GHD

HILLSBOROUGH ROAD DUPLICATION -WINDING CREEK 80% DESIGN – FLOOD IMPACT ASSESSMENT

FINAL REPORT

OCTOBER 2022

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: (02) 9299 2855
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

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Project Hillsborough Road Duplication -Winding Creek 80% Design – Flood Impact Assessment	**Project Number** 118072-02
Client GHD	**Client's Representative** Derek Wylde
Authors Urvisha Kiri Monique Retallick	**Prepared by** UK MER
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80% DESIGN – FLOOD IMPACT ASSESSMENT

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AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (now OEH)
DNR	Department of Natural Resources (now OEH)
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2019) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2019 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance

Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

1. EXECUTIVE SUMMARY

WMAwater was engaged by GHD to undertake a flood impact assessment for the Hillsborough Road Duplication Upgrade located within the Winding Creek catchment.

The design (currently at 80% Design Stage) has been incorporated into the hydraulic model based on information provided by GHD. These design options incorporate the lane duplication and widening of Hillsborough Road and an extension of the culverts. The design also incorporated flood mitigation options, including an upgrade of culverts and pit network. Various design storm events were modelled including the 1 EY, 20% AEP, 10% AEP, 2% AEP, 1% AEP and 1 in 2000 year.

Overall, the proposed duplication causes changes to flood behaviour in the immediate area. Generally the increase in water levels as a result of the project occur in undeveloped areas or within or near the road corridor with reductions in water levels within downstream residential properties. A maximum increase of 0.515m in the 1% AEP occurs upstream of Hillsborough Road. Some minor water level reductions (up to 0.057m) occur in Higham and King Streets with one property no longer flooded. It was not investigated if this reduction affects the above floor flooding. Some minor increases in flooding (up to 0.044m) occurs on Chadwick Street and Hillsborough Road.

It is noted that blockage prevention devices should be installed on the culverts under Hillsborough Road downstream of Basin 3 to ensure the culverts are not blocked during an event due to their importance in the flow of water from the Basin 3 outlet. No change in basin behaviour occurs as a result of the project.

There are no significant changes in velocity between the proposed design and existing flood conditions.

2. INTRODUCTION

WMAwater was engaged by GHD to undertake a flood impact assessment for the Hillsborough Road Duplication Upgrade located within the Winding Creek catchment. This report informs the 80% design stage of the Hillsborough Road upgrade.

A hydraulic model (TUFLOW) of the Winding Creek catchment was established by WMAwater for the Winding Creek and Lower Cockle Creek Flood Study commissioned by Lake Macquarie City Council (LMCC) in January 2011 (Reference 4). Permission was sought and granted for the use of the Winding Creek model for use by Roads and Maritime was sort prior to adopting the model for the purposes of the Hillsborough Road design.

As a part of the current study, the model was updated to the latest ARR Guidelines (2019) and refined to a finer grid size to better represent the topography. Various storm events were modelled as agreed upon with GHD, including the 1 EY, 20% AEP, 10% AEP, 2% AEP, 1% AEP and 1 in 2000 year. This report presents a summary of the model updates and flood impact assessment of the proposed design at the 80% stage.

3. BACKGROUND

3.1. Study Area

The Hillsborough Road Duplication lies within the Winding Creek catchment area. Winding Creek has a catchment area of approximately 23.3km^2. It drains into Lake Macquarie at Cockle Bay. Approximately 4.3km^2 of the catchment situated upstream of Hillsborough Road which lies within the boundaries of the City of Lake Macquarie Local Government Area. Flooding of roads and residential areas within the catchment has occurred on several occasions in living memory. The most notable being April 2001, February 1990 and June 2007.

The floodplain within the catchment area includes part of the suburbs of Barnsley, Edgeworth, Argenton, Glendale and Cardiff. The business centre of Cardiff on Winding Creek is particularly prone to flooding and the creek system in this reach consists of a wide concrete lined channel. Upstream of the business centre of Cardiff there are expansive overbank grassed areas of parkland adjoining the lined channel of Winding Creek but through the centre there is development to nearly the boundary of the channel. Significant overbank flooding occurred in February 1990 and June 2007 causing significant damage and risk to life (Reference 4). It will have also occurred in many other events but no records are available of these.

The Western and Northern parts of the catchment are heavily vegetated but urban development in the other areas has meant that in these areas the pervious coverage has been replaced with impervious surfaces (houses, roads). However, there are large areas of open space including golf courses and parks within the developed areas of the catchment. Of significance is the construction of two retarding basins by Hunter Water in 1993 (Basins 3 and 5 shown on Figure 1) in the Winding Creek catchment to reduce the peak flows downstream. Basin 3 is upstream of Hillsborough Road.

The study area that incorporates the Hillsborough Road duplication is located between the Crockett Street intersection and NICB intersection (roundabout). Figure 1 shows the study extent.

3.2. Project

Key features of the proposal include:

- Duplication of about 1.8 kilometres of Hillsborough Road from the NICB roundabout west to a tie in point about 300 metres west of Crockett Street.
- Two lanes each a minimum 3.3 metre wide each way with a solid central median barrier.
- Posted speed of 60 kilometres per hour.
- New traffic lights at the Chadwick Street intersection including pedestrian crossings.
- Modification of Higham Road intersection.
- New traffic lights at the Baker Avenue intersection including pedestrian crossing.
- U-turn bay on Barker Avenue.
- Access gates to be relocated beyond u turn facility.
- New traffic lights at the Crockett Street intersection including pedestrian crossings.
- Provision for on road cyclists within shoulder in both directions.
- Off road concrete shared path on the northern side tying into existing path.

