Lower Macleay Flood Study
Kempsey Shire Council

Data Review Report

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Lower Macleay Flood Study

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Document history and status

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<th>Description</th>
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<th>Review</th>
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# Data Review Report

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Foreword

The primary objective of the New South Wales Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods, wherever possible. Under the Policy, Kempsey Shire Council is responsible for local land use planning in its service area, including management of both mainstream and overland flooding within the Kempsey Local Government Area.

The policy provides for a floodplain management system comprising the following five sequential stages:

1. **Data Collection**
   Involves compilation of existing data and collection of additional data

2. **Flood Study**
   Determines the nature and extent of the flood problem

3. **Floodplain Risk Management Study**
   Evaluates management options in consideration of social, ecological and economic factors relating to flood risk with respect to both existing and future development

4. **Floodplain Risk Management Plan**
   Involves formal adoption by Council of a plan of management for the floodplain

5. **Implementation of the Plan**
   Implementation of flood, response and property modification measures (including mitigation works, planning controls, flood warnings, flood preparedness, environmental rehabilitation, ongoing data collection and monitoring by Council)


This study represents Stages 1 and 2 of the management process and has been prepared for Council by Jacobs. This report is a progress report of the study Stage 1 Data Collection and Review.
Important note about this report

The sole purpose of this report and the associated services performed by Jacobs is to undertake a flood study for the Lower Macleay River floodplain, in accordance with the scope of services set out in the contract between Jacobs and Kempsey Shire Council (the Client). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client, third parties, and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.
1. Introduction

1.1 General

The Lower Macleay River floodplain (refer to Figure 1-1) occupies 400km² of coastal floodplain downstream of Kempsey, to the Macleay River’s main outlet at South West Rocks. The floodplain drains an upstream catchment area of 11,500km² and also has several secondary outlets to the ocean at Hat Head and Crescent Head and a hydraulic link to the Hastings River to the south, all owing to improved channel linkages constructed during historic flood mitigation schemes. The river’s historic outlet to the ocean was at Grassy Head, to the north of its current outlet, until a major flood in 1893 cut an entrance at its current location. River training walls have been constructed to stabilise the current river course.

The floodplain is generally low lying and contains numerous watercourses including Belmore River, Kinchella Creek, Collombatti Creek and Clybucca River, in addition to a number of wetland areas. The towns and villages of Smithtown, Gladstone, Kinchella, Jerseyville, Fishermans Reach and Stuarts Point are situated in the floodplain, with South West Rocks, Hat Head and Crescent Head accessed by roads through the floodplain.

Significant floods occurred in the valley in 1838, 1893, 1949, 1950, 1963, 2001, 2009, 2011 and 2013. A major flood mitigation scheme was implemented from 1955 to the mid-1970s consisting of numerous flood gates, drainage channels and levees to help protect Kempsey township and the agricultural area, and to provide flood warning and improved drainage. Recent infrastructure works in the floodplain include the Pacific Highway Kempsey Bypass, which crosses the river and floodplain via a 3.2km bridge to the east of Kempsey.

Council has engaged Jacobs to undertake a catchment-scale flood study of the entire Lower Macleay floodplain, downstream of Kempsey. Numerous flooding studies and assessments have been conducted for the Lower Macleay River in the past, with the recent studies including the Kempsey CBD Floodplain Risk Management Study in 2017. The recent studies are fragmented in their study extents.

This current study will provide an expansive floodplain-wide assessment of flooding conditions according to the latest floodplain management guidance and policy, using contemporary best-practice technology and analysis techniques. The design flood estimates and hydraulic models produced by the study will guide future floodplain planning and management such as land use planning, emergency response and management and assessment of existing mitigation works and their potential enhancement.

1.2 Purpose of This Study

The purpose of this study is to undertake investigation to assess mainstream flood behaviour in the study area. Key objectives of this study are to:

- Review all available catchment, topographic, flood and drainage infrastructure data; flood study reports, overland flow path studies and associated hydrologic and hydraulic models.
- Undertake hydrologic analysis of upstream catchment inflows to define the river inflow characteristics for historic and design flood events and establish hydrologic models to estimate flood event inflows for the study area downstream of Kempsey.
- Establish and calibrate a hydraulic model for the study area to determine flood hydraulic behaviour, with consideration of interactions with flooding in adjacent river catchments and the ocean. There will be a particular emphasis on floodplain villages, flood mitigation infrastructure and flood flow ocean outlets.
- Prepare flood mapping including peak flood extents & levels, depths and velocities for all modelled events;
- Assess the sensitivity of flooding to the removal of the existing flood mitigation works;
- Assess the sensitivity of flooding to climate change, including sea level rise and increased rainfall;
- Undertake community consultation to gain acceptance of the study from the community; and
- Prepare a report on the above.
1.3 Structure of the Report

Details on the relevant reports and data available to this study are provided in Section 2 of the report. A review of the available information was undertaken to identify gaps in the topographic data which is discussed in Section 3. Additional data to be collected as part of this study are identified in Section 3. Conclusions and recommendations are provided in Section 4. Section 5 acknowledges contributions received from the community and organisations to undertake this study. References cited in the report are detailed in Section 6 and glossary of terms are provided in Section 7.
2. Review of Available Information

2.1 General

A review of information available from Council has been undertaken to determine what previous assessments were conducted and to identify additional data which needs to be collected for this study. Existing flood models have been reviewed to determine if extension of these models will be sufficient for the purposes of this study or if a new model needs to be developed.

2.2 Previous Studies and Reports

2.2.1 General

Numerous flood study and flood assessment reports have previously been prepared for localities in the Lower Macleay Valley, including Kempsey, the rural villages and floodplains and for the Pacific Highway Kempsey Bypass. A number of other reports have also been prepared and made available for this study including levee condition reports, geomorphology, hydrography, estuary management studies, etc. The reports most pertinent to this current flood study are summarised below.

2.2.2 Kempsey Hydraulic Model TUFLOW Update Final Report (WMAwater, 2015)

This report discusses the development of a TUFLOW model for the Kempsey CBD Floodplain Risk Management Study and Plan. The RMS TUFLOW model (developed for the Kempsey bypass) was updated with more recent LiDAR data to form the TUFLOW model used for this study. Peak inflows adopted in the modelling are summarised in Table 2-1. The adopted inflows were derived with the WBNM model from the Macleay River Flood Study (1999). The probable maximum flood (PMF) is based on a probable maximum precipitation (PMP) estimated using the Generalised Tropical Storm Method (GTSM; BOM, 2003).

Table 2-1 Macleay River Peak Flows. Reproduced from Table 6 in WMAwater, 2015.

<table>
<thead>
<tr>
<th>Event</th>
<th>Macleay River Inflow (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 year ARI</td>
<td>3,500</td>
</tr>
<tr>
<td>5 year ARI</td>
<td>5,400</td>
</tr>
<tr>
<td>10% AEP</td>
<td>7,700</td>
</tr>
<tr>
<td>5% AEP</td>
<td>9,900</td>
</tr>
<tr>
<td>1% AEP</td>
<td>15,300</td>
</tr>
<tr>
<td>0.5% AEP</td>
<td>20,400</td>
</tr>
<tr>
<td>0.2% AEP</td>
<td>24,800</td>
</tr>
<tr>
<td>PMF</td>
<td>67,500</td>
</tr>
</tbody>
</table>

2.2.3 Kempsey CBD Floodplain Risk Management Study and Plan (WMAwater, 2017)

Builds on the flood study documented in Kempsey Hydraulic Model TUFLOW Update Final Report (WMAwater, 2015). Outlines the existing flooding problem in Kempsey CBD to Frederickton area including hydraulic and hazard characterisation, flood damages, flood planning level; the catchment context (planning, social, environmental); and identifies and assesses a number of floodplain management measures.

2.2.4 Lower Macleay Floodplain Management Plan, Supplementary Report covering the Floodplain between Kempsey and Frederickton – Final (Webb McKeown & Associates, 2004)

This study updated the RUBICON model from Webb McKeown & Associates (1997) with survey along No. 1 Floodway in Kempsey and cross section data of the main river between Aldaville and Frederickton. Design flood
levels and velocities were estimated for the entire floodplain from Kempsey to South West Rocks, including the ocean outlets at Hat Head and Crescent Head.

2.2.5 Lower Macleay Floodplain Management Study (Webb McKeown & Associates 1997)
This study investigates the flooding issues in the Lower Macleay floodplain at that time and presents options to improve the performance of the area during and after flooding and in non-flood periods. Hydrologic modelling - Watershed Bounded Network Model (WBNM) was used for the study based on the Macleay River Flood Study (Webb McKeown & Associates/NSW Public Works, 1989). Hydraulic modelling was undertaken of the floodplain downstream of Kempsey in RUBICON which is a one-dimensional hydraulic model.

2.2.6 Macleay River Flood Study April (WMAwater/NSW Public Works, 1989)
This flood study estimated flood behaviour for the 5%, 2%, 1% AEP events and an extreme event for the floodplain downstream of Aldaville and flood outlets at Ryan's Cut, Korogoro Creek, South West Rocks Creek and Killick Creek. Hydrologic modelling was undertaken in a WBNM model with the catchment divided into 35 sub-catchments for the entire Macleay River catchment to the outlet. An assumed spatial distribution of rainfall across the catchment was adopted for the design flood events. Hydraulic modelling was undertaken using a CELLS quasi-2D model.

The modelling was calibrated to the May 1963 event and verified with the August 1949, May 1977 and May 1980 events. A design 1% AEP peak flow of 15,300m$^3$/s was estimated at Kempsey Bridge, and a peak of 13,400m$^3$/s at Bellbrook, approximately 45km north-west of Kempsey. The latter estimate was validated using partial series flood frequency analysis of the Bellbrook stream gauge. The report stated that a hydrologic modelling approach is preferred over the flood frequency analysis for estimation of larger floods in this catchment.

The rainfall for the extreme event was estimated by BOM in 1982 based on the available techniques at the time, with a catchment-averaged 24 hour PMP depth of 464mm. The adopted extreme event flow was 40,000m$^3$/s, which is significantly lower than the estimate made by WMAwater in 2015.

It is noted that the hydraulic modelling adopted an ocean tailwater level of 2.6m AHD for the 1% AEP design flood. Sensitivity to the condition of the minor ocean outlets (silted or scoured out) to flood levels was assessed.

The report also outlines a series of floodplain works which were constructed following the 1949 flood, from August 1949 to May 1980.

2.2.7 Kempsey Levee Sensitivity Assessment (Webb McKeown & Associates, 2008)
Assessment of the sensitivity of constructed levees in the Kempsey area to variations in flood gradient including the frequency of overtopping of each levee.

Compares the peak flood level and rate of rise at Kempsey Traffic Bridge for a number of historic flood events, design flood events and “modified” flood events

2.2.8 Kinchela Flood Channel EIS Stage 1 Report (Webb McKeown & Associates, 1994)
The report describes the capacity of the Kinchela floodway as being in the range of 41 to 47m$^3$/s in a design flood of 2500m$^3$/s at Fredrickton, depending on whether the flood lift gates are in place or removed, based on modelling in RUBICON. The capacity of the floodway assessed by the RUBICON model was approximately half of the design capacity of 71m$^3$/s, derived using physical modelling.

The report describes the findings of a Public Works Department assessment of the Belmore River floodways to be about 400m$^3$/s, about 70% of the design capacity of 560m$^3$/s. The modelling further indicated that the Belmore River channel was the system constraint, and not the floodway.

This report describes the impacts on flooding of the flood mitigation works constructed in the floodplain starting 1955, in terms of flood levels, extent and times of inundation.

2.2.10 Macleay River Flood March 2001 Flood Damages Data Collection (Webb McKeown & Associates 2004)

Following the March 2001 flood event, staff from Webb McKeown & Associates undertook field reconnaissance and detailed inspection to ascertain the extent of flooding and damages. This included resident interviews and distribution of a questionnaire. The flood event was described as a 1 in 13 AEP event and is to be used as a calibration event for this current study.

The report describes that Council undertook survey of flood and floor levels and mapped the flooding extent for Kempsey CBD, in addition to a presentation by Council on the flood behaviour, flood warnings and data collected, which was appended to the report. Observed point depths of flooding were mapped for Kempsey CBD and Smithtown. Observations of flooding in the vicinity of the Pacific Highway were reported by Roads and Traffic Authority (RTA; now Roads and Maritime Services) away from the main river including locations and timing of flooding a number of flood photographs during the event were presented.

The report also describes rainfall and river gauge data provided by BOM for the flood event. Cumulative rainfall depth and water level plots were presented for stations across the catchment. The report describes issues with the BOM data including malfunctioning of the automatic river gauge located at Kempsey Traffic Bridge some 10 – 12 hours before the peak of the flood.

The report also summarises data on the flood damages and clean-up costs incurred during and after the flood event.

A review of computer modelling of the flood event was undertaken. The flow hydrograph generated by the WBNM hydrologic model at Kempsey Traffic Bridge was said in the report to have a good match to the recorded flows, although the modelled hydrograph had to be shifted by 9 hours to match the gauge records. The stage hydrographs at Kempsey Traffic Bridge from the RUBICON hydraulic model and gauge records were also compared and provided a good match.

2.2.11 Kempsey Shire Local Flood Plan (Kempsey Shire Council/SES, 2011)

The Local Flood Plan describes the flood threat including flood behaviour and relevant incidents during historic floods including the March 2001 event. Details on the malfunctioning of the Kempsey river gauge are provided which may help to reconcile issues between the recorded data and the modelling results during model calibration. Timing of the flood peak and overtopping of Kempsey CBD levees is described. Gladstone, Smithtown, South West Rocks, Hat Head, Crescent Head and many upstream and downstream rural areas are identified as being isolated during the flood event.

The levee systems throughout the Lower Macleay floodplain (including Korogoro Creek) are described. The operation of the Belmore River and Kinchela flood control structures are described, namely that when a flood warning is predicted for flood levels greater than 5.0m AHD at Kempsey Traffic Bridge gauge, Council will issue a preliminary notice that the flood control structures may need to be opened. The control gates are opened gradually in several stages as required or until full outflow is achieved. As soon as possible after the flood has receded off local roads and the level has dropped below 5.0m AHD at Kempsey gauge, the flood control structures will be progressively closed.

The figures and flood extent maps contained in the flood plan were not provided for this review.
2.2.12 Flood Levee Audit Reports (Kempsey Shire Council, 2015/2016)

Nine (9) levee audit reports are available for the flood levee system in the Lower Macleay floodplain, including around Kempsey. The reports indicate the surveyed crest levels and condition of the levee banks which can be used to verify the LiDAR data along the levees, or to help to accurately define the crest levels in the hydraulic modelling. Survey was undertaken in 2014.

2.3 Flood Models

As outlined in Section 2.2, a number of hydrologic and hydraulic models were developed over the years for the purposes of the various studies undertaken. The different models were developed based on the software and techniques available at the time of each study and were updated to provide better detail at various times. Hydraulic models developed include CELLS (1980s), RUBICON (early 1990s), SOBEK (c. 2009) and recently TUFLOW. Generally, details on the topography, waterways and hydraulic structures were transferred from one model to the next as upgrades occurred.

Key TUFLOW models which have been developed by consultants WMAwater for the Lower Macleay floodplain have been obtained from Council and RMS. These are summarised in Table 2-2 in order of priority, as determined by their date of development and adoption in Council’s floodplain management program. The model extents and modelled hydraulic structures are indicated on Figure 2-1. Culverts and drainage structures represented in the models are shown on Figure 2-8 along with other culverts in Council’s spatial layers outside the model domains. A number of the models have similar extents to the Kempsey CBD model, confirming that the model for that area was updated over time to suit the purposes of each separate flooding assessment.

There is an extensive gap along the F2E section of the Pacific Highway upgrade between Model 1 and Model 2 and covering the Collombatti Creek floodplain. The Pacific Highway Upgrade Frederickton to Eungai Flood Study Report – Developed Concept Design 15% (HAJV, 2013) states that as this area is largely influenced by the Macleay River backwater flooding and no detailed hydraulic modelling was undertaken as a part of the F2E project. Data on the hydraulic structures on the Pacific Highway will be extracted from the RMS work-as-executed information, refer to Section 2.10.
<table>
<thead>
<tr>
<th>ID/ Priority</th>
<th>Study Model and Date</th>
<th>Development Scenario</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Kempsey CBD FRMS July 2017</td>
<td>Existing case and Proposed mitigation case</td>
<td>Adopted model and design flood estimates by Council. Includes Macleay River bridge with updated details compared to model ID 4 (model 4 has an embankment/break in the road viaduct halfway along the floodplain). Includes road cross drainage on major and some local roads. The modelled Macleay River bridge details are inconsistent with the 2016 LiDAR elevations of the bridge approaches (bridge deck uniform 7.5m AHD, soffit uniform 6.7m AHD; northern bridge approach 10.8m AHD, southern bridge approach 8.5m AHD). Hence there is inconsistency of 1 – 2.3m in the level of the deck. This will not affect the design flood estimates for up to the 0.5% AEP flood (flood level below soffit) but would impact on flood hydraulics for rarer floods. River bathymetry based on OEH data.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Pacific Highway Upgrade Frederickton to Eungai (F2E) – Model 1 and Model 2 February 2013</td>
<td>Developed case (Detailed Design)</td>
<td>Collombatti Creek floodplain not modelled. A number of culverts and bridges represented. Results files not provided. Will need to be run by Jacobs to output results.</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>South West Rocks Road Upgrade 2010 – 2013</td>
<td>Developed case (3 road raising preliminary options)</td>
<td>Flood assessment involving uniform raising of South West Rocks Road by 100mm, 200mm and 300mm. For the purposes of the Lower Macleay Flood Study, it is assumed that the upgrade has been built and is represented in the 2016 LiDAR, or has not been constructed to date and LiDAR is to be adopted for undeveloped case.</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Pacific Highway Upgrade Kempsey to Frederickton (Macleay River bridge) June 2010</td>
<td>Developed case</td>
<td>Kempsey CBD model considered to supersede this model.</td>
</tr>
</tbody>
</table>
2.4 Flood Photography

Council provided oblique aerial photographs, captured by Council staff from a helicopter during the 2013 flood event, showing inundation of villages and the floodplain and flood behaviour in various parts of the floodplain.

2.5 Rainfall Data

Sub-daily rainfall gauges located in the vicinity of the study area are shown on Figure 2-2. The gauges are located on the western extremity of the study area or outside the study area to the north and south, hence there is not good coverage of the study area itself.

Data from sub-daily rain gauges located in the vicinity of the study area have been obtained from Manly Hydraulics Laboratory (MHL). The data has been collected for the March 2001 and February 2013 calibration events and one month either side of the event, and will be used to generate local catchment runoff in the model calibration and verification. There is missing data from Aldaville gauge following 20 February 2013, however, this is after the main flood event for that period. The gauge at Aldaville was not active in the 2001 event and the Euroka gauge was decommissioned before the 2013 event. However, the gauges at Aldaville and Euroka are in close proximity.

Sub-daily rainfall has been obtained from BOM for the Kempsey (Wide Street) gauge for the period of record (December 1956 to September 2012). This data will be used for a sanity check on design rainfall intensity, frequency and duration.

The sub-daily rainfall for the historic storm events will be supplemented by daily rainfall for BOM gauges at Collombatti, Fishermans Reach, South West Rocks, Eungai and Crescent Head, also shown on Figure 2-2, as appropriate, for improved spatial coverage. The daily rainfall depths will be discretised with the sub-daily temporal patterns.

Temporal distribution of rainfall recorded in the Lower Macleay floodplain for the nominated calibration/verification flood events of 2001 and 2013 are shown in Appendix A.
2.6 Stream Gauge Data

2.6.1 Peak Flood Levels

Council provided a summary of peak flood levels recorded at BOM water level gauges. This is presented in Table 2-3. Council is to clarify what the asterisks denote. From the flood plan it appears that single asterisk denotes that the telemetered gauge failed and a manual reading was taken.

An additional spreadsheet file was provided by Council summarising the peak flood levels and time of peak at the various river gauges for the August 1949, May 1963, February 1997 and March 2001 floods and then numerous floods between January 2008 and March 2013.

Table 2-3 Historical flood heights (m AHD)

<table>
<thead>
<tr>
<th>Date</th>
<th>Georges Creek</th>
<th>Bellbrook</th>
<th>Kempsey</th>
<th>Smithtown</th>
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<tr>
<td>1838</td>
<td>-</td>
<td>-</td>
<td>7.2</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>7.2</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
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<tr>
<td>Feb 1863</td>
<td>-</td>
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<td>-</td>
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<td>July 1866</td>
<td>-</td>
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<tr>
<td>April 1867</td>
<td>-</td>
<td>-</td>
<td>7.2</td>
<td>-</td>
</tr>
<tr>
<td>March 1870</td>
<td>-</td>
<td>-</td>
<td>6.8</td>
<td>-</td>
</tr>
<tr>
<td>March 1875</td>
<td>-</td>
<td>-</td>
<td>8.14</td>
<td>-</td>
</tr>
<tr>
<td>June 1879</td>
<td>-</td>
<td>-</td>
<td>6.6</td>
<td>-</td>
</tr>
<tr>
<td>March 1890</td>
<td>-</td>
<td>-</td>
<td>6.6</td>
<td>-</td>
</tr>
<tr>
<td>April 1892</td>
<td>-</td>
<td>8.8</td>
<td>6.6</td>
<td>-</td>
</tr>
<tr>
<td>March 1893</td>
<td>-</td>
<td>-</td>
<td>7.2</td>
<td>-</td>
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<tr>
<td>June 1893</td>
<td>-</td>
<td>17.1</td>
<td>8.14</td>
<td>-</td>
</tr>
<tr>
<td>July 1921</td>
<td>-</td>
<td>16.16</td>
<td>7.84</td>
<td>-</td>
</tr>
<tr>
<td>Feb 1928</td>
<td>-</td>
<td>-</td>
<td>6.14</td>
<td>-</td>
</tr>
<tr>
<td>Feb 1929</td>
<td>-</td>
<td>12.20</td>
<td>6.84</td>
<td>-</td>
</tr>
<tr>
<td>March 1946</td>
<td>-</td>
<td>12.73</td>
<td>6.10**</td>
<td>-</td>
</tr>
<tr>
<td>Aug 1949</td>
<td>14.10</td>
<td>17.22</td>
<td>8.52</td>
<td>-</td>
</tr>
<tr>
<td>June 1950</td>
<td>-</td>
<td>18.06</td>
<td>8.31</td>
<td>-</td>
</tr>
<tr>
<td>Aug 1952</td>
<td>-</td>
<td>13.03</td>
<td>6.56</td>
<td>-</td>
</tr>
<tr>
<td>Feb 1954</td>
<td>-</td>
<td>11.23</td>
<td>6.36</td>
<td>-</td>
</tr>
<tr>
<td>Nov 1959</td>
<td>-</td>
<td>9.75</td>
<td>6.43</td>
<td>-</td>
</tr>
<tr>
<td>April 1962</td>
<td>-</td>
<td>8.15</td>
<td>6.08</td>
<td>-</td>
</tr>
<tr>
<td>May 1963</td>
<td>13.50</td>
<td>15.54</td>
<td>7.68</td>
<td>Estimated 4.50</td>
</tr>
<tr>
<td>June 1967</td>
<td>-</td>
<td>10.24</td>
<td>6.56</td>
<td>-</td>
</tr>
<tr>
<td>Jan 1968</td>
<td>-</td>
<td>8.84</td>
<td>6.31</td>
<td>-</td>
</tr>
</tbody>
</table>
### 2.6.2 Continuous Streamflow and Water Level Data

Available streamflow and water level recording stations in the vicinity of the study area are shown on Figure 2-3.

PINEENA (a surface water and groundwater monitoring data base published by DPI Water) version 10.2 data base contains continuous water level and streamflow data for non-tidal river gauges on the Macleay River upstream of Kempsey. The data from the Turners Flat gauge has been extracted and is shown in Figure 2-4 for the February 2013 event.

Water level data for river gauges in the tidal reaches of the Macleay River and Hastings River system were obtained from MHL for the following gauges:

- Aldaville Downstream
- Borirgala Creek
- Crescent Head
- Dennis Bridge Downstream (Hastings River)
- Euroka Upstream
- Green Valley (Maria River)
- Hat Head
- Kempsey
- Smithtown
- South West Rocks
- Telegraph Point (Wilson River).

Tidal gauge data has been obtained from MHL for the Coffs Harbour and Port Macquarie tide gauges for historic ocean water levels.

The streamflow, river and tidal water level data has been extracted for the nominated calibration and verification flood events (March 2001 and February 2013).

### 2.7 Floodgate Management

Council provided a spreadsheet summarising the floodgate operation for flood events from February 2009 to March 2013 including opening and closing times and the coinciding flood level at Kempsey Traffic Bridge at that time. Structures covered include Belmore floodgate, Belmore flood control structure, Kinchela floodgates, Kinchela Left and Right Bank flood control structures, and Euroka Creek and Christmas Creek floodgates.
Legend

Water Level Gauges near Study Area

Study Area

Korogoro Creek at Hat Head

Macleay River at South West Rocks

Macleay River at Smithtown

Killick Creek at Crescent Head

Maria River at Green Valley

Wilson River at Telegraph Point

Macleay River at Aldaville

Macleay River at Kempsey Road Traffic Bridge

Macleay River at South West Rocks

Korogoro Creek at Hat Head

Legend

Water Level Gauges near Study Area

Study Area
2.8 Topographic Data

Council has provided the topographical data in the form of Digital Terrain Model (DTM) of 1m, 5m and 10m spatial resolution for the Kempsey, Macleay River and Nambucca based on LiDAR survey of the study area. Years of capture are 2009/2010, 2016 and 2009/2010, respectively. The data coverage is shown on Figure 2-5.

The topographical data covers the entire study area (including the areas to the south of Crescent Head and extending into the Hastings River catchment. The Macleay River LiDAR data set covers the whole Lower Macleay floodplain and most of the study area, and its recent date of capture means that existing topographic features are likely to be represented. The 2009/2010 Kempsey data set covers peripheral areas of the study area including areas to the west of Kempsey and areas along and adjacent to the Maria River, and while is an older data set, appears to represent the existing main features on the floodplain and is considered suitable for use. The Nambucca data set falls outside and to the north of the study area and is unlikely to be used.

Survey data of the flood levees in the study area, collected for the levee audit reports, has been provided by Council.
2.9 Bathymetric Data

Bathymetric data held by the Office of Environment and Heritage (OEH) was downloaded from their website http://www.environment.nsw.gov.au/estuaries/list.htm. The data set consists of spot soundings captured in 2001 to 2005. Waterways surveyed include Macleay River, Belmore River, Kinchela Creek, Spencers Creek, Clybucca Creek, Korogoro Creek and Killick Creek. Bathymetric terrain models of this data have been requested from OEH, if available. On the Macleay River survey was undertaken along river cross sections at 100 – 250m intervals upstream of Jerseyville, and point-cloud data at typically 10m spacing in the lower river downstream of Jerseyville.

Review of the sounding data in comparison to the LiDAR and aerial imagery indicates that there have been some changes to the river bed caused by flood events after the data collection. For example, there are several very shallow or exposed sand bars just upstream of Jerseyville as shown on the imagery and represented by the LiDAR, though the sounding data indicates water depths of up to 4.5m present in 2003 at some of these locations. Refer to Figure 2-6. New bathymetric survey as a part of this study is suggested to verify river depths in selected locations in the vicinity of the main villages. Manual adjustment to the bathymetry will be required where possible.

A horizontal error of approximately 200m was observed for the Killick Creek survey point data, compared to the georeferenced aerial imagery and supplied watercourse outline layers. Figure 2-7 illustrates the offset of the point data to the waterway and other features. This data was manually adjusted for its location to fit the waterway and surveyed features (e.g. edge of pavement and buildings) on the aerial photos. The survey plans prepared by OEH, showing pavement, buildings and other features, were used to verify the manual adjustment. The error may have been from a projection error in the original data collection or the survey plan preparation however this is not for certain. The data sets for the Macleay River and Korogoro Creek do not display an inconsistency with the aerial imagery and watercourse outline layers.

The OEH bathymetric data will be used to form digital elevation models (DEMs) of the waterway channel beds for input into the TUFLOW hydraulic model.

**Figure 2-6 Comparison of 2003 Macleay River bathymetric data (spot levels) and 2014 aerial photo – upstream of Jerseyville**

Sand bar deposited after 2003 survey. Inconsistent with spot depths of up to 4.5m depth
2.10 Pacific Highway Upgrade Design Data

In addition to the TUFLOW hydraulic models for the various sections of the Pacific Highway upgrade as discussed in Section 2.3, additional detailed design and work-as-executed design data was obtained from RMS for F2E and Kempsey Bypass. Details of the road geometry and hydraulic structures from these sources will supplement those in the existing TUFLOW models.

RMS were contacted and attempts were made to obtain detailed design or WAE drawings for the Pacific Highway Macleay River bridge to verify the existing TUFLOW model data, however, these attempts were not successful.

2.11 Aerial Imagery

Aerial imagery plates were provided by Council for various locations across the study area. The dates of capture range from 2010 to 2014 and are of varying resolution from 10cm to 50cm. Review of the data indicates that it is suitable for use in this study.

2.12 GIS Layers Provided by Council

GIS layers provided by Council includes:

- Floodgates (Council and joint-owned). Some of the features have pipe and/or gate size indicated. Council to confirm how the pipe size and the gate size relate to each other in the case of features having both attributes. Invert levels are listed for some features, typically in feet RL to local datum (100’ is at mean sea level, i.e. 0m AHD) and rounded to the nearest foot (i.e. 0.3m approximately). Some of the features are also logged in an Excel file register with hyperlinks to pdf scans of the flood mitigation works designs (dated late
1950s/1960s). The currency of the data needs to be confirmed with Council, for example, structures where the flood gates have been removed (i.e. Yarrahapinni floodgates). Floodgates are shown on Figure 2-8.

- Drains (Council and joint-owned). Some of the features are also logged in an Excel file register with hyperlinks to pdf scans of the flood mitigation works designs (dated late 1950s/1960s). It is likely that the current forms of the drains do not match the design plans due to the time elapsed since construction and progressive changes over time (scour, siltation, etc.).

- Culverts and stormwater pipes. Details on these features include location and dimensions. Council advised that this dataset is not updated regularly and some information may be outdated. This dataset provides a broad indication of drainage structures across the study area. The locations of culverts and pipes larger than 600mm are shown on Figure 2-8. Features with no dimension details are indicted. Key features will be selected for survey.

- Levees. Some of the features are also logged in an excel file register with hyperlinks to pdf scans of the flood mitigation works designs (dated late 1950s/1960s)

- Bank rock protection along the Macleay River banks

- Timber bridges crossing the floodplain drains. These are typically minor structures. Locations are identified and bridge span and deck dimensions are included but levels are not available. Comparison to aerial photography indicated that not all bridges are identified in this spatial layer.

- House levels and floor levels for properties on the floodplain. Properties in Hat Head, South West Rocks, parts of Frederickton and Kempsey are not included.

- Streams and rivers

- Flood planning level/area (currently adopted by Council).
3. **Collection of Additional Data**

3.1 **Additional Data Requested from Council**

The following information is requested from Council:

- Agreement on the study area extent shown on Figure 1-1.
- The currency of the data needs to be confirmed with Council, for example, structures where the flood gates have been removed (i.e. Yarrahapinni floodgates).

3.2 **Additional Data to be Collected**

The main data which needs to be collected consists of key hydraulic structures which are not in the existing TUFLOW models or which are not in Council GIS layers or where there are missing details. Most of the floodgate data is complete but there are a number where level data is missing.

Selected culverts and pipes connected to key drainage features will be surveyed if there are missing details. The structures on main drains/waterways and flood control structures with missing level information (e.g. Kinchela Creek west and east flood control structures) will be selected for survey. It is recommended that other culverts and pipes to be modelled (e.g. larger than 600mm diameter or width) may have their levels estimated by LiDAR, to limit the number of structures to be surveyed.

Bridges including Smithtown Bridge, Jerseyville Bridge, Killick Creek, Korogoro Creek and others are likely to influence flood hydraulics and have been selected for survey. Additionally, as mentioned in Table 2-2 there is discrepancy in the bridge level details of the Pacific Highway Macleay floodplain bridge between the existing TUFLOW models and LiDAR and selective survey of this bridge is recommended to confirm details. These bridges would be difficult to survey using traditional survey methods and alternative methods such as laser scanning survey may be required.

