SARFIIP – Katarapko Floodplain hydraulic modelling

Managed inundation options assessment scenarios – 2014–15

DEWNR Technical note 2016/07

Government of South Australia
Department of Environment, Water and Natural Resources

SARFIIP – Katarapko Floodplain hydraulic modelling

Managed inundation options assessment scenarios – 2014–15

Daniel McCullough, Mahdi Montazeri, Matt Gibbs
Department of Environment, Water and Natural Resources

June, 2016

DEWNR Technical note 2016/07

Government of South Australia
Department of Environment,
Water and Natural Resources

Department of Environment, Water and Natural Resources

GPO Box 1047, Adelaide SA 5001

Telephone	National (08) 8463 6946
	International +61 8 8463 6946
Fax	National (08) 8463 6999
	International +61 8 8463 6999
Website	www.environment.sa.gov.au

ISBN 978-1-925369-55-7

Preferred way to cite this publication

McCullough DP, Montazeri, M, Gibbs, M, 2016, *SARFIIP – Katarapko Floodplain hydraulic modelling – Managed inundation options assessment scenarios – 2014–15*, DEWNR Technical note 2016/07, Government of South Australia, through the Department of Environment, Water and Natural Resources, Adelaide

Acknowledgements

SARFIIP is a $155 million investment program funded by the Australian Government and implemented by the Government of South Australia to improve the watering and management of River Murray floodplains in South Australia's Riverland.

The authors wish to acknowledge the project support provided by Major Projects Branch and Natural Resources SA Murray-Darling Basin, Department of Environment, Water and Natural Resources, in particular Benita Dillon, Manager – Katarapko Floodplain and Emma Hicks, Project Manager – Katarapko.

The authors also wish to acknowledge the peer reviewers for their input into the report, including Matt Gibbs and David McInerney of the Department of Environment, Water and Natural Resources, and Keiko Yamagata (DHI Water and Environment).

Contents

List of figures

List of tables

Summary

Katfish Reach is a floodplain habitat of the River Murray, located on the western side of the River Murray between Berri and Loxton in South Australia, which is comprised of the Katarapko/