- Upgraded bus stop facilities on Hillsborough Road at Crockett Street intersection, Chadwick Street intersection and on Crockett Street. All bus stops are to have shelters with the exception of the southbound bus lay over on Crockett Street.
- Culvert widening on Winding Creek both up stream and down stream of existing culvert structure.
- Culvert widening and full replacement of existing culvert between Crockett Street and Baker Avenue.
- New separated left in only entry and left out only exit for the CNCC Showgrounds located east (entry) and west (exit) of Chadwick Street intersection.
- Maintained access to the Hillsborough Road fire trail opposite Crockett Street.
- Left in / left out only access from existing business fronting Hillsborough Road, east of the CNCC Showgrounds.
- Left in / left out only access to residences on Hillsborough Road, east of CNCC Showgrounds.
- Relocation of utilities including, telecommunications, water, power, street lighting and minor adjustments to sewer infrastructure.
- New as well as upgraded street lighting on Hillsborough Road.
- Reinforced concrete retaining walls including facing panels.
- Site investigations, including but not limited to geotechnical investigations.
- Installation of fauna connectivity structures, such as rope crossings.
- Minor property acquisition and adjustments including fencing, access and driveway adjustments.
- Site preparation works, including establishing ancillary facilities, vegetation clearing, site fencing, temporary drainage measures, and implementation of environmental management measures.
- Temporary construction facilities, including site compounds and stockpile sites at the former Whalan’s Nursery site– Hillsborough Road, and at vacant commercial buildings within the Warners Bay Commercial Centre – Accessed by northern commercial access road of Hillsborough Road.

Construction of the proposal is planned to be delivered in stages. The NSW Government has announced $35 million to deliver the first stage of the Hillsborough Road upgrade. Stage 1 involves upgrading Crockett Street intersection, including installation of traffic lights. Stage 1 is expected to commence construction in 2025 and take about 18 months to complete depending on final staging arrangements. Timing for construction of the remaining stages is subject to project approvals and funding.

3.3. Previous Studies

3.3.1. Flood Study & Floodplain Risk Management Study

WMAwater was engaged by Lake Macquarie City Council (LMCC) in 2011 to undertake a Flood Study and Floodplain Risk Management Study of the Winding Creek and Lower Cockle Creek catchment. The model was calibrated to the February 1990, April 2001 and June 2007 flood events. The study was initially published in 2013 with a final revision published in 2017 which incorporated a review of 2013 ARR design rainfall intensities and fix to erroneous survey data of the lined channel between Elizabeth Street and Newcastle Street. Additionally, the revision also included an extension to the hydraulic model extent on Tickhole and Argenton Creeks. This model has been used as the basis for the current study.

3.3.2. Hunter Water Basin Studies

AECOM was engaged by Hunter Water Corporation (HWC) in 2015 to undertake a dam break study and consequence category assessment to evaluate the consequence category of Basin 5 and to determine if Basin 3 is required to be declared under the Dam Safety Act 2015. The assessment made use of the WMAwater Flood Study TUFLOW model with an update to the Digital Terrain Model (DTM) through the use of LiDAR provided by HWC. Additionally, AECOM recalibrated the model to the 2015 and 2016 flood events. The study found that both basins have a severity of damage and loss consequence of medium and a flood consequence category of significant. A number of issues were identified with the model and therefore the model was not adopted for the current study.

3.3.3. Gap Identification and Preliminary Assessment of Hillsborough Road to Newcastle Inner City Bypass

WMAWater was engaged by Roads and Maritime Services during the gap identification and preliminary assessment stage of the Hillsborough Road to Newcastle Inner City Bypass. The TUFLOW model developed as a part of the flood study for LMCC was adopted. To better describe floodplain behaviour in the vicinity of Hillsborough Road and ensure an accurate representation of the impacts of the project and overtopping behaviour a number of updates to the 2D hydraulic model were undertaken, including include changes to the model extent, inflow locations and the inclusion of additional hydraulic structures. As part of this investigation, WMAwater also updated the Winding Creek model to run on the at time latest version of TUFLOW (2018 HPC Version AC). The model was deemed to be fit for purpose for the preliminary assessment of the Hillsborough Road to Newcastle Inner City Bypass project and therefore the updated to the base model developed for LMCC has been adopted for the current study.

4. AVAILABLE DATA

4.1. Winding Creek Flood Model

The original Winding Creek model was initially developed for the Winding Creek Flood Study prepared in July 2013 and later updated in June 2017 to include updated survey and for the use in the Winding Creek Floodplain Risk Management Study. The model was also updated as a part of the Gap Identification and Preliminary Assessment of Hillsborough Road to Newcastle Inner City Bypass project. The hydraulic model was a TUFLOW combined one and two dimensional model simulating the main creek channels and overbank areas within the Winding Creek catchment. The model has been calibrated to the February 1990 and June 2007 events.

The data was considered appropriate for use in the impact assessment for the properties in Hillsborough. It should be noted that the flood model did not incorporate the pit and pipe network in Hillsborough or details in the footpath grade/fencing around properties. It is generally not common practise to include detailed stormwater networks and topography within the properties as it does not have an added benefit for flood studies – and is more important for local drainage and overland flow considerations.

4.2. Topographic Data

The Winding Creek FRMS model uses 2010 LiDAR data that was provided during the project by LMCC and survey data of project corridor provided by Transport for NSW/GHD. Both datasets have been used to generate the surface within the TUFLOW model.

4.3. Structures

Key hydraulic structure data based on survey and as constructed data were included in the Winding Creek TUFLOW model. These structures include concrete lined channels, basins, weirs and culvert data. As stated previously, updated survey of the project corridor was undertaken for use in this study. This survey was checked against the existing structure data included in the Winding Creek model and found to align and therefore no changes were made. The culvert structures pertinent to this study are detailed in Table 1.

