and ecological considerations.

h) To control development and other activity within each of the individual floodplains within the LGA having regard to the characteristics and level of information available for each of the floodplains, in particular the availability of flood risk management studies and plans prepared in accordance with the *Flood Risk Management Manual*, issued by the NSW Government.

i) To deal equitably and consistently with applications for development on land affected by potential floods, in accordance with the principles contained in the *Flood Risk Management Manual*.

I1.3 Procedure for Determining What Controls Apply to Proposed Development

The procedure Council will apply for determining the specific controls applying to proposed development in flood liable areas is set out below. Upon enquiry by a prospective applicant, Council will make an initial assessment of the flood affectation and flood levels at the site using the following procedure:

- ➢ Assess whether the development is located on flood liable land from the **Flood Planning Map**.
- ➢ Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map**.
- ➢ Identify the category of the development from **Schedule1: Land Use Categories.**

- Determine the appropriate flood level at the site from the results of the location specific flood or flood risk management study.
- Determine which part of the floodplain the development is located in from the **Flood Planning Constraint Category Map**.
- Confirm that the development conforms with the relevant performance criteria, as well as the prescriptive controls set out in **Schedules 2A** and **2B**.

With the benefit of this initial information from Council, the applicant will:

- Prepare the documentation to support the Development Application according to the requirements of **Section I1.9**.

A survey plan showing natural surface levels over the site will be required as part of the Development Application documentation. Provision of this plan by the applicant at the initial enquiry stage will assist Council in providing flood related information.

I1.4 Land Use Categories

The policy recognises twelve different types of land use for which a graded set of flood related controls apply. They are included in **Schedule 1: Land Use Categories**.

I1.5 Flood Planning Constraint Categories

For those floodplains where Council has adopted a flood or flood risk management study, the identified flood liable land has been divided into the following four *Flood Planning Constraint Categories* (**FPCCs**):

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls that are set out in **Appendix I** of this report.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises areas that lie between the FPA and the extent of the Extreme Flood/PMF where no flood related development controls currently apply. This area is identical to the *Outer Floodplain* shown on the **Flood Planning Map**.

I1.6 Development Controls

The development controls have been graded relative to the severity and frequency of potential floods, having regard to the FPCCs determined by the relevant Flood Risk Management Study and Plan or, if no such study or plan exists, Council's interim considerations.

The objectives of the development controls are:

a) To require developments with high sensitivity to flood risk to be designed so that they are subject to minimal risk.

b) To allow development with a lower sensitivity to the flood hazard to be located within the floodplain, provided the risk of harm and damage to property is minimised.

c) To minimise the intensification of the high flood risk areas, and if possible, allow for their conversion to natural waterway corridors.

d) To ensure design and siting controls required to address the flood hazard do not result in unreasonable social, economic or environmental impacts.

e) To minimise the risk to life by ensuring the provision of reliable access from areas affected by flooding.

f) To minimise the damage to property arising from flooding.

g) To ensure the proposed development does not expose existing development to increased risks associated with flooding.

The performance criteria which are to be applied when assessing a proposed development are:

a) The proposed development should not result in any increase in risk to human life, or in a significant increase in economic or social costs as a result of flooding.

b) The proposal should only be permitted where effective warning time and reliable access is available to an area free of risk from flooding, consistent with any relevant Flood Plan or flood evacuation strategy.

c) Development should not increase the potential for damage or risk to other properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain.

d) Procedures would be in place, if necessary, (such as warning systems, signage or evacuation drills) so that people are aware of the need to evacuate and are capable of identifying the appropriate evacuation route.

e) Development should not result in impacts upon the amenity of an area by way of unacceptable overshadowing of adjoining properties, privacy impacts (e.g. by unsympathetic house–raising) or by being incompatible with the streetscape or character of the locality.

