Production of 80 000 ML/day flood inundation map for the South Australian section of River Murray

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
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Acknowledgements

This technical note has been delivered to inform the Constraints Management Strategy that was established under section 7.08 of the Basin Plan, which seeks to pursue the enhanced environmental outcomes under Schedule 5 of the Basin Plan.

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1 Introduction

1.1 Background

The Murray-Darling Basin Authority (MDBA) released the Constraints Management Strategy (CMS) in 2013 to address physical constraints to improve the delivery of environmental water throughout the Murray-Darling Basin. The CMS outlines a broad implementation program that will result in environmental benefits from enhanced floodplain inundation and mitigation of potential impacts to private and public land and infrastructure for flows up to 80,000 megalitres per day (ML/day) at the South Australian border.

Early stages of CMS analysis were conducted using data from the River Murray Floodplain Inundation Model (RiM-FIM) developed by Overton et al. (2006), however since then hydrodynamic models of the River Murray and its floodplains have been developed and calibrated as part of other River Murray projects.

For this analysis the Surface Water team within the Department for Environment and Water has been asked to simulate the extent of inundation for flow of 80 000 ML/day from the South Australian border to Wellington using in-house hydrodynamic models. The objective is to inform assessment of environmental benefits and potential impacts to land and infrastructure during the 2016 high flow event to identify the physical constraints that need to be addressed for the River Murray in South Australia. The Surface Water team has also been asked to compare an inundation dataset from RiM-FIM used previously at the earlier stages of this program against the results of the calibrated hydrodynamic models for a flow to SA of 80 000 ML/day.

Hydrodynamic models have been developed and calibrated over recent years in four different sections of the River Murray in South Australia using MIKE FLOOD software, as shown in Figure 1.1. These models cover the South Australian part of the River Murray, including its floodplains, downstream of Lock 6.

Refinement and calibration of two hydrodynamic models upstream of Lock 3 (i.e. Lock 6 to Lyrup model and Lyrup to Lock 3 model) was performed previously by McCullough et al. (2017) using historical monitoring data and satellite imagery for comparison. The models were validated against the 2016 unregulated River Murray high flow event. Final model outputs for both models showed acceptable correspondence with observed data through a flow range of between 10 000 and 75 000 ML/day, while also matching the observations from the 2016 high flow event. Details of refinement and calibration of these hydrodynamic models are summarised in McCullough et al. (2017).

The two hydrodynamic models downstream of Lock 3 (i.e. Lock 3 to Lock 1 model and Lock 1 to Wellington model) were initially developed by DHI (2014) for steady state flows of 10 000 and 50 000 ML/day and validated to two dynamic events in 2010 and 2012. Overall, the results showed good matches with the observed water levels and discharges. However, at the time it was stated that further improvement may be achieved by refinement of the mesh and further calibration of the roughness coefficients. The improvement of these models is the focus of this report, described below.

1.2 Scope

The aim of this study was to:

1. Improve the performance of hydrodynamic models downstream of Lock 3 in order to simulate full extent of inundation for flow of 80 000 ML/day within the South Australian section of the River Murray
2. Compare the results with the previously used RiM-FIM dataset.