Table 1: Exiting Culvert Structure Details

ID	Details	Latitude	Longitude
P07	2 x 1500 x 900 RCBC	-32.9594	151.6681
P06	900 x 450 RCBC	-32.9588	151.6697
R_Basin03_02	1500 x 1500 RCBC	-32.9584	151.6723
R_Basin03_01	2400 x 1500 RCBC	-32.9583	151.6723
HRSx01	3 x 2150 x 1850 RCBC	-32.9580	151.6723

4.4. Design Tin and Stormwater Infrastructure

The design tin and details of the hydraulic structures and culvert extensions/upgrade were provided by GHD on 23 June 2022 for the 80% design stage, as shown in Figure 1. This includes details of the 750mm diameter pipe near Whalan's Nursery.

Flood mitigation options were proposed to upgrade the culvert near Barker Avenue (ID P06) to 3000 x 750 RCBC and an integrated stormwater network along Hillsborough Road connected to the pipe near Whalan's Nursery. The design tin for the road also included an open drain arrangement along the southern embankment of Hillsborough Road and to the West of Barker Avenue to convey and direct flow towards the culverts . This has also been incorporated in the model.

5. MODEL UPDATE

As a part of the current study several modifications were made to the model in accordance with latest design flood guidelines and refined the model topography. The reader is referred to WMAwater 2019 for more detail on the previous model development. Overall, the model reproduces previously modelled flood behaviour well and is considered suitable for the purposes of undertaking the 80% design for the Hillsborough Road upgrade. Details of the model changes are provided in the appropriate sections below. Refinements to the hydrologic subcatchments was also made to better represent flood behaviour in the road corridor.

5.1. Grid Size

To better represent the storage and floodplain behaviour in the vicinity of Hillsborough Road, the model grid was refined to 2m. A comparison of the 1 % AEP design event from the Winding Creek flood study for the grid size has been presented in Figure 3.

Differences between the previous and current modelling were noted close to the Hillsborough road, residential areas and narrow channel sections where storage estimation in the model is critical for the flow path. The impact of the modelling varied from -0.27m to 0.40m predominantly upstream of Hillsborough Road. The results were considered acceptable, and to be a better representation of the flood behaviour on Hillsborough Road and its vicinity.

5.2. Hydrology

The Winding Creek hydrology and hydraulic model was updated to incorporate the recommendations in the latest Australian Rainfall and Runoff guidelines (2019). The key changes in the latest hydrology guidelines from the previous flood study is the recommendations on the spatial distribution of rainfall and the concept of ensemble modelling ten temporal patterns to estimate a probability neutral flood event. There has also been an update in the design rainfall depths in Australia since the latest ARR was introduced.

For the hydrology model update, design rainfalls available from the Bureau of Meteorology (BoM) were sampled at each sub-catchment to distribute the rainfall spatially. As recommended in ARR, an aerial reduction factor was applied to the rainfall based on the data available on the ARR Datahub. The probability neutral burst loss and continuing losses were also adopted from the ARR Datahub. The continuing losses were factored by 0.4, as suggested for catchments in New South Wales. Based on the frequency of the storm event and duration, the initial and continuing loss ranged from 2.5 – 21 mm and 0.8 – 1.1 mm/h, respectively. Ensemble modelling of 10 temporal patterns and various storm durations (ranging from 1 hour to 18 hour) was used to assess the critical storm event.

The model set up for the catchment flows has been shown in Figure 2. Figure 4 presents the difference in the 100 year ARI flood event from the initial flood study and the 1% AEP flood event estimated following the latest ARR guidelines. Note that an industry terminology change means that the 100 year ARI is now referred to as the 1% AEP event. Overall, the results are generally consistent with the previously modelled flood extents. The flood elevation in the minor flow paths is slightly lower in the model results following ARR 2019, this may be due to the omission of the embedded burst patterns within the previous temporal patterns. The flood elevation at the junction of Winding Creek and flow from the West of Barker Avenue is greater than the previously modelled levels, this may be as a result of the ensemble modelling of various temporal patterns and shorter durations. For the ARR 1987 100 year ARI flood event, the critical duration for Winding Creek was 9 hours whereas following the ARR 2019 the critical duration for the 1% AEP flood event was estimated to be 3 hours.

6. EXISTING FLOOD CONDITIONS

Following ARR 2019, ensemble modelling of various temporal patterns and storm durations was completed for the existing (pre upgrade case). The Critical Duration and selected temporal patterns selected by resultant flood level for all modelled design events can be seen in Table 2,

Table 2: Event Critical Duration and Temporal Patterns

Event	Duration (Hours)	Temporal Pattern
1 EY	6	TP4739
	9	TP4771
20% AEP	2	TP4642
	6	TP4737
10% AEP	1	TP4565
	6	TP4660
2% AEP	2	TP4614
	6	TP4722
1% AEP	1	TP4558
	2	TP4611
	3	TP4653
1 in 2000 Year	1	TP4558
	2	TP4499

6.1. Flood Levels and Depth

Figure 5 to Figure 10 present peak flood depths and level contours for 1EY, 20% AEP, 10% AEP, 2% AEP, 1% AEP and 1 in 2000 year events under existing conditions. Flood levels and depths at key locations along Hillsborough Road are shown in Table 3 and Table 4.