The prescriptive controls which apply to development that is proposed on land that is affected by either Murray and Darling River Flooding or Local Catchment Flooding are set out in **Schedules 2A** and **2B**, respectively

I1.7 Proposals to Modify Flood Planning Constraint Categories

In certain situations it may be feasible to modify existing flood behaviour through engineering works which in turn would enable the extent of the FPCCs to be modified at a particular location. Proposals to modify an FPCC at a particular location would need to be supported by a detailed flooding investigation, further details of which are set out in **Section I1.9** below. Proposals would also need to demonstrate consistency with the flood related objectives and performance criteria of both the *Wentworth Local Environmental Plan 2011* and the DCP.

I1.8 Special Requirements for Fencing

The objectives are:

a) To ensure that fencing does not result in the obstruction of the free flow of floodwater.

b) To ensure that fencing does not become unsafe during floods so as to threaten the integrity of structures or the safety of people.

c) To ensure fencing is to be constructed in a manner which does not increase flood damage or risk on surrounding land.

The performance criteria which are to be applied when assessing proposed fencing are:

a) Fencing is to be constructed in a manner that does not affect the flow of floodwater so as to detrimentally increase flood affection on surrounding land.

b) Fencing must be certified by an engineer specialising in hydraulic engineering stating that the proposed fencing would be constructed to withstand the force of floodwater, or collapse in a controlled manner to prevent the impediment of floodwater.

The prescriptive controls which apply to any proposed fencing on land designated FPCC 1 and FPCC 2 are:

a) An applicant will need to demonstrate that the fence (new or replacement fence) would not create an impediment to the flow of floodwater. Fences must satisfy the following:

- comprise pool/louvre type fencing or a collapsible hinged type fence structure;
- be configured so as to allow floodwaters to equalise on both sides of the fence; and
- be configured so as to minimise entrapment of flood debris.

I1.9 Explanatory Notes on Lodging Applications

The following steps must be followed in the lodgement of a development application:

a) Check the proposal is permissible in the zoning of the land by reference to any applicable environmental planning instruments.

b) Consider any other relevant planning controls of Council (e.g. controls in any other relevant part of the DCP).

c) Check whether the property is located either partially or wholly within the Flood Planning Area or Outer Floodplain, as defined on the **Flood Planning Map**.

d) Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map**.

e) Determine which FPCC applies to the developable portion of the property by reference to the **Flood Planning Constraint Category Map**. Enquire with Council regarding existing flood risk mapping or whether a site–specific assessment may be warranted. A property may be located in more than one FPCC and the assessment must consider the controls that apply in each.

f) Determine the land use category relevant to the development proposal, by firstly confirming how it is defined by the relevant environmental planning instrument and secondly by ascertaining the land use category from **Schedule 1: Land Use Categories**.

g) Assess and document how the proposal will achieve the performance criteria for proposed development and associated fencing set out in **Sections I1.6** and **I1.8**.

h) Check if the proposal will satisfy the prescriptive controls for different land use categories in different FPCCs, as specified in **Schedules 2A** and **2B**.

i) If the proposal does not comply with the prescriptive controls, determine whether the performance criteria are nonetheless achieved.

j) Illustrations provided in this plan to demonstrate the intent of development controls are diagrammatic only. Proposals should satisfy all relevant controls contained in this plan and associated legislation.

k) The assistance of Council staff or an experienced engineer or planner may be required at various steps in the process to ensure that the flood risk management related requirements of this Plan are addressed.

Note that compliance with all the requirements of this DCP does not guarantee that an application will be approved.