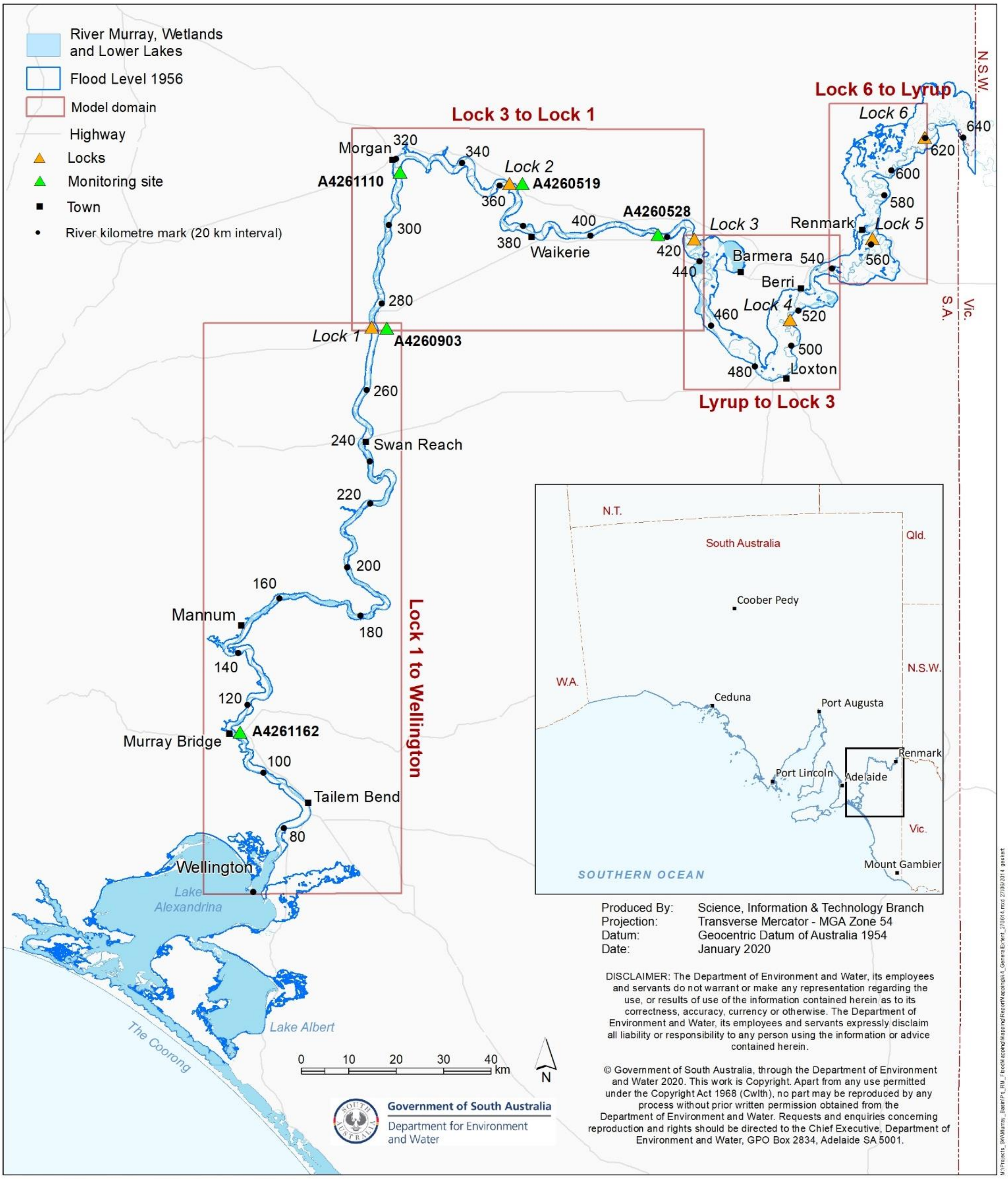

Figure 1.1 Hydrodynamic Model Extents

2 Methodology

The model refinement and calibration approach was an iterative process, requiring the models to be run at certain flows under steady state conditions and assessed against available data. The available data included observed water levels for lower flows and/or satellite imagery for higher flows, which allowed the identification of areas of the model domain requiring refinement of the roughness coefficients.

Steady state simulations of each flow condition were used for calibration purposes in preference to dynamic simulation of actual flooding events due primarily to gaps in available flow and level data at elevated flows. In addition, travel time from the state border to Lock 1 as well as upstream losses differ between events, which complicates the development of accurate hydrographs for simulation of historical events.

It should be noted that the steady state modelling approach is considered to provide a maximum estimate of the extent and depth of flooding on parts of the floodplain away from the main channel. In some locations, such as wetlands on the outer extent of the floodplain, it can take several days for water to fill floodplain areas to a water level equal to the river channel. For flood peaks that are short in duration, it is possible that these areas on the floodplain at distance from the main channel will still be in the process of filling as the peak passes, thus never equalising to the same level as the channel.

2.1 Scenarios and boundary conditions

Scenarios used for calibration of the models include:

- Base flow condition (10 000 ML/d at Lock 1)
- Medium flow condition (1966 event - 25 700 ML/d at Lock 1)
- High flow condition (2016 event - 81 400 ML/d at Lock 1)

Model boundary conditions were set by using the targeted flows indicated above as upstream boundaries and deriving the corresponding water levels from backwater curves as downstream boundaries. Table 2.1 shows the boundary condition values for two hydrodynamic models.

Table 2.1. Boundary conditions

Model	Flow @ upstream boundary (ML/day)	Water level @ downstream boundary (m AHD)
Lock 3 to Lock 1	10 000	1.0
	25 700	1.8
	81 400	4.3
Lock 1 to Wellington	10 000	0.75
	25 700	0.75
	81 400	0.88

2.2 Model calibration

The roughness coefficient value usually forms the main tool, which can be adjusted in the calibration process to achieve expected results. The South Australian land cover dataset (https://data.environment.sa.gov.au/Land/Data-Systems/SA-Land-Cover) was used to identify areas of different vegetation and land use to create a roughness coefficient map for use in the model. The choice of a suitable roughness value for each land cover class was guided by the detailed description of classes. An example of a roughness coefficient map for a reach on the South Australian River Murray is shown in Figure 2.1.