Table 3: Peak Flood Levels at Key Locations

No.	Location Name	Ground Level (mAHD)	Peak Flood Level (mAHD)					
			1EY	20% AEP	10% AEP	2% AEP	1% AEP	1 in 2000 year
1	Hillsborough Road (Between Barker Avenue & Crockett Street)	28.33	28.41	28.45	28.48	28.56	28.61	28.66
2	Hillsborough Road (Near Barker Avenue)	25.08	-	25.09	25.12	25.16	25.17	25.20
3	Hillsborough Road (D/S of Basin 3)	24.38	-	-	-	24.48	24.55	24.78
4	U/S of Hillsborough Road (320m East of Crockett Street)	27.80	27.90	27.94	27.95	27.99	28.00	28.07
5	D/S of Hillsborough Road (320m East of Crockett Street)	26.87	27.13	27.22	27.24	27.36	27.39	27.51
6	U/S of Hillsborough Road (510m East of Crockett Street)	25.15	25.24	25.28	25.29	25.35	25.37	25.45
7	D/S of Hillsborough Road (25m West of Barker Avenue)	23.89	24.04	24.09	24.10	24.15	24.16	24.21
8	Basin 3	21.16	24.90	24.90	25.03	25.61	25.68	25.84
9	U/S of Hillsborough Road (Basin 3/ Winding Creek)	20.91	22.20	22.22	22.37	23.68	24.19	24.81
10	D/S of Hillsborough Road (Basin 3/ Winding Creek)	19.88	22.00	22.00	22.13	22.82	23.03	23.56
11	U/S of Hillsborough Road (60m East of Chadwick Street)	25.52	-	25.57	25.58	25.61	25.63	25.67
12	Hillsborough Road (Near Whalan's Nursery)	26.88	26.88	26.89	26.90	26.91	26.92	26.95
13	D/S of Hillsborough Road (Whalan's Nursery)	28.00	27.99	28.00	28.00	28.00	28.01	28.02

Table 4: Peak Flood Depth at Key Locations

No.	Location Name	Ground Level (mAHD)	Peak Flood Depth (m)					
			1EY	20% AEP	10% AEP	2% AEP	1% AEP	1 in 2000 year
1	Hillsborough Road (Between Barker Avenue & Crockett Street)	28.33	0.08	0.12	0.15	0.23	0.28	0.33
2	Hillsborough Road (Near Barker Avenue)	25.08	-	0.01	0.04	0.08	0.09	0.11
3	Hillsborough Road (D/S of Basin 3)	24.38	-	-	-	0.10	0.18	0.40
4	U/S of Hillsborough Road (320m East of Crockett Street)	27.80	0.10	0.14	0.15	0.19	0.20	0.27
5	D/S of Hillsborough Road (320m East of Crockett Street)	26.87	0.27	0.35	0.38	0.49	0.53	0.65
6	U/S of Hillsborough Road (510m East of Crockett Street)	25.15	0.09	0.13	0.14	0.20	0.22	0.30
7	D/S of Hillsborough Road (25m West of Barker Avenue)	23.89	0.16	0.20	0.21	0.26	0.27	0.32
8	Basin 3	21.16	3.74	3.74	3.87	4.45	4.52	4.68
9	U/S of Hillsborough Road (Basin 3/ Winding Creek)	20.91	1.30	1.31	1.46	2.77	3.28	3.90
10	D/S of Hillsborough Road (Basin 3/ Winding Creek)	19.88	2.12	2.12	2.25	2.94	3.15	3.67
11	U/S of Hillsborough Road (60m East of Chadwick Street)	25.52	-	0.05	0.06	0.09	0.11	0.15
12	Hillsborough Road (Near Whalan's Nursery)	26.88	<0.01	0.02	0.02	0.04	0.04	0.07
13	D/S of Hillsborough Road (Whalan's Nursery)	28.00	<0.01	<0.01	<0.01	0.01	0.01	0.02

Under existing flood conditions, Hillsborough Road to the West of Barker Avenue is overtopped in the 1EY event while the section of the road crossing Winding Creek is overtopped in the 2% AEP event. As 1EY is most frequent event modelled for this study and no additional events between the 10% AEP and 2% AEP were modelled, the exact frequency of overtopping is uncertain.

Initial overtopping occurs along Hillsborough Road between the intersections of Barker Avenue and Crockett Street. It is likely that the capacity of the culvert under and open drains conveying flow along Hillsborough Road at the overtopping location is not sufficient to carry the 1EY event flow. Near the Basin, overtopping occurs on the Northern side of the roadway East of Chadwick Street and is caused by a combination of flow arriving from North and South of Hillsborough Road. In rarer events, such as the 1% AEP, partial overtopping occurs (between the Higham Road and Chadwick Street) due to flow from South of Hillsborough Road.

As demonstrated in Figure 5 to Figure 10 flooding in the area is typically contained within the creeks and channels with some notable exceptions. The first is flow breaks out from Winding Creek across the Dog Park area (occurring in the less frequent events). This flow is contained within the drain on the southern side of Hillsborough Road in the 10% AEP event but overtops the roadway in the 2% and 1% AEP events causing inundation to the estate north of Hillsborough Road. Secondly, the same estate is inundated by flow from the east which eventually re-joins Winding Creek to the north. Furthermore, flow to the east of Basin 3 (within the golf park) is largely unchanneled upstream of Hillsborough Road and is conveyed to the culverts through an open drain, once discharged at the culvert outlet the flow becomes channelised, eventually joining Winding Creek and Basin 5.

6.2. Velocities

Figure 11 to Figure 16 show the velocities for the 1EY, 20% AEP, 10% AEP, 2% AEP, 1% AEP and 1 in 2000 year events. Velocities upstream and downstream of Hillsborough Road across all events are generally within 1.25 – 1.75m/s. Higher velocities occur between the Basin 3 weir and Hillsborough road, reaching 2 – 3m/s.

6.3. Hydraulic Hazard

In recent years, there has been a number of developments in the classification of hazard. *Managing the floodplain: a guide to best practice in flood risk management in Australia* (AIDR 2017) provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice.