WAE or design drawings of the Pacific Highway Macleay floodplain bridge will be requested again from RMS (these were not previously obtained from RMS). If not available then this bridge will be selected for survey.

The available bathymetric survey is dated 2003 and the aerial photography indicates that changes to the river bed form have occurred since the survey. Council should consider commissioning bathymetric survey of a limited number of river cross sections at key locations (e.g. in the vicinity of the main villages) to validate the 2003 bathymetric survey for use in the hydraulic modelling.
4. Conclusions and Recommendations

The relevant data available to this study have been reviewed and gaps in the data have been identified. Selected hydraulic structures for which no information was available and other features have been identified for survey.
5. Acknowledgements

This study is being undertaken by Jacobs on behalf of Kempsey Shire Council. Council has prepared 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 Office of Environment and Heritage.

A number of organisations and individuals have contributed both time and valuable information to this study. The assistance of the following in providing data and/or guidance to the study is gratefully acknowledged:

- Residents of the study area;
- Council officers;
- Roads and Maritime Services and their consultants WMAwater;
- Manly Hydraulics Laboratory; and
- NSW Office of Environment and Heritage.
6. References

Hyder Aurecon Joint Venture (2013) Pacific Highway Upgrade Frederickton to Eungai Flood Study Report – Developed Concept Design 15%

Kempsey Shire Council/SES (2011) Kempsey Shire Local Flood Plan

Kempsey Shire Council (2015/2016) Flood Levee Audit Reports


Webb McKeown & Associates (1994) Kinchela Flood Channel EIS Stage 1 Report


WMAwater (2017) Kempsey CBD Floodplain Risk Management Study and Plan
7. Glossary

**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. In this study AEP has been used consistently to define the probability of occurrence of flooding. It is to be noted that design rainfalls used in the estimation of design floods up to and including 100 year ARI (ie. 1% AEP) events was derived from 1987 Australian Rainfall and Runoff. Hence the following relationship between AEP and ARI applies to this study.

20% AEP = 5 year ARI; 10% AEP = 10 year ARI; 5% AEP = 20 year ARI; 2% AEP = 50 year ARI; 1% AEP = 100 year 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 occurrences 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.

**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.

**Development**

Is defined in Part 4 of the 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. Eg. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power.

Redevelopment: refers to rebuilding in an area. Eg. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.

**Effective Warning Time**

The time available after receiving advise 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.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>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.</td>
</tr>
<tr>
<td>Flood fringe areas</td>
<td>The remaining area of flood prone land after floodway and flood storage areas have been defined.</td>
</tr>
<tr>
<td>Flood liable land</td>
<td>Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).</td>
</tr>
<tr>
<td>Floodplain</td>
<td>Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.</td>
</tr>
<tr>
<td>Floodplain risk management options</td>
<td>The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.</td>
</tr>
<tr>
<td>Floodplain risk management plan</td>
<td>A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.</td>
</tr>
<tr>
<td>Flood plan (local)</td>
<td>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 SES.</td>
</tr>
<tr>
<td>Flood planning levels (FPLs)</td>
<td>Are the combination 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 &quot;designated flood&quot; or the &quot;flood standard&quot; used in earlier studies.</td>
</tr>
<tr>
<td>Flood proofing</td>
<td>A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.</td>
</tr>
<tr>
<td>Flood readiness</td>
<td>Readiness is an ability to react within the effective warning time.</td>
</tr>
<tr>
<td>Flood risk</td>
<td>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.</td>
</tr>
<tr>
<td>Existing flood risk</td>
<td>the risk a community is exposed to as a result of its location on the floodplain.</td>
</tr>
<tr>
<td>Future flood risk</td>
<td>the risk a community may be exposed to as a result of new development on the floodplain.</td>
</tr>
</tbody>
</table>
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 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 flow, or a significant increase in flood levels.

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.

Hazard
A source of potential harm or 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.

Local overland flooding
Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

m AHD
Metres Australian Height Datum (AHD)

m/s
Metres per second. Unit used to describe the velocity of floodwaters.

m³/s
Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.

Mainstream flooding
Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

Modification measures
Measures that modify either the flood, the property or the response to flooding.

Overland flow path
The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.

Probable Maximum Flood (PMF)
The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet 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.

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.

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 a streamflow, also known as rainfall excess.

Stage  Equivalent to water level (both measured with reference to a specified datum)

TUFLOW  TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.
Appendix A. Cumulative Rainfall Plots for Historic Storm Events
A.1  Cumulative Rainfall for the Storm event of March 2001 and Preceding Period

A.2  Cumulative Rainfall for the Storm event of February 2013 and Preceding Period