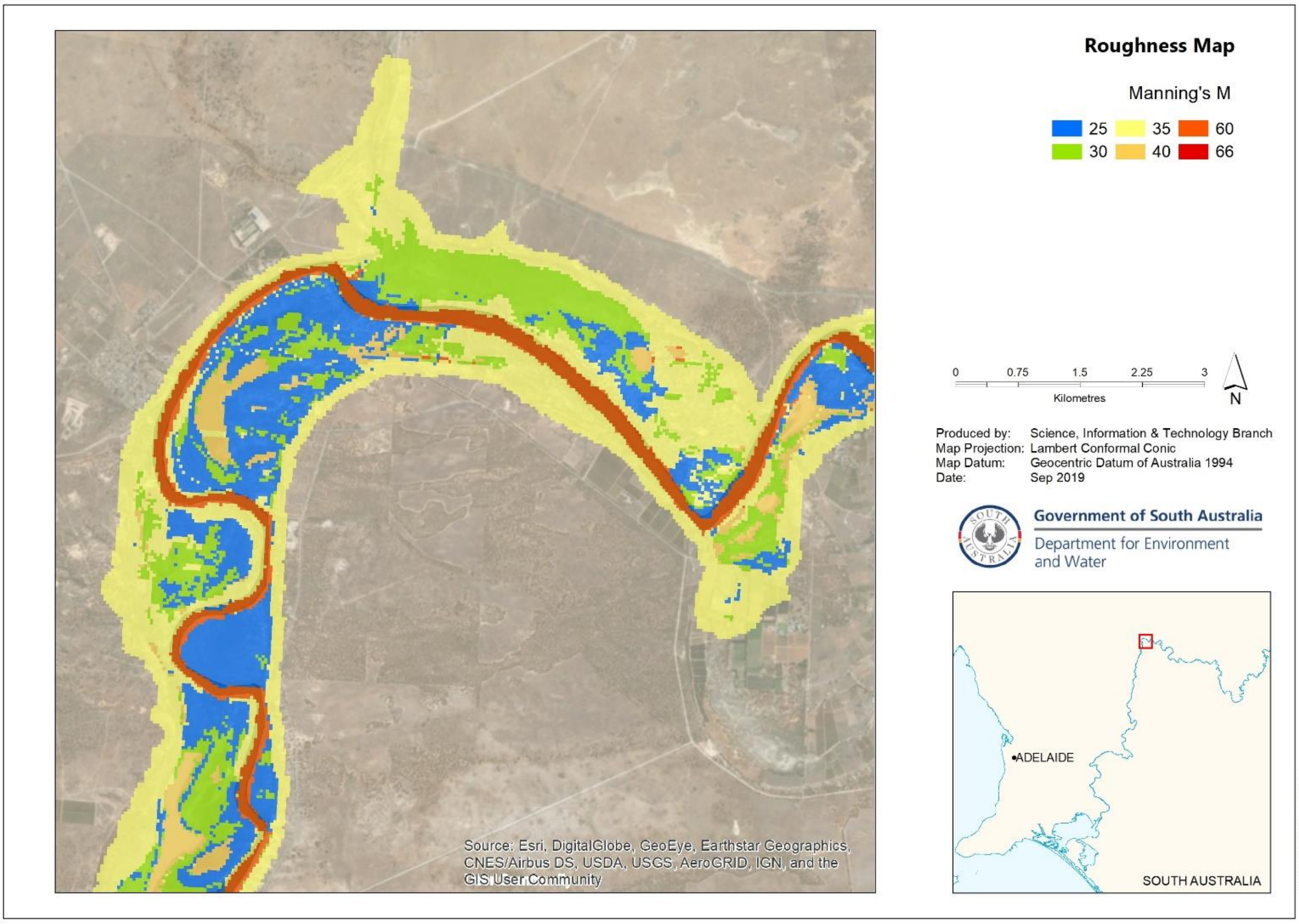

Figure 2.1 Example of a roughness coefficient map

The roughness coefficient values generally adopted for this study are presented in Table 2.2 (Manning's M is the inverse of the more commonly used Manning's n). The main channel roughness is expected to be smoother than typical values downstream of Mannum since it is less meandering and shallower than upstream sections. In addition, depending on the density and type of vegetation, roughness values outside of the typical range can be expected.

Table 2.2. Roughness coefficient (Manning's M) ranges used for calibration

Land use	Calibrated value ranges
Salt pan, low growing vegetation	20 - 30
Vegetated (small shrubs to medium density large trees)	30 - 35
Agriculture	30 - 40
Minor channels	40 - 50
River Murray main channel	60 - 66

Adjustments were made to roughness coefficient values at discrete areas across the model domain in at iterative process until acceptable comparisons between model results and observed data were obtained for the three scenarios listed above.

3 Results

3.1 Steady state results

Modelled levels in the River Murray at various gauging stations between Lock 3 and Wellington for 10 000, 25 700, and 81 400 ML/day flows were compared to observed water level data over a similar range of flows at Overland corner and Lock 1, depending on the locations, in Figure 3.1, All observed data in the period of record are included in the plot, which incorporates both rising and falling limbs of high flow events. From these scatter data, the steady state water level for a given flow is assumed to fall at the approximate mid-point of the data for the purposes of calibration. Table 3.1 shows the gauging stations used for the purpose of model calibration.

Table 3.1. Gauging stations used for calibration

Station number	Station name	Year period of record commenced
A4260528	**Overland Corner**	1956
A4260519	**Lock 2 Downstream**	1924
A4260554	**Morgan**	1974
A4260903	**Lock 1 Downstream**	1916
A4261068	**Swan Reach**	1964
A4261163	**Walker Flat**	2009
A4261067	**Mannum Pump**	1978
A4261162 & A4261003	**Murray Bridge**	1934

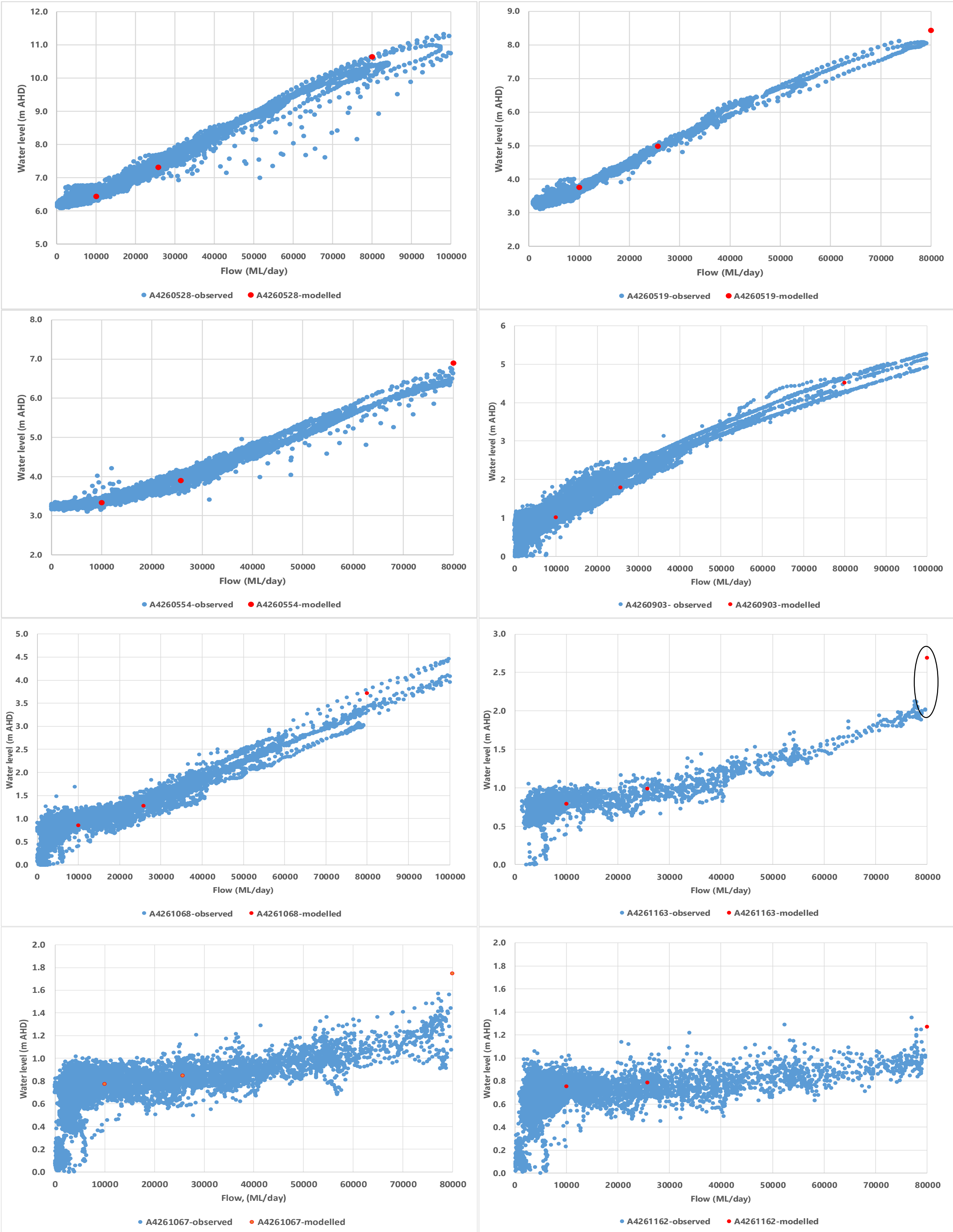

Figure 3.1 Comparison of modelled to observed water levels at various gauging stations

The modelled water levels for the majority of gauging stations are toward the upper extent of the scatter plots of observed levels to flow downstream of Lock 1 for each flow. Given the model represents the maximum level expected to be reached at steady state conditions (as outlined above) this suggests the model is representing observed river levels accurately at these locations. This is further demonstrated in Figure 3.2, where the modelled water level profile corresponding to flow of 81 400 ML/day between Lock 1 and Wellington is plotted against water level profiles derived from minimum, median and maximum recorded water levels for this flow rate.