The classification is divided into six categories (Diagram 1) which indicate the restrictions on people, buildings and vehicles:

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.

- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

Hydraulic hazard is presented in Figure 17 to Figure 22. In a 1% AEP Event, the hydraulic hazard within the catchment is generally H1 (Generally safe for people vehicles and buildings) other than within Basins and channels/creeks. Within the channels, creeks and basins, the hydraulic hazard is typically H5 (Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure). Across Hillsborough Road the floodwaters are typically H1 but areas of H2 (Unsafe for small vehicles) do occur.

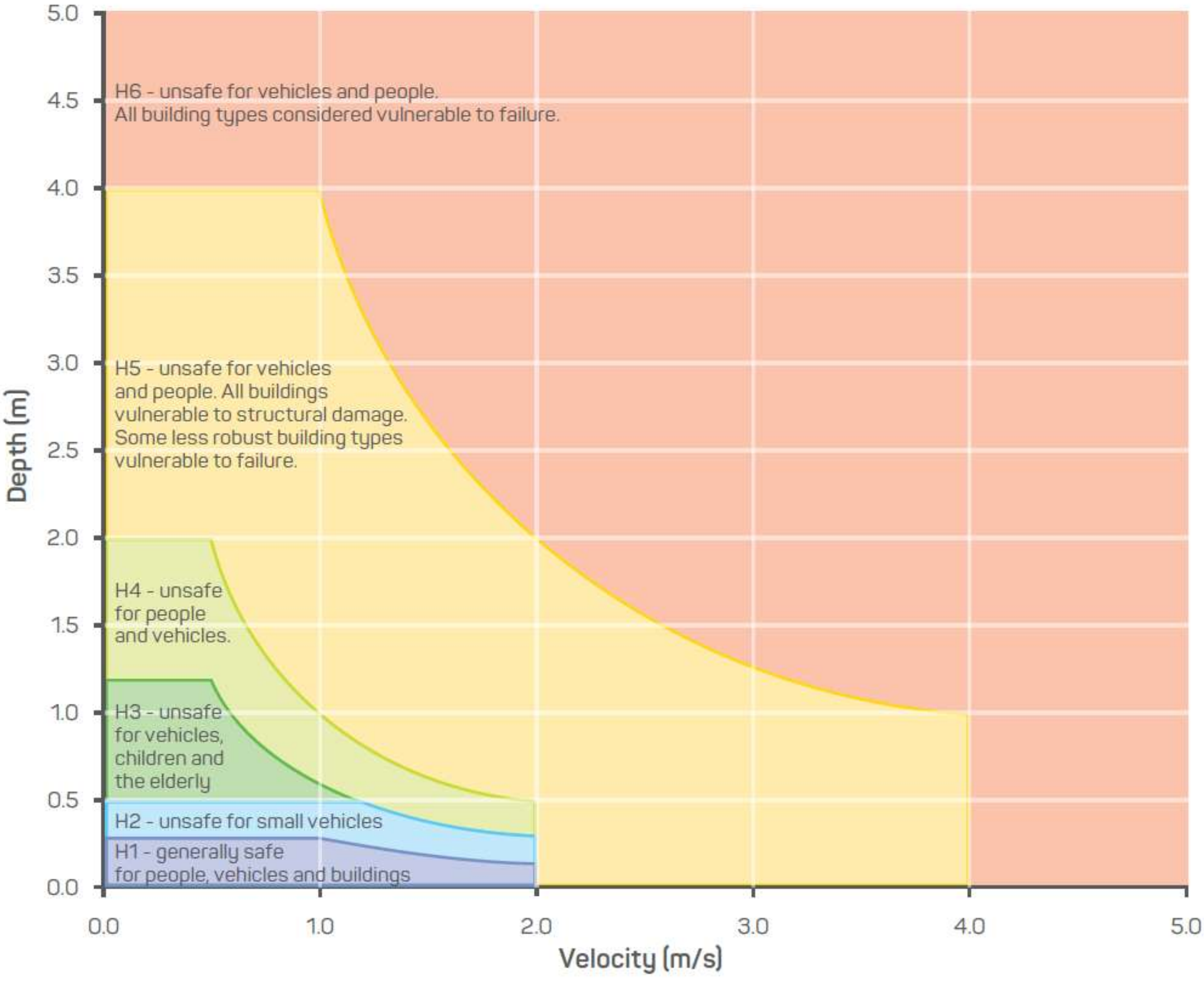

Diagram 1: Hazard classifications (AIDR 2017)

7. DESIGN CONDITIONS

The proposed concept design for the Hillsborough Road duplication has been incorporated into the hydraulic model based on information provided by GHD (As discussed in Section 4), dated 23 June 2022. The design involves modifications to the topography with the lane duplication and widening of Hillsborough Road. The hydraulic model was updated to include the proposed design based on the design tin provided. Checks were undertaken to ensure the design tied into the surrounding terrain.

A range of mitigation measures have been considered as part of the project and incorporated into the current design:

- Changes to the stormwater network for flood mitigation particularly close to Barker Avenue and Whalan's Nursery including pits and connections to the existing 750mm pipe. A standard sag pit flow curve, which was converted to a stage-flow curve for input in TUFLOW, based on the road geometry provided by GHD dated 12 August 2022.
- Upgrade of the culvert near Barker Avenue (ID P06) to 3000 x 750 RCBC
- An open drain arrangement along the southern side of Hillsborough Road and to the West of Barker Avenue to convey and direct flow towards the culverts
- Modification to the terrain near Higham Road to reduce the flow into the area which results in reduced flood levels.

Additional mitigation measures considered as part of the optioneering but not incorporated into the final design include modifications to the barriers near Whalan's Nursery and culvert arrangements downstream of Basin 3.

The following design events were assessed for the design: 1EY, 20% AEP, 10% AEP, 2% AEP, 1% AEP and 1 in 2000 year events.

7.1. Impact Assessment and Criteria

Impacts are calculated as the change in flood level between the option and the existing conditions. Positive impacts indicate that the flood level is higher in the option case compared to the existing conditions. Negative impacts indicate flood levels are reduced in the option case compared to the existing conditions.

There is limited industry guidance available on what is an acceptable impact. Australian Rainfall and Runoff Revision Project 15: Two dimensional modelling of Rural and Urban floodplains (Babister and Barton, 2012) recommends not reporting impacts less than 0.01m as they are considered to be within the precision of the numerical model and data.

Retallick and Babister (2018) proposed a set of criteria for the assessment of impacts of works on the floodplain based on land use type (refer to Table 5). These are based on an assessment of a number of recent major infrastructure projects. These have been used in the assessment of the current proposed design and in the gap analysis phase.

Table 5: Acceptable impacts for major transport infrastructure (adapted from Retallick and Babister, 2018)

Project	Residential (mm)	Industrial (mm)	Commercial (mm)	Agricultural (mm)#	Open Space/ Forest (mm)*
Major Transport Infrastructure	50 (general) 15-30 (sensitive receiver)	150	150	250-400	400

*conditional on no ecologically sensitive communities where flooding is an issue
#dependent on the type of agriculture and its tolerance. Other criteria may be more important than peak level for example time of inundation.

Time of inundation impact criteria of increases of 10% have been applied for this study.

7.2. Flood Impacts and Newly Flooded Areas

Flood levels and depths are shown on Figure 23 to Figure 28. The impacts of proposed design, compared to the existing case, at key reporting locations is shown in Table 6 and presented in Figure 41 to Figure 58, for the respective modelled events and areas of focus. The peak depth has been summarised in Table 7.

West of Barker Avenue
The proposed design has a distinct impact on water levels overtopping Hillsborough Road at/and to the West of the Barker Avenue intersection, when compared to existing conditions. At key reporting location 3, flood levels increased by 0.09m in the 1% AEP event compared to existing conditions. This may be as a result of the higher road level in the proposed design. The impacts on the upstream side of the road, at key reporting location 6 are 0.06 m in the 1% AEP event. This area is TfNSW road corridor and therefore the impacts are considered acceptable. Impacts within the open space is less than the 0.4m recommended in Table 6. A channel was incorporated into the design in this area providing connectivity between the culverts in the 80% design and should be retained for the 100% design. On the downstream side of the road there is a minor increase in 1% AEP flood levels as a result of the project (0.01m at key reporting location 7).

The proposed concept design has a road level lower than the existing conditions at the intersection of Barker Avenue and Hillsborough Road. This area is flooded in the 1% AEP in the design case. The lowered road level in the design is 25.07mAHD where as the road level was 26.16mAHD in the existing case.

Winding Creek and Basin 3
The proposed design widens the road predominantly on the southern side of Hillsborough Road which causes a reduction to the storage area resulting in a loss of storage of approximately 650m³ (the base of the road on upstream side is extended by 12m and into the storage area) between Hillsborough Road and the Basin 3 weir. Limited hydraulic options are available to reduce the impacts such as making the culverts bigger which would increase the flow downstream. Where

possible the slope of the embankment should be as steep as possible and the road alignment moved as far north as possible at Basin 3.

Increases on flood levels occur upstream of the project at Winding Creek up to 0.515m in a 1% AEP event. This increase is contained within the road corridor and and between Hillsborough Road and the Basin 3 outlet. This increase is likely as a result of the road level increase and does not correlate to an increase in overtopping frequency of the roadway which, based on the results the road section at Winding Creek crossing culvert first overtops in the 1% AEP event the same as in the existing conditions.

The increase in Hillsborough road level reduces flood levels in the residential area North of Hillsborough Road and close to Higham Road compared to the existing conditions. Some minor water level reductions (up to 0.057m) occur in Higham and King Streets with one property yard no longer flooded. It was not investigated if this reduction affects the above floor flooding. Some minor increases in flooding (up to 0.044m) occurs on Chadwick Street and Hillsborough Road.

Whalan's Nursery
To the East of Chadwick Street and close to Whalan's Nursery (Location 12), partial overtopping of Hillsborough Road occurs for the 1EY event for the existing and design conditions. However, the flood depth is less than 20mm. The inundated area of Hillsborough Road is reduced compared to when the road is overtopped in the existing conditions.

There is no significant flood impact at Whalan's nursery (Location 13) or properties adjacent to the road (Location 11). It was noted that although the stormwater network was proposed to convey the flow over Hillsborough road in this area as part of the design, the invert level along the road itself was lower than the invert level of the connecting pipe such that the water may not be effectively draining away from the road. It was also noted that the topography in this area slopes into the West-bound lane and is naturally higher than the road itself. An open channel may be appropriate to direct the flow away from Hillsborough Road.

Overall, the impact is contained to the area immediately surrounding Hillsborough Road and there is no significant changes in flood levels in the upstream or downstream of Winding Creek, including Basin 3 and 5.

Table 6: Impacts at Key Locations – Proposed Design

No.	Location Name	Ground Level (mAHD)	Peak Flood Level (mAHD)						Impact (m)					
			1EY	20% AEP	10% AEP	2% AEP	1% AEP	1 in 2000 year	1EY	20% AEP	10% AEP	2% AEP	1% AEP	1 in 2000 year
1	Hillsborough Road (Between Barker Avenue & Crockett Street)	28.85	-	-	-	-	28.82	28.82	Wet now Dry	Wet now Dry	Wet now Dry	Wet now Dry	0.21	0.16
2	Hillsborough Road (Near Barker Avenue)	25.34	-	-	-	-	-	25.36	<0.01	Wet now Dry	Wet now Dry	Wet now Dry	Wet now Dry	0.16
3	Hillsborough Road (D/S of Basin 3)	24.21	-	-	-	24.49	24.64	24.94	<0.01	<0.01	<0.01	0.01	0.09	0.16
4	U/S of Hillsborough Road (320m East of Crockett Street)	27.22	27.50	27.71	27.81	27.89	27.92	28.08	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
5	D/S of Hillsborough Road (320m East of Crockett Street)	26.89	27.17	27.25	27.29	27.36	27.40	27.45	0.04	0.03	0.05	0.01	0.01	<0.01
6	U/S of Hillsborough Road (510m East of Crockett Street)	24.94	25.04	25.15	25.18	25.36	25.42	25.70	<0.01	<0.01	<0.01	0.01	0.06	0.25
7	D/S of Hillsborough Road (25m West of Barker Avenue)	23.89	24.01	24.06	24.08	24.15	24.17	24.27	<0.01	<0.01	<0.01	<0.01	0.01	0.06
8	Basin 3	21.16	24.90	24.90	25.17	25.64	25.69	25.84	<0.01	<0.01	0.14	0.02	0.02	<0.01
9	U/S of Hillsborough Road (Basin 3/ Winding Creek)	20.78	22.34	22.35	22.61	24.11	24.61	24.96	0.14	0.13	0.24	0.44	0.42	0.15
10	D/S of Hillsborough Road (Basin 3/ Winding Creek)	19.89	21.97	21.99	22.17	22.92	23.12	23.64	<0.01	<0.01	0.04	0.10	0.09	0.08
11	U/S of Hillsborough Road (60m East of Chadwick Street)	25.52	-	25.58	25.59	25.63	25.64	25.68	<0.01	<0.01	<0.01	0.01	0.01	0.01
12	Hillsborough Road (Near Whalan's Nursery)	26.86	-	27.00	27.00	27.00	27.00	27.00	Wet now Dry	0.10	0.10	0.08	0.08	0.06
13	D/S of Hillsborough Road (Whalan's Nursery)	28.01	27.99	28.00	28.00	28.00	28.01	28.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 7: Peak Flood Depth at Key Locations

No.	Location Name	Ground Level (mAHD)	Peak Flood Depth (m)					
			1EY	20% AEP	10% AEP	2% AEP	1% AEP	1 in 2000 year
1	Hillsborough Road (Between Barker Avenue & Crockett Street)	28.80	-	-	-	-	0.02	0.02
2	Hillsborough Road (Near Barker Avenue)	25.35	-	-	-	-	-	<0.01
3	Hillsborough Road (D/S of Basin 3)	24.41	-	-	-	0.08	0.23	0.53
4	U/S of Hillsborough Road (320m East of Crockett Street)	27.21	0.29	0.50	0.59	0.68	0.71	0.87
5	D/S of Hillsborough Road (320m East of Crockett Street)	26.87	0.30	0.38	0.43	0.50	0.54	0.58
6	U/S of Hillsborough Road (510m East of Crockett Street)	24.83	0.21	0.31	0.35	0.53	0.59	0.87
7	D/S of Hillsborough Road (25m West of Barker Avenue)	23.89	0.12	0.17	0.19	0.26	0.29	0.39
8	Basin 3	21.16	3.74	3.74	4.01	4.48	4.53	4.68
9	U/S of Hillsborough Road (Basin 3/ Winding Creek)	20.37	1.97	1.98	2.24	3.74	4.24	4.59
10	D/S of Hillsborough Road (Basin 3/ Winding Creek)	19.88	2.09	2.11	2.29	3.03	3.24	3.75
11	U/S of Hillsborough Road (60m East of Chadwick Street)	25.52	-	0.05	0.06	0.10	0.12	0.16
12	Hillsborough Road (Near Whalan's Nursery)	26.99	-	0.01	0.01	0.01	0.01	0.01
13	D/S of Hillsborough Road(Whalan's Nursery)	28.00	-	<0.01	<0.01	0.01	0.01	0.02

7.3. Other flood characteristics

7.3.1. Velocity and Hazard

There is no significant change in velocity between the proposed design and existing flood conditions. Velocities are within the 1.25 – 1.75m/s range downstream of Hillsborough Road along Winding Creek and 2 – 3m/s upstream of Hillsborough Road near the basin. There is a slight increase in velocities along the side drains of Hillsborough road and embankments of the road where overtopping occurs. Flood velocity is presented on Figure 29 to Figure 34.

Similar to the velocity results, there is no significant change in the hydraulic hazard categories within the catchment as a result of the proposed design. Hydraulic hazard is presented on Figure 35 to Figure 40.

7.3.2. Inundation time and overtopping

The design decreases Hillsborough Road flood inundation time. The inundation time has reduced by approximately 7 minutes for the 1% AEP event (refer to Diagram 2). While the peak level is increased the water level reduces quicker than the existing case.