Information required with an application is as follows:

a) Applications must include information which addresses all relevant controls.

b) Applications for alterations and additions (see **Schedules 2A and 2B**) to an existing dwelling on flood liable land must be accompanied by documentation from a registered surveyor confirming existing floor levels.

c) Development applications must be accompanied by a survey plan showing:

    i. The position of the existing building(s) and/or proposed building(s);

    ii. The existing ground levels to Australian Height Datum around the perimeter of the existing and/or proposed building(s) and contours of the site; and

    iii. The existing and/or proposed floor levels to Australian Height Datum.

d) Applications for earthworks, filling of land or subdivision shall be accompanied by a survey plan (with a contour interval of 0.25 m) showing relative levels to Australian Height Datum.

e) Where an existing catchment based flood study is not available, a flood study using a fully dynamic one or two dimensional computer model may be required. For smaller developments an existing suitable flood study may be used if available (e.g. it contains sufficient local detail), or otherwise a flood study prepared in a manner consistent with the latest edition of *Australian Rainfall and Runoff* and the *Flood Risk Management Manual*, will be required and the following information must be submitted in plan form:

    i. water surface contours;

    ii. velocity vectors;

    iii. velocity and depth product contours;

    iv. delineation of flood risk precincts relevant to individual floodplains; and

    v. show both existing and proposed flood profiles for the full range of events for total development including all structures and works (such as revegetation/ enhancements).

    This information is required for both pre–developed and post–developed scenarios.

f) Where the controls for a particular development proposal require an assessment of structural soundness during potential floods, the following impacts must be addressed:

   i. hydrostatic pressure;
   ii. hydrodynamic pressure;
   iii. impact of debris; and
   iv. buoyancy forces.

   Foundations need to be included in the structural analysis.

I1.10 Glossary of Terms

TERM	DEFINITION
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Extreme Flood	The Extreme Flood defines the upper limit of potential flooding on the Murray and Darling rivers and has been assessed to have a peak flow three (3) times that of the 1% (1 in 100) AEP flood event
Floodplain	Area of land which is subject to inundation by floods up to and including the Extreme Flood/Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie within the extent of the Flood Planning Area where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie within the extent of the *Flood Planning Area* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies between the extent of the Flood Planning Area and the Extreme Flood/PMF. Given the extended warning time available to areas within the Wentworth Shire Local Government Area, no flood related controls apply to development that is located in this zone. This area is identical to the Outer Floodplain shown on the Flood Planning Map.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted flood risk management study and plan, or as part of a site specific study In the absence of an adopted flood risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the Extreme Flood/PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the *Flood Planning Level*.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Murray and Darling River Flooding	Occurs when floodwater surcharges the inbank area of the Murray and Darling rivers. Murray and Darling River Flooding is typically characterised by relatively deep and faster flowing floodwater in the main channel of the river but can include shallower and slower moving floodwater in overbank areas
Local Catchment Flooding	Is experienced at the four urban centres during periods of heavy rain. Local catchment flooding is characterised by relatively shallow and slow-moving floodwater.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land in the two urban centres where they are not impacted by the Extreme Flood.

SCHEDULE 1
LAND USE CATEGORIES

Land Use Category	Subdivision	LEP Land Uses
Critical Uses and Facilities	*Community facilities which may provide an important contribution to the notification or evacuation of the community during flood events.*	Health services facility; Electricity generating works; Emergency services facility.
Sensitive Uses and Facilities	*Uses which involve vulnerable members of the community;* *Uses which may cause pollution of a watercourse or town water supply;* *Uses, which if affected, would significantly affect the ability of community to return to normal after flood event;*	Bio-solids treatment facility; Cemeteries; Child care centre; Correctional centre; Heavy industrial storage establishment; Heavy industries; Highway service centre; Group home; Passenger transport facilities; Respite day care centre; Schools; Seniors housing; Service Stations; Sewage treatment plant; Veterinary hospital; Waste or resource management facility; Water treatment facility.
Subdivision	*Subdivision of land which involves* *the creation of new allotments, with* *potential for further development;*	Camping grounds; Caravan parks; Eco-tourist facilities; Home business/ child care/occupations; Residential accommodation (excluding Group Home and Seniors housing); Tourist and visitor accommodation.
Residential		Attached dwellings Dwelling houses Multi dwelling housing Residential flat buildings Semi-detached dwellings Shop top housing
Commercial and Industrial		Amusement centre; Commercial premises (excluding Market); Crematorium; Depots; Entertainment facility; Freight transport facilities; Function centre; General industries; Industrial retail outlet; Industrial training facility; Light industries; Mortuaries;