The exception to this close alignment between modelling results and maximum recorded water level is at Walker Flat. It can be seen from Table 3.1 that this station has the shortest data record commencing in 2009, compared to 1978 or earlier for the other stations. As such, the small sample size of events in the order of 80,000 ML/d at the Walker Flat station is expected to be the reason the model overestimates water levels at this station, but provides a close match to the other data available below Lock 1.

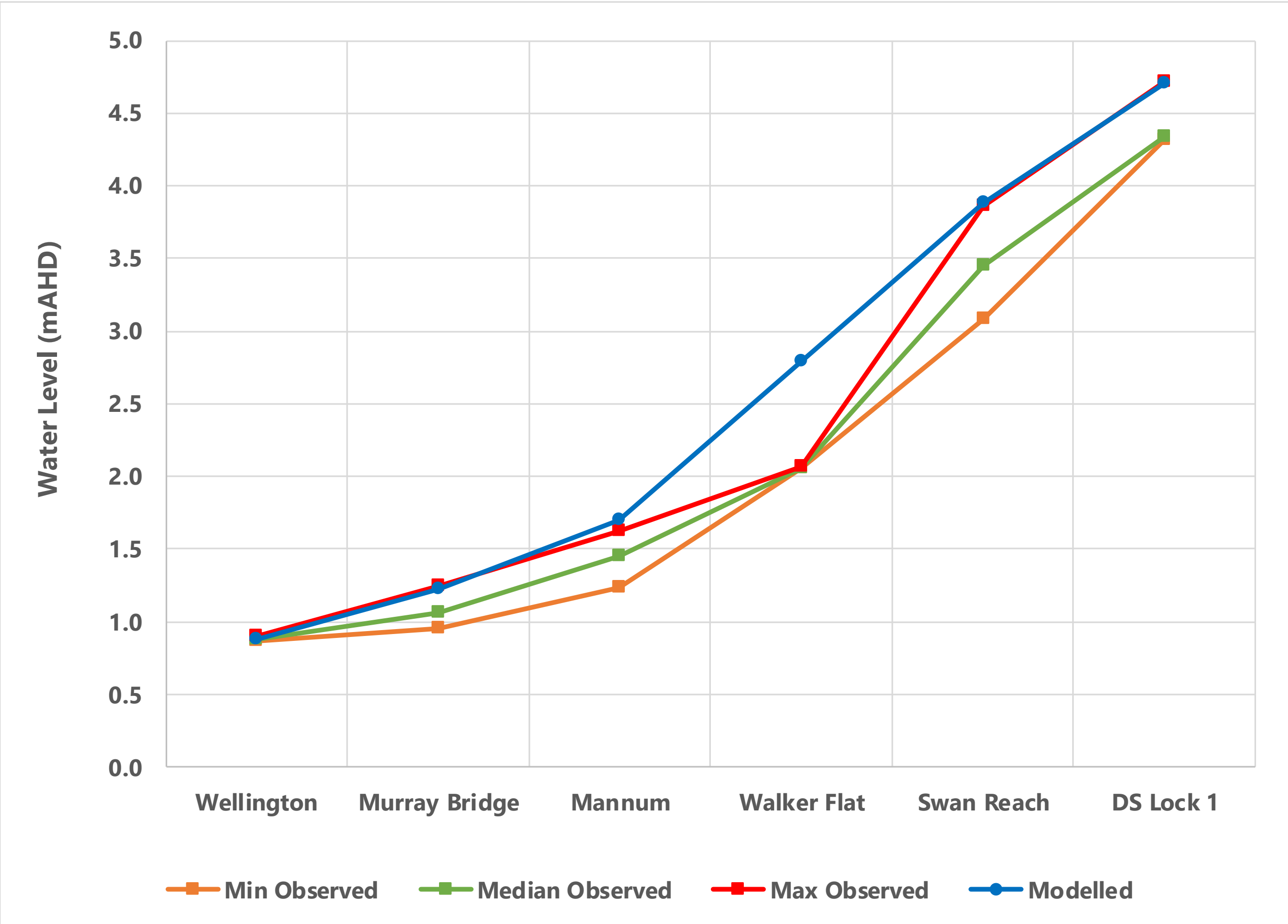

Figure 3.2 Comparison of modelled water level profile with observed water level profiles downstream of Lock 1

3.2 Inundation extents

USGS Landsat imagery was used for inundation extent comparisons to compare the model results to actual events. Imagery captured as close as possible to the peak of events representing the simulated flows were used to allow the closest representation of steady state conditions. Details of images used for comparisons are provided in Table 3.2.

Given that the comparison data represents only a snapshot of inundation extent for one particular event, rather than complete inundation after steady state conditions, it is expected that the modelled inundation extent may be greater than that showing in the Landsat imagery in some cases This difference should be taken into account when assessing modelled against observed data from each steady state simulation.

It should also be noted that inundation in the USGS Landsat Imagery becomes obscured in areas of thick vegetation, which reduces the ability to delineate flooded from dry areas. This also limits the ability to make quantitative comparisons between modelled and observed inundation extents, and thus only visual comparisons can be achieved.

The comparisons shown in Figure 3.3 to Figure 3.6 indicate the modelled extents provide an appropriate representation of observed extent of inundation for flows of 10 000 ML/day and 81 400 ML/day.