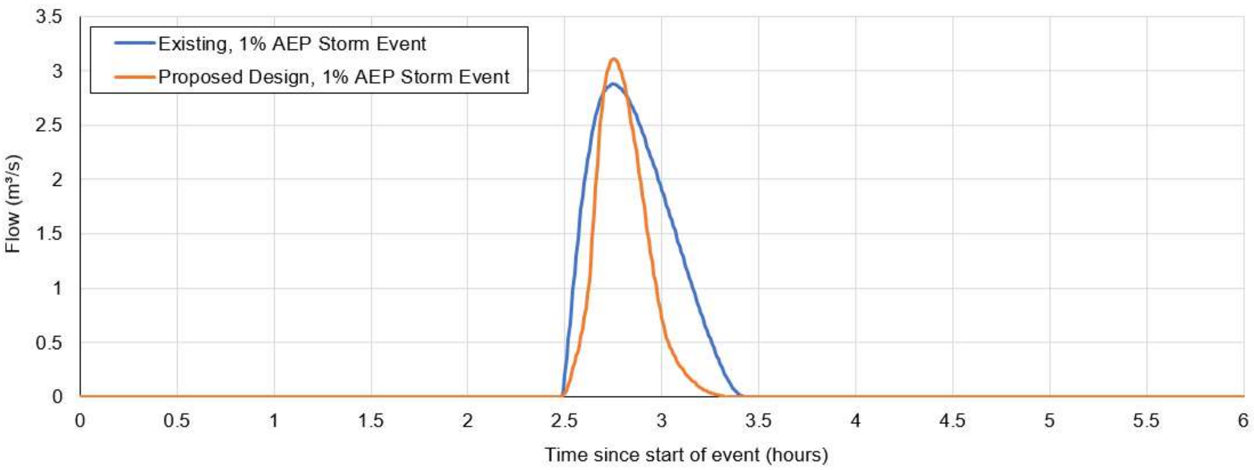

Diagram 2: Inundation hydrograph Hillsborough Road

The proposed road while not having a set design flood immunity target improves the flood immunity of sections of the project. Initial overtopping, similar to the existing case scenario, occurs along Hillsborough Road between the intersection of Barker Avenue and Crockett Street however overtops in the 1 EY storm event. At Winding Creek, the road initially overtops during the 2% AEP event, also indicating the same flood immunity at this location to the existing conditions.

The overtopping conditions of the Hillsborough Road West of Barker Avenue, near Winding Creek at Basin 3 and near Whalan's Nursey have been summarised in Table 8. The ponding at Whalan's Nursey is very shallow and likely largely collected by drainage infrastructure not included in the model. Water is present in the modelling in the southern lane in a 1EY. Overtopping near Winding Creek crossing at Basin 3 occurs just to the east of the crossing at Higham Road in the 2% AEP.

At the crossing itself water substantially enters the southern lane in a 1% AEP.

Table 8: Hillsborough Road Overtopping Conditions

Location	**First Inundation Event**		**Max Overtop Depth 1% AEP Event (m)**		**Time Overtopped 1% AEP Event (mins)**	
	Existing	Design	Existing	Design	Existing	Design
West of Barker Avenue	1EY	1EY	0.09	N/A	1650	N/A
Near Winding Creek Crossing at Basin 3	2% AEP	2% AEP	0.18	0.23	57	50
Near Whalan's Nursery	1EY	1 EY	0.04	0.01	Ponding on Road during Event	

8. Other Considerations

8.1. Impacts of other flood mitigation works in the catchment

Any works proposed by Hunter Water for Basin 3 have the potential to affect the immunity and overtopping behaviour of Hillsborough Road. It is recommended that Transport for NSW and Hunter Water continue their communication over works in the area. The detailed design of the Hillsborough Road should not increase the consequence category of the basin.

9. CONCLUSIONS

A flood assessment has been undertaken to investigate the flood impact of the Hillsborough Road duplication upgrade. The TUFLOW model created for the Winding Creek Flood Study has been updated in order to undertake the assessment, including a refinement of the grid size and hydrological modelling following the latest ARR guidelines. The updated model was then used to define the existing conditions for the 1EY, 20% AEP, 10% AEP, 2% AEP, 1% AEP and 1 in 2000 year storm events. The design for the Hillsborough Road duplication, was been incorporated into the hydraulic model based on information provided by GHD at 80% stage. The design involves the lane duplication and widening of Hillsborough Road and an extension of the existing culverts along Hillsborough Road.

Overall the proposed design causes changes to flooding in the area but generally the increases in water levels occur in undeveloped areas with general reductions in water levels within downstream residential properties. There is no significant changes in the flood hazard or velocity and an overall reduction in the time of inundation of the Hillsborough Road.

It is recommended that appropriate scour protection measures should be included in the design as a result of the increase in velocities along the side drains of Hillsborough road and embankments of the road where overtopping occurs. Potential changes in the consequence category for Basin 3 as a result of the road upgrade should be investigated.

10. REFERENCES

1. Pilgrim DH (Editor in Chief)
Australian Rainfall and Runoff – A Guide to Flood Estimation
Institution of Engineers, Australia, 1987.

2. NSW State Government
NSW Floodplain Development Manual
April 2005

3. DECC
Floodplain Risk Management Guideline – Residential Flood Damages
NSW Government, 2007

4. WMAwater
Winding Creek Flood Study
January 2011

5. WMAwater
Gap Identification and Preliminary Assessment of Hillsborough Road to Newcastle Inner City Bypass
May 2019

Figures

Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
critical duration	The critical duration refers to the rainfall duration, e.g. 1-hour rainfall event, that produces the design flood for a given catchment or location of interest within a catchment. This critical duration depends on the interplay of catchment and rainfall characteristics; it is usually determined by trialling a number of rainfall durations and then selecting the one that produces the highest flood peak (or volume) for the specific design situation.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

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

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

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

- water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or

- the potential to affect a number of buildings along the major flow path.

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

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

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

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

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

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

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

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

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling

	development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
TIN (Triangulated Irregular Network)	A TIN is a Triangulated Irregular Network is a representation of a surface, typically an elevation surface, consisting of triangular facets. The vertices of the triangles, when representing an elevation surface, represent spot elevations.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.