DECEMBER 2010 VALIDATION WORK

Appendix D

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WAGGA WAGGA MOFFS VERIFICATION

FINAL

AUGUST 2011

Project Wagga Wagga MOFFS Verification	**Project Number** 29030-02
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Date 11 August 2011	**Verified by**

Revision	Description	Date
3		
2	Final	Aug 2011
1	Final	Jun 2011

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EXECUTIVE SUMMARY

In November of 2010 WMAwater submitted the Draft Final version of the Major Overland Flow Flood Study (MOFFS) to Wagga Wagga City Council (Council). This study examined local flooding in Wagga (i.e. non-riverine).

Following submission, in December of 2010 Wagga experienced localised flooding due to two extreme events on December 2nd and December 9th respectively. Both events occurred as the Murrumbidgee River was in flood (Hampden Bridge gauge recorded a 15Y ARI event at Wagga Wagga on December 6th). As such both events were exacerbated by the inability of the local drainage system to freely flow into the Murrumbidgee River.

Subsequent to the events it was considered that they presented an opportunity to test the modelling developed as part of the MOFFS with the chance to increase the confidence in model results and hence in the models definition of design flood behaviour. As such WMAwater proposed a variation to the original works contract which Council and the Office of Environment and Heritage (OEH) subsequently approved.

Prior to deciding which event to use, rainfall data plus flooding observations were collected as available. Following the identification of a large observation data set (76 photos taken from a helicopter) for the event of the 9th and suitable rainfall data, this event was selected for verification. The event appears to be reasonably spatially consistent with large rainfalls over December 8 and 9 but with a predominant burst occurring in the early hours of the 9th. Observations of flooding are mainly concentrated in the Ashmont/Moorong St area however observations are also available for areas upstream of Lake Albert (Stringybark Creek) down to the Sturt Highway industrial area near Marshalls Creek.

The verification dataset of 76 photos has been utilised and this demonstrates that the model is able to adequately emulate observed behaviour within all MOFFS model domains examined (3 of 4 domains were examined). This result enhances confidence in the MOFFS model and also the MOFFS design flood results.

1. INTRODUCTION

Late 2009 WMAwater commenced work on the MOFFS for Council with the goal of defining design flood behaviour for local flooding in major overland flow paths through the Wagga Wagga LGA. At the time review of historic rainfall data indicated that no suitable historic events existed for calibration purposes (Reference 2). During the course of the study a minor event did occur on February 5th 2010 that was subsequently used to verify City model domain performance, although flood observations were mainly limited to the Glenfield Drain area.

Subsequently December of 2010 saw two extreme events occur in conjunction with elevated River levels. On December 9th in particular a significant rainfall event occurred and Council was able to collect photographic records from a helicopter near the flood peak. The photographic records effectively define flood extent at a variety of locations namely:

- Ashmont/Moorong St areas;
- Sturt Hwy industrial area to the east of Wagga CBD;
- Upstream of Lake Albert to both the south plus west; and
- Downstream of Lake Albert upstream of the Marshalls Ck outlet to the Murrumbidgee River

As such the December 9th 2010 event provides an excellent opportunity to retrospectively review the hydrological and hydraulic model developed for the MOFFS. The rainfall event in question coincided with a riverine flood event so a variety of modelled flood mechanisms are able to be assessed ranging from upper catchment rainfall response to the influence of elevated tailwater levels on downstream flooding.

This report describes the Wagga Wagga rainfall events of December 2010 and model setup for the validation runs (hydrologic plus hydraulic). The ability of the hydraulic model to match recorded results is assessed along with a conclusion as to the suitability of the developed MOFFS model based on results from the verification event described herein.

2. DESCRIPTION OF DECEMEMBER 2010 LOCALISED EVENTS

2.1. Introduction

On the 2nd and 9th of December 2010 heavy rainfall occurred over Wagga Wagga leading to two separate localised flood events. These events coincided with a period of Murrumbidgee River flooding. The Wagga Wagga Murrumbidgee river peak on the 6th was a 15Y ARI event. Both local events were significant and suitable as verification events (based purely on flood magnitude where larger floods, approaching the flood planning event are preferred). It was subsequently found that as the December 2nd event had occurred in the evening no suitable observations existed. Also rainfall records for the event, which was not spatially widespread, were deficient and likely not representative.

In contrast the event of the 9th peaked in the morning and photographs from the vantage point of a helicopter were taken at first light to record the flood extent. Whilst observations are likely not of the flood peak they approximate the flood peak, particularly in more volume centric downstream locations. This report is therefore aimed at describing the rainfall event of the 9th and the prevailing antecedent conditions and influencing Murrumbidgee River tailwater levels. Available data sets are summarised below in Section 2.2. In subsequent sections comments on the data's suitability for model verification and likely accuracy will be made.

2.2. Rainfall and Murrumbidgee River level data

Available rainfall and river gauged data is outlined below:

1. Daily rainfall depths for the month of December 2010 were obtained from the Bureau of Meteorology (BOM) for the 5 nearby rainfall gauges (Figure 1).
2. Continuous pluviograph records for the month of December 2010 were obtained from BOM for the airport gauge (AMO).
3. 10 minute interval rainfall data from the Rural Fire Service (RFS) gauge was sourced by Council for the 2nd, 8th and 9th of December.
4. One hour interval rainfall data for the Gregadoo gauge was sourced by Council for the 2nd and the 9th of December.
5. A continuous record of river level data at Hampden Bridge gauge was obtained from the NSW Office of Water for the month of December 2010.

2.3. Rainfall distribution and antecedent conditions

Figures 1 and 2 show daily rainfall depths recorded at 9am on the 3rd and 9th of December respectively. Figure 1 additionally shows the study area hydrological domain. Figure 2 shows the hydrological domain of the sub models (the overall study area is covered by four separate hydraulic model domains). As is clearly evident both storms were spread over a large spatial extent with rainfall totals from the December 9th event being relatively consistent. Table 1 below shows the daily depths at these locations recorded from the 3rd through to the December 9th. Further, cumulative rainfall depth for the 7 days prior to the event of the 2nd is shown.

Table 1 Recorded daily rainfall depths for December 2010

Station	Location	7days*	3rd	4th	5th	6th	7th	8th	9th
74234	Euberta	39.6	19.8	0	0	0	3	0.4	57
73127	Ag Inst	46.2	82.4	0	0	0	0	3	48
72040	Berrillee	ND	ND	ND	ND	ND	ND	ND	ND
74241	RSL	21.2	85	0	0	0	0	0	57
72150	AMO	31	52.2	0	0	0	0	0	67.6
74127	Gurwood St	44.2	65	0	0	0	0	2.4	58
	RFS	ND	24.4	ND	ND	ND	ND	ND	54.4
	Gregadoo	ND	66.4	ND	ND	ND	ND	ND	52.2

** Cumulative rainfall for seven days rainfall prior*

ND – indicates no data

Based on guidance from Australian Rainfall and Runoff (Reference 1) the rainfall loss parameters for design modelling of the MOFFS were 15 mm of initial loss and a continuing loss of 2.5 mm/hr (Reference 2). Table 1 shows that much (if not all) of the total catchment had been pre-wet before the storm on the 2nd (approximately 40 mm per station for the week prior). 5 days of dry weather preceded the event of the 9th however if the 12 days prior to the event of the 9th are considered approximately 100 mm had fallen, saturating the catchment. Initial losses for verification modelling of the 9th are logically assumed to be negligible (1 mm). The continuing loss parameter of 2.5 mm/hr utilised as per Reference 1 in the MOFFS (Reference 2) was retained for all model domains.

It is assumed that, prior to the event of the 9th, primary storages within Wagga including Wollundry Lagoon and Lake Albert had been filled by the preceding rainfall. Levels in these storages are assumed to equal the lowest free draining level (consistent with design model assumptions) just prior to the storm on the 9th. It is noted that Council had significantly emptied Wollundry lagoon prior to the event of the 9th following the storm of the 2nd however the level it was lowered to is not known and given there are few calibration points proximate to the lagoon for the event, the importance of having the right starting level in the lagoon is diminished.

Daily rainfall readings (to 9 am) over the lower City model domain were spatially consistent with three daily stations giving matching observations; 57, 58, 54.4 mm for the RSL, Gurwood St and Rural Fire Station (Ashmont) gauges respectively.

Over the larger Wagga area the event was not as spatially uniform. Figure 3 gives an indication of how the rainfall varied. As can be seen from west to east (RFS to AMO) rainfall varied significantly with no specific pattern obvious. Whilst no stations are available to document it it's also likely that there was higher rainfall near the River and less rainfall further to the south.

East rainfall is represented by the AMO gauge (which lies to the east within the model area) whilst the Lake Albert domain is represented by the Gregadoo gauge. Gregadoo recorded a depth of 52.2 mm which is approximately 75% of the recorded rainfall depth of the AMO (67.6 mm). There is little justification to extrapolate a broad scale gradient based on these two data points. Instead rainfall is applied to the East and Lake Albert models spatially uniformly with a factor applied as an ad hoc method of accounting for anticipated spatial variability. Note that the reduction factor is used as a convenient way of accounting for the spatial variability of the rainfall. It is not the studies intent to recommend for design purposes, for example, an Aerial Reduction Factor (ARF).

2.4. Rainfall intensity

In order to track the storm path over the catchment, pluviograph data from various available stations is plotted on the same time scale. The available pluviograph data is noted below in Table 2.

Table 2: Sub-daily rainfall stations

Location	Resolution
AMO	1 min
RFS	10 min
Gregadoo	1 hour

Since the most coarse sub-daily data set is hourly for Gregadoo station, the rainfall intensities for the above stations were plotted at 1 hourly resolution to aid comparison (Figure 3). As noted in the previous section the comparison of rainfall patterns shows no obvious storm path over time nor any consistent gradient.

2.5. Murrumbidgee River tailwater conditions

Overland flooding in Wagga Wagga on the 9th of December coincided with riverine flooding. The river level at Hampden Bridge gauge peaked at a gauge level of 9.7 m on the 6th December as shown in Figure 5. The river was still receding when the storm of the 9th occurred and was 8.7 m or 178.8 mAHD (approximately a 5Y ARI River level).

Drainage of the CBD area through the levee system via flap gate culverts is retarded during periods of elevated river level. To re-create this in the modelling a sloping Murrumbidgee River tailwater was used as a downstream boundary condition for the hydraulic model. Water slope up and downstream of Hampden Bridge was based on Murrumbidgee River hydraulic modelling carried out as part of Reference 3. Due to the elevated River levels many outlets were closed in order to avoid Murrumbidgee River water flowing into the City as peak water levels created suitable head to achieve such backflow.

2.6. Flood gate operation during flood event

Various gates/controls exist within the Wagga Wagga local drainage system and these have various functions, ranging from controlling water levels in internal water bodies such as Wollundry Lagoon for water quality, aesthetic, maintenance and drainage requirements to ensuring that Murrumbidgee River water does not pass through the drainage system into Wagga Wagga itself. Some of the controls require manual operation although in the main controls are automatic, for example flap gated outlets at discharge locations in the Murrumbidgee River servicing Marshalls Creek, Flowerdale Lagoon etc.

At the time of the December 9th 2010 event Murrumbidgee River levels were high. December 6th had seen Hampden Gauge record a peak flow level of 9.7 m (179.7 mAHD or approximately a 15 yr ARI event). As per Figure 5 by the time of the heavy rainfall (early hours of December 9th in the main) river levels had fallen by 1.0 m from their peak of the 6th.

This implies that in most cases, local drainage elements which connected to the Murrumbidgee River via automatic flap gated outlets were restricted and manual operated controls were closed. At Flowerdale and Wollundry Lagoons pumping was still in operation from the event of the 2nd however rates of flow are small enough that they can be ignored for validation modelling.

3. AVAILABLE FLOOD SURVEY INCLUDING AERIAL PHOTOGRAPHY

Ideally calibration marks would be clearly observed peak levels surveyed to AHD. Failing that observations of peak depth or extent would be preferable.

The main data used to verify the MOFFS model is a set of 76 photos taken from a helicopter at approximately 6 am on the morning of the 9th December. The set of photos in their entirety are presented in Annex A. The location of each photo was manually geo-referenced and is shown on Figure 6. The photos are primarily in the CBD region and downstream of Marshall's Creek with limited photos distributed across the Moorong/Spring Street area of the CBD, upstream of Marshalls Creek and to the south and south west of Lake Albert.

Photos were taken near the event peak and are helpful for indicating flood extent only.

From the photographic record, a point layer marking areas of flood inundation and flood extent has been derived to assess model performance.

Attempts were made to obtain further records of flood inundation from the storm of the 9th by searching online media such as facebook and news articles. The facebook page developed for the October flooding has no material published for the December flooding and newspaper records are primarily concerned with the December 2nd event which caused flooding of Wagga Library and Art Gallery. Results of this search were not included in the verification dataset but are included in Annex B.

4. MODEL CONFIGURATION AND RESULTS

Three of the four model domains were run in order to simulate the observed flooding of December 9. The three model domains are East, Lake Albert and City. Descriptions of model domains are provided in Reference 2.

4.1. Hydrologic Model Configuration

A WBNM hydrological model configured for the MOFFS (Reference 2) was used to generate runoff for the recorded rainfall event of the 9th Dec. Input parameters specific to the verification exercise were initial and continual loss parameters as well as a factor to manipulate applied rainfall depth. Note that rather than a factor applied to input rainfall a loss parameter could just as easily have been manipulated. The intent is simply to account for actual applied rainfall depth and how this might have varied over the larger area modelled. In using a reduction factor there is no intent to apply similar to design flood modelling.

The City model used the temporal pattern recorded at the RFS pluviograph station in Ashmont. Whilst rainfall gauges within the lower part of the domain indicated relatively consistent daily totals the magnitude of rainfall further south was unknown. During the modelling process a reduction factor was used as a means to address the likely gradient to the south with the final value being used 0.65.

The East and Lake Albert models are dynamically linked. Hydrological model assumptions adopted for East model were applied to the Lake Albert model. The temporal pattern for the East and Lake Albert models are defined by the AMO pluviograph station. Rainfall for East and Lake Albert model was assumed to be spatially uniform. Through iteration a reduction factor of 0.5 was adopted.

For all modelled domains rainfall losses were represented by an initial loss of 1 mm and a continuing loss of 2.5 mm/hr[1].

Table 3 summarises the hydrological model configuration for the three model domains.

Table 3 Summary of hydrological model configeration

Domain	Temporal Pattern	Spatial Gradient	Reduction Factor	IL (mm)	CL (mm/hr)
Lake Albert	AMO	Nil	0.50	1	2.5
East	AMO	Nil	0.50	1	2.5
City	RFS	Nil	0.65	1	2.5

[1] Note that given the lack of gauging and the use of at least three volume related parameters (initial loss, continuing loss and areal reduction factor) the combined effect becomes critical, not necessarily the individual parameters used.

4.2. Hydraulic Model Results

Lake Albert, East and City hydraulic models have been re-run with hydrological inputs as discussed in Section 4.1. No changes to the model schematisation were made in order to assess the MOFFS model construction with the revised verification event.

Since real time pluviograph data was used, results from hydraulic models are extracted for a comparable time to which photos were taken.

It is noteworthy that when flows from the model runs are inspected that they indicate the event lies between a 5 and 10 Y ARI. Note that this assessment was made using design runs from the MOFFS.

Figure 7 shows the flood extent modelled for all three model domains. Figure 8 shows a close up of the modelled flood extent in the CBD area including Moorong Street and Wollundry Lagoon. Figure 9 shows a close up of the modelled flood extent of the light industrial area upstream of and adjacent to Marshalls Creek. Figure 10 shows a close up of the modelled flood extent (Stringybark Creek) just upstream and to the west of Lake Albert.

All flood extent figures additionally include points marking observed inundation areas derived from aerial photography. Model results compare favourably with observations. A more detailed assessment of the match is provided in Table 4. For each key area of photographed flood extent the observed flooding is described and comment is made on whether the modelling replicates observed flooding.

Table 4 Assessment of hydraulic model results against observed photographic record of flood inundation

Photo #:	Domain:	Observation:	Model:
Photo 1	City	Open channel flow downstream of Bunning's is in-bank with out of bank flooding nearing Sturt Highway. Sturt Highway flood free.	Confirmed
Photo 22	City	Moorong St overtopped with substantial flooding upstream of Moorong St.	Confirmed
Photo 23	City	Corner of Spring St and West Pd inundated. Upstream corner of West Pd flood free while downstream corner inundated.	Confirmed
Photo 25	City	Shaw St inundated north to Gurwood St. Undeveloped land on the corner of Shaw St and Albury St inundated with shallow ponding.	Confirmed
Photo 11	City	Corner of Flowerdale Rd and Olympic Hwy inundated and roadside drain south to roundabout full.	Confirmed
Photo 19	City	Low point to centre of Evans St inundated. Approximately 20% of road length inundated.	Confirmed (increased extent in model – 70%)
Photo 8	City	Vestey St inundated with reserve area between Vestey St and Olympic Hwy inundated.	Confirmed
Photo 27	City	Wollundry lagoon full and overtopping at southern bank near Trail St.	Confirmed
Photo 30	City	Flooding at most downstream point of Wollundry Lagoon contained within banks of Lagoon.	Confirmed
Photo 48	City	Low points under railway line near Bolton Park inundated	Confirmed
Photo 48	City	Ponding in low points in Bolton Park	Confirmed
Photo 40	City	East-West alignment of Nagle Rd inundated	Confirmed
Photo 43	City	Corner of Jones St and Nesbit St inundated with inundation along Jones St from intersection West to Nagle St.	Confirmed
Photo 54	East	Shallow inundation behind decommissioned railway line east of Marshall's Ck with full roadside flow along Bakers Ln.	Confirmed
Photo 53	East	Very full in-bank flow in open channels south of Copland St feeding Marshall's Ck.	Confirmed
Photo 52	East	Flow at confluence of Marshall's Ck and Gregadoo Ck mostly in-bank.	Confirmed
Photo 49	East	Sturt Hwy between Marshalls Ck and Kooringal Rd overtopped from local run-off.	Dry-In model flow allocated to Creek
Photo 64	LA	Lloyd Rd overtopped though flow immediately downstream is in-bank.	Confirmed
Photo 61	LA	Springvale Dr dry. Flow upstream and downstream of Springvale Dr is flowing full though in-bank.	Confirmed
Photo 68	LA	Plumpton Rd dry. Flow upstream and downstream of Plumpton Rd is flowing full though in-bank.	Confirmed
Photo 57	LA	Crooked Ck upstream of Vincent Rd entirely in-bank.	Confirmed

Table 4 demonstrates that the modelling of the December 9 event closely matches observed data. There are some isolated discrepancies such as overestimating the flood extent of Evans St however the model generally fitted very well.

The sole occasion where model results differed with observations was at the Sturt Highway east of Marshall Creek however inspection of the model schematisation explains the discrepancy. In the model Sturt Highway sub-catchment flow was allocated into Marshall Creek directly. This is an appropriate assumption in line with the project scope of modelling major overland flow paths. It appears that the flooding observed on the Sturt Highway/Hammond Avenue was due to the flood gates being closed preventing drainage to Marshall's Creek.

5. CONCLUSION

Section 4.2 provides verification modelling results for the three Wagga Wagga MOFFS model domains south of the Murrumbidgee River. As discussed the model results fit the observed data sets of flood extents very well.

Based on verification modelling further confidence is gained in the MOFFS results and it is recommended that, at this stage, no further revision of the MOFFS model schematisation be carried out. The model has demonstrated an ability to represent those areas that do typically flood and particularly those areas exposed to a higher risk of flooding during events dominated by elevated Murrumbidgee River levels.

Based on this work and recent work carried out for Moorong Street on behalf of Council it is apparent that tailwater influenced events should be included in a matrix of design events when assessing selection of the flood planning event. This is particularly the case for lower catchment areas (e.g. Moorong Street) and those locations immediately upstream of significant drainage points potentially influenced by elevated River levels.

6. REFERENCES

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