Table 3.2. Dates of images used for comparisons

Corresponding flow at Lock 1	Imagery date
10 000 ML/day	25 December 2013
81 400 ML/day	24 December 2016

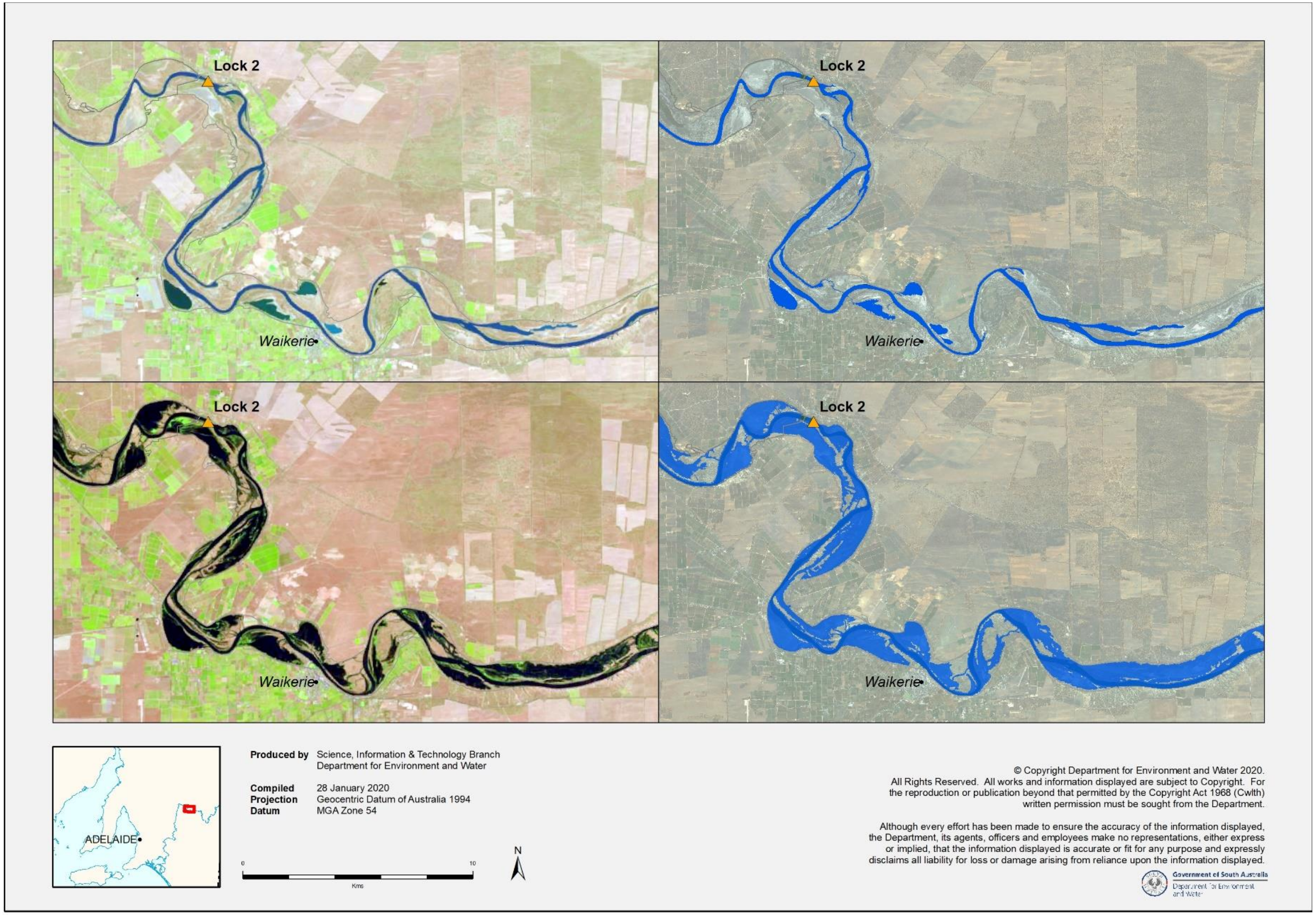

Figure 3.3 Comparison of observed (left) to modelled (right) inundation extents upstream of Lock 2 for flows of 10 000 ML/day (top) and 81 400 ML/day (bottom)

Figure 3.4 Comparison of observed (left) to modelled (right) inundation extents downstream of Swan Reach for flows of 10 000 ML/day (top) and 81 400 ML/day (bottom)

Figure 3.5 Comparison of observed (left) to modelled (right) inundation extents upstream of Mannum for flows of 10 000 ML/day (top) and 81 400 ML/day (bottom)

Figure 3.6 Comparison of observed (left) to modelled (right) inundation extents downstream of Mannum for flow of 81 400 ML/day

Downstream of Mannum, levees are constructed either side of the main channel to protect the farmlands along the River Murray. Bloss et al. (2015) identified that overtopping of levees due to flooding occurs at flows greater than 100 000 ML/day. It should be noted that based on this assumption, for the purpose of this study the levees were modelled as “zero flow” elements to be excluded from the numerical calculations. For the simulation of events exceeding 100 000 ML/day revision of the levee representation is required.

3.3 Dynamic event results

To ensure the hydrodynamic models downstream of Lock 3 were configured correctly for the purpose of simulating actual events, the models were used to simulate the period from July 2016 to February 2017 and the results compared to observed water level data. Flow data recorded downstream of Lock 1 (a reliable gauging station) was used as an input to the models to simulate downstream conditions.

The modelled water levels at five locations were compared to available observed data and can be seen in Figure 3.7. While there is a slight lag in the increase in water levels in the model compared to observed, overall good agreement was achieved between modelled and recorded datasets for the 2016 high flow event. The flat water level hydrograph at Murray Bridge (A4261162) represents river conditions where water levels are impacted by backwaters from the Lower Lakes located just downstream of this section.

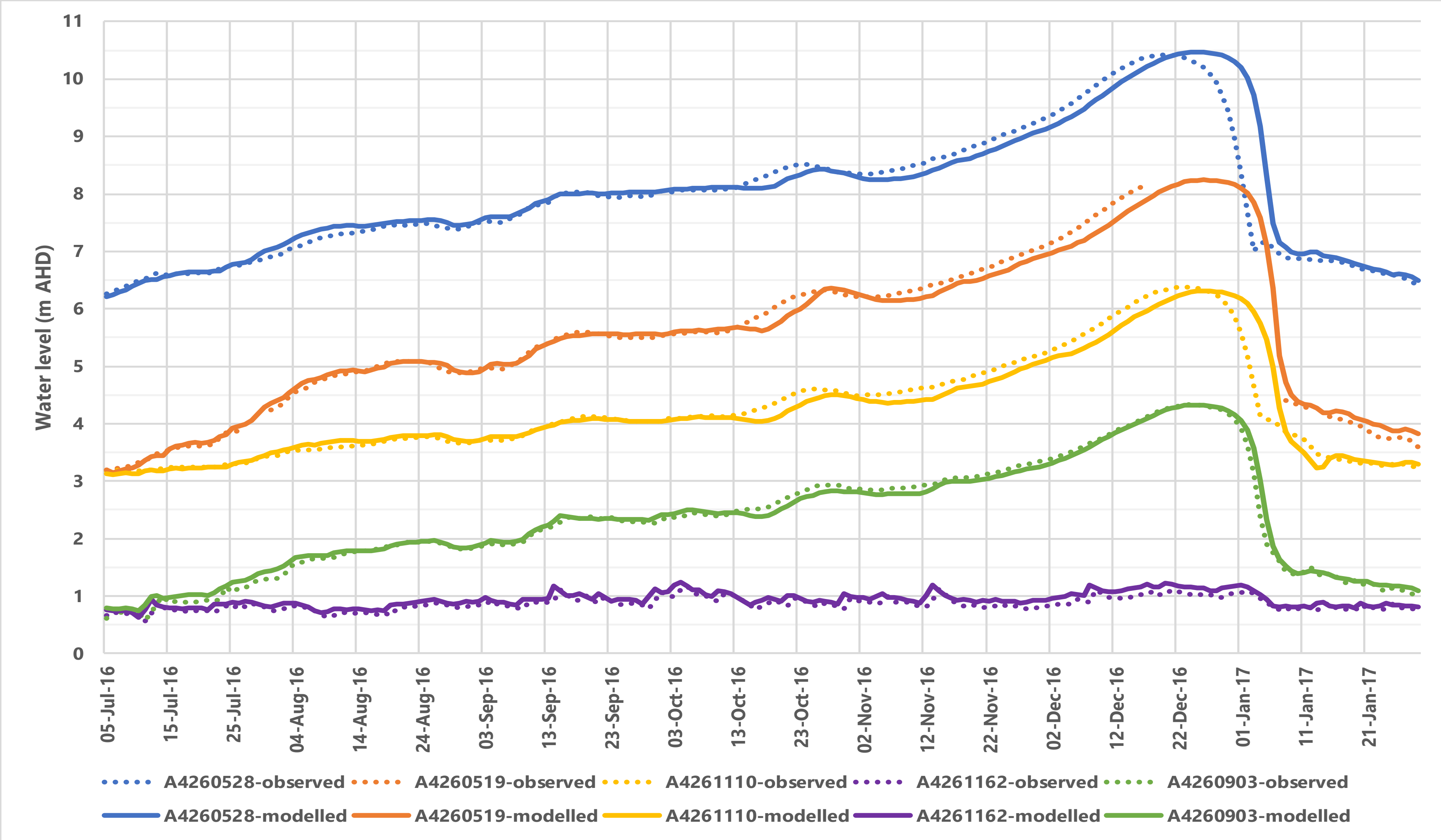

Figure 3.7 Comparison of modelled and recorded water levels under 2016 dynamic high flow event (locations of monitoring sites are provided Figure 1.1)

3.4 Simulating the full extent of inundation for flow of 80 000 ML/day and comparison with RiM-FIM data

Calibrated hydrodynamic models were used to simulate extents of inundation for a flow of 80 000 ML/day to help with assessment of environmental benefits and potential impacts to land and infrastructure that may have occurred during the 2016 high flow event to identify physical constraints to be addressed for the River Murray in South Australia.

As it is stated by Bloss et al. (2015), there are no major tributaries to the River Murray in South Australia and the maximum flow from a flood event in the River Murray will decrease, rather than increase, as it moves down the river in South Australia. Reduction of the flood peak will occur through attenuation, that is, the flattening out of the hydrograph through water moving into temporary floodplain storage, as the peak moves down the river. However, since hydrographs of flood events reaching South Australia can have long, flat rises in water level, for long duration events very little attenuation of the hydrograph will occur and the flow rate recorded at Lock 1 will be nearly as high as that recorded at the border. The more rapid and spiky the event, the more a reduction of peak flow would be expected to occur.

To represent this plausible, most conservative case, a steady state condition of 80 000 ML/day as upstream boundary conditions at both Lock 3 and Lock 1 was adopted, assuming no attenuation occurs from the border.

The modelled extent of inundations derived from the four calibrated hydrodynamic models were processed and combined to produce a single dataset representing the full extent of the South Australian section of River Murray to allow comparison with the extent of inundation for a flow of 80 000 ML/day from the RiM-FIM study.

A 15-cm high resolution aerial image was captured for shack areas between Cadell and Mannum during the high flow event in 2016, which corresponds to the timing of a flow of approximately 80 000 ML/day at Lock 1. This aerial image was used as another data source to compare the new modelled inundation dataset with the dataset from RiM-FIM around this section of the River Murray. Figure 3.8 to Figure 3.10 show some examples of comparisons where the new modelled extent of inundations are considered to provide a more appropriate representation of observed extent as shown in the aerial image. 80 000 ML/day was only exceeded for 6 days at Lock 1, and as such it expected that the modelled extent may be larger in some areas than the aerial imagery, as there may not have been sufficient time for some backwaters to fill during the 2016 high flow event.

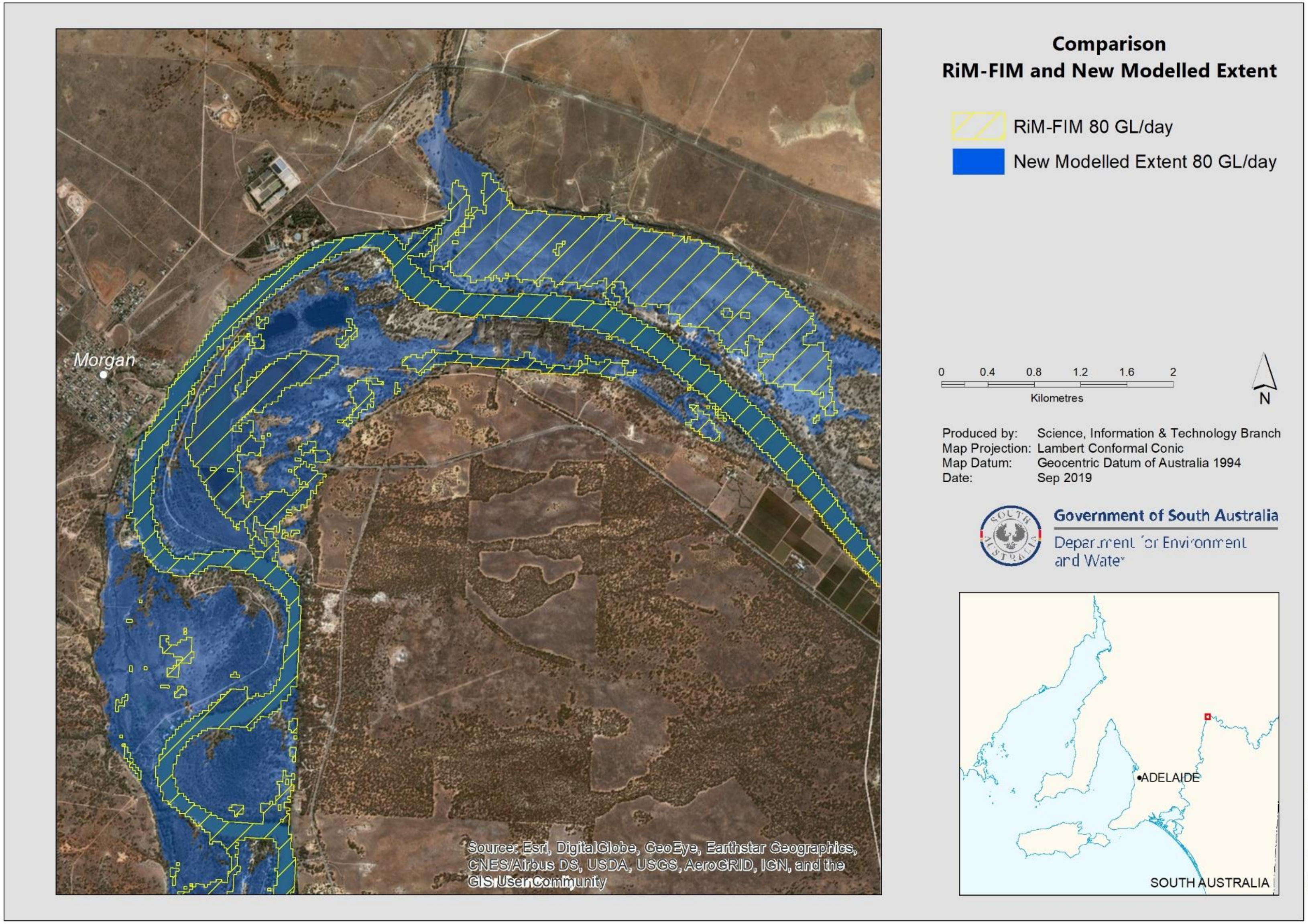

Figure 3.8 Comparison of new modelled dataset with RiM-FIM dataset – 80 000 ML/d (upstream of Morgan)

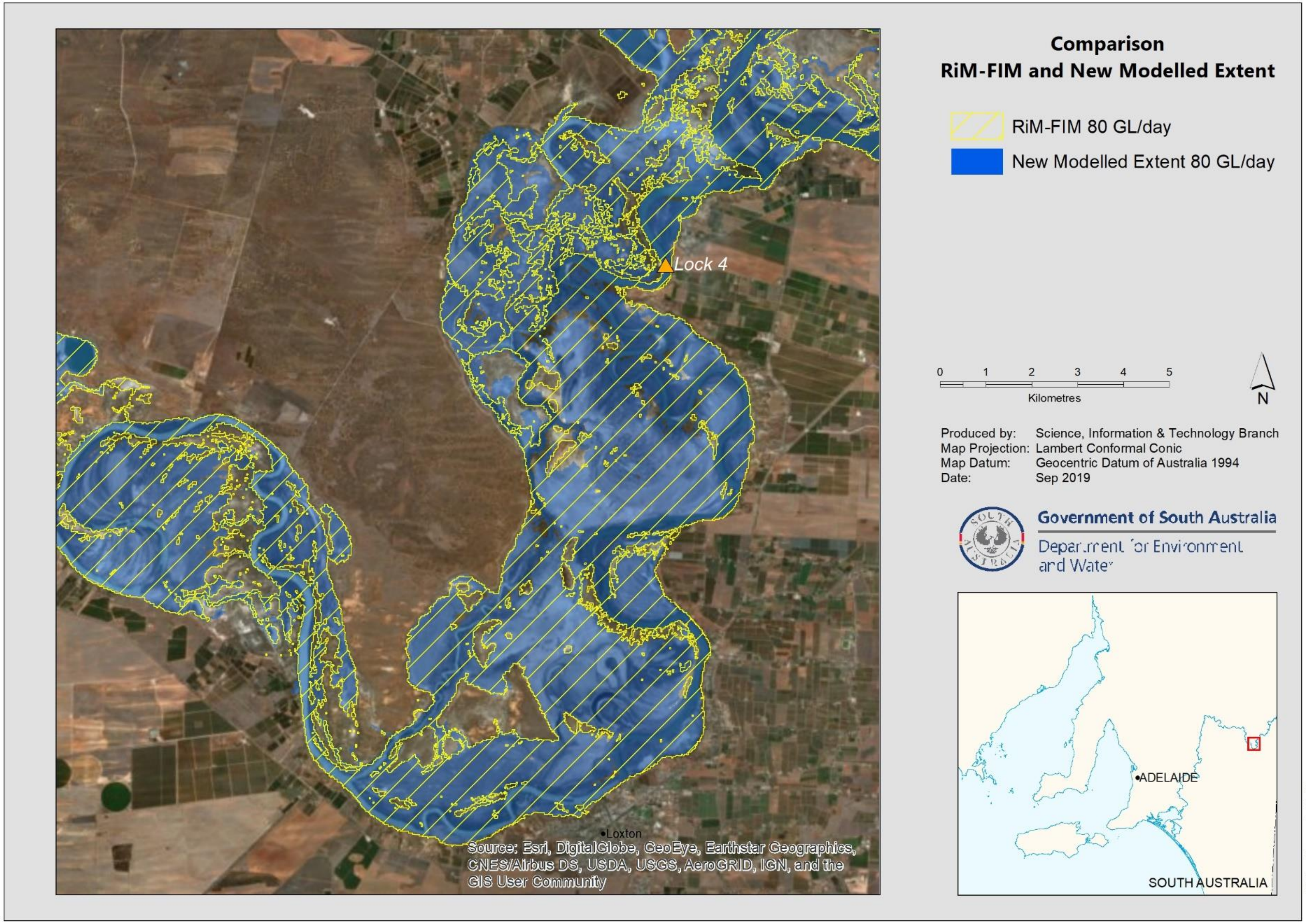

Figure 3.9 Comparison of new modelled dataset with RiM-FIM dataset – 80 000 ML/d (downstream of Lock 4)

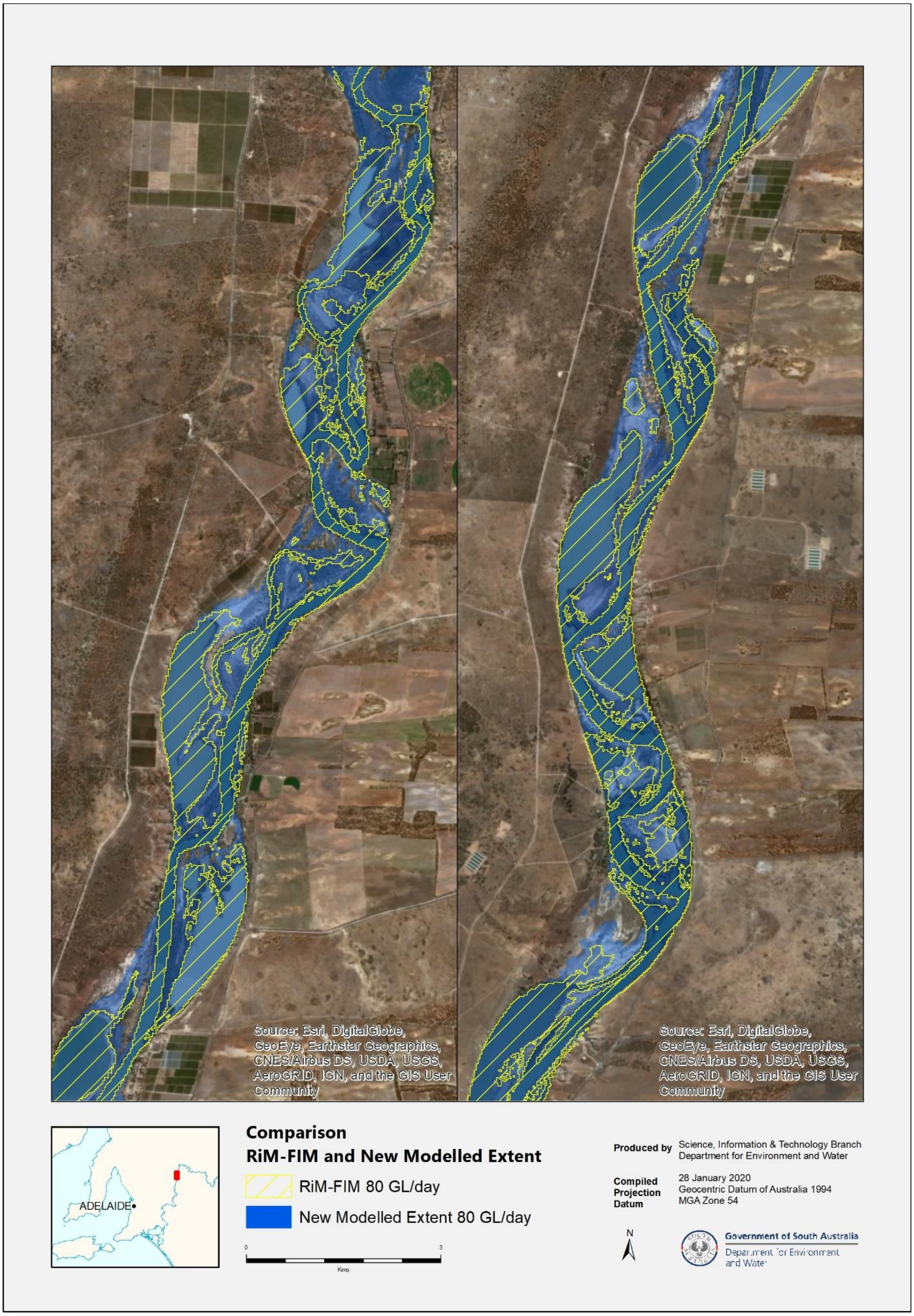

Figure 3.10 Comparison of new modelled dataset with RiM-FIM dataset – 80 000 ML/d – Murbko Lagoon (left) and Donald Flat Lagoon (right)

4 Summary

Using the MIKE FLOOD software, hydrodynamic models have been developed and calibrated over a number of years recently, four different models are used to represent sections of the South Australian River Murray, including its floodplains, downstream of Lock 6.

Refinement and calibration of two hydrodynamic models upstream of Lock 3 (i.e. Lock 6 to Lyrup model and Lyrup to Lock 3 model) was performed previously by McCullough et al. (2017) using historical monitoring data and satellite imagery for comparison. The models were validated against the 2016 River Murray high flow event.

This report summarises the improvements in the calibration of the two hydrodynamic models downstream of Lock 3 (i.e. Lock 3 to Lock 1 model and Lock 1 to Wellington model) and also the methodology for production of inundation extents for a flow of 80 000 ML/day for the South Australian section of the River Murray from the border to Lock 1. Calibration of these hydrodynamic models was carried out for steady-state simulations with the selected inflow boundaries and calibration results showing reasonable matches with the observed water levels and aerial images for the event.

The models were validated against a high flow dynamic event, which occurred in 2016 and the results showed overall good matches with the observed water levels for the data period of the hydrograph. Based on these calibration and validation scenarios the models are considered to be suitably accurate for use as a guide in supporting management and planning decisions. Due to constraints in the modelling, it should be noted that an investigation of the levees in the lower reaches downstream of Mannum should be undertaken for investigation of high flow events above 100 000 ML/day in this reach.

The modelled extent of inundation for flow of 80 000 ML/day was compared with the extent of inundation derived from the RiM-FIM study. Compared with the RiM-FIM dataset, the new modelled extent has the following advantages:

- Better representation of minor channels and smaller tributaries
- Availability of detailed information such as water level depth and velocity at each element along the inundation extent.

5 References

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