		Place of public worship; Public administration building; Recreation facility (indoor & major); Registered club; Research station; Restricted premises; Sex services premises; Storage premises; Transport depots; Truck depots; Warehouse or distribution centre; Wholesale suppliers; Vehicle body repair workshops; Vehicle repair stations;
Recreation and Non-Urban		Agriculture (excluding intensive livestock agriculture); Animal boarding and training establishment; Boat sheds; Charter & tourism boating facilities; Car park; Community facility; Extractive industry; Forestry; Jetties; Market; Open cut mining; Recreation area; Recreation facility (outdoor).
Alterations and additions		i. An addition to existing premises of not more than 10% of the floor area which existed at the date of commencement of this DCP; ii. Rebuilding of a development which substantially reduces the extent of flood effects to the existing development; iii. A change of use which does not increase flood risk having regard to property damage and personal safety; or iv. Subdivision which does not involve the creation of new allotments with potential for further development.

SCHEDULE 2A
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MURRAY AND DARLING RIVER FLOODING

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions
Minimum Habitable Floor Level						A1	A2 A3				A2	A4	A1	A2 A3	A2	A2		A2	A4	A1	A2 A3							
Building Components						B1	B1				B1	B1	B1	B1	B2	B2		B1	B1	B1	B1							
Structural Soundness						C1	C1				C1	C1	C1	C1	C2	C2		C1	C1	C1	C1							
Flood Affectation						D1	D3			D1	D1	D1	D1	D3	D2	D2	D2	D2	D2	D2	D2							
Emergency Response						E1	E1			E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1							
Management and Design						F2 F3	F2 F3			F1	F2	F2 F3 F4	F2 F3	F2 F3	F2 F3 F4	F2 F3	F1		F4									
Stormwater						G2	G2			G1 G2	G1 G2	G1 G2	G2	G2	G1	G1	G1 G2	G1 G2	G1 G2	G2	G2							
Parking and Driveway Access						H1	H1			H1	H1	H1	H1	H1	H1	H1	H1	H1	H1	H1	H1							

(green)	Not Relevant	(purple)	Unsuitable Land Use

SCHEDULE 2B
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – LOCAL CATCHMENT FLOODING

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions
Minimum Habitable Floor Level						A1	A2 A3				A2	A4	A1	A2 A3	A2	A2		A2	A4	A1	A2 A3							
Building Components						B1	B1				B1	B1	B1	B1	B2	B2		B1	B1	B1	B1							
Structural Soundness						C1	C1				C1	C1	C1	C1	C2	C2		C1	C1	C1	C1							
Flood Affectation						D1	D3			D1	D1	D1	D1	D3														
Emergency Response						E1	E1			E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1	E1							
Management and Design						F2 F3	F2 F3			F1	F1	F1	F1	F1	F1	F1	F1		F1									
Stormwater						G2	G2			G1 G2	G2	G2	G2	G2	G1	G1	G1 G2	G2	G2	G2	G2							
Parking and Driveway Access						H1	H1			H1	H1	H1	H1	H1	H1	H1	H1	H1	H1	H1	H1							

	Not Relevant		Unsuitable Land Use

Prescriptive controls for associated planning considerations under each FPCC		
Minimum Habitable Floor Level **A1** Habitable floor levels to be set no lower than the 5% AEP flood level plus freeboard(1) unless justified by site specific assessment. **A2** Habitable floor levels to be set no lower than the 1% AEP flood level plus freeboard(1). **A3** Habitable floor levels to be as close to the Minimum Habitable Floor Level as practical and no lower than the existing floor level when undertaking concessional development. **A4** Habitable floor levels to be as close to the 1% AEP flood level plus freeboard(1) as practical, but no lower than the 5% AEP flood level plus freeboard(1). In situations where the habitable floor level is set below the 1% AEP flood level plus freeboard(1), a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard(1).	**Building Components & Method** **B1** All structures to have flood compatible building components below the 1% AEP flood level plus freeboard(1) (refer **Schedules 3A** and **3B**). **B2** All structures to have flood compatible building components below the 1% AEP flood plus freeboard(1) or the Extreme Flood/PMF level, whichever is the highest (refer **Schedules 3A** and **3B**).	**Structural Soundness** **C1** Engineers report to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard(1). **C2** Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard(1) or an Extreme Flood/PMF, whichever is the greatest.
Flood Affectation **D1** Engineers report required to certify that the development will not increase flood affectation elsewhere. **D2** Engineers report required to certify that the development will not increase flood affectation elsewhere only where the proposed development is located on land that is inundated in a 1% AEP flood event. **D3** The impact of the development on flooding elsewhere to be considered.	**Emergency Response** **E1** The development is to be consistent with any relevant flood evacuation strategy or similar plan.	**Management and Design** **F1** Applicant to demonstrate that potential development as a consequence of a subdivision or development proposal can be undertaken in accord with this Development Control Plan. **F2** Flood Safe Plan (home or business or farm houses) to address safety and property damage issues (including goods storage and stock management) considering the full range of flood risk. **F3** Site Emergency Response Flood Plan required considering the full range of flood risk **F4** No external storage of materials below the Minimum Habitable Floor Level which may cause pollution or be potentially hazardous during any flood.
Stormwater **G1** Engineers report required to certify that the development will not affect stormwater drainage. **G2** The impact of the development on local overland flooding to be considered.	**Parking and Driveway Access** **H1** The minimum surface level of open car parking spaces, carports or garages shall be as high as practical	

1. Unless stated otherwise in an adopted location specific Flood Risk Management Study and Plan, freeboard is equal to 0.5 m for development being assessed under Schedule 2 and 0.3 m for development being assessed under Schedule 2B.

SCHEDULE 3A
GENERAL BUILDING MATTERS

Electrical and Mechanical Equipment

For dwellings constructed on land to which this policy applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.

Main Power Supply

Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the relevant elevation referred to in control B1 or B2 of **Schedule 2**. Means shall be available to easily isolate the dwelling from the main power supply.

Wiring

All wiring, power outlets, switches, etc, should be, to the maximum extent possible, located above the relevant elevation referred to in control B1 or B2 of **Schedule 2**. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. Earth leakage circuit breakers (core balance relays) must be installed. Only submersible type splices should be used below the relevant elevation referred to in control B1 or B2 of **Schedule 2**. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment

All equipment installed below or partially below the relevant elevation referred to in control B1 or B2 of **Schedule 2** should be capable of disconnection by a single plug and socket assembly.

Reconnection

Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and Air Conditioning Systems

Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above the relevant elevation referred to in control B1 or B2 of **Schedule 2**. When this is not feasible, every precaution should be taken to minimise the damage caused by submersion according to the following guidelines:

i) Fuel

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

ii) Installation

The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks should be vented to the relevant elevation referred to in control B1 or B2 of **Schedule 2**.

iii) Ducting

All ductwork located below the relevant elevation referred to in control B1 or B2 of **Schedule 2** should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a watertight wall or floor below the relevant flood level, a closure assembly operated from above the relevant elevation set out under B1 or B2 of **Schedule 2** should protect the ductwork.

Sewer

All sewer connections to properties in flood prone areas are to be fitted with reflux valves.

SCHEDULE 3B
FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slab-on-ground construction which could be inundated. • Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
Floor Covering	• Clay tiles • Concrete, precast or in situ • Concrete tiles • Epoxy formed-in-place • Mastic flooring, formed-in-place • Rubber sheets or tiles with chemical set adhesive • Silicone floors formed-in-place • Vinyl sheets or tiles with chemical-set adhesive • Ceramic tiles, fixed with mortar or chemical set adhesive • Asphalt tiles, fixed with water resistant adhesive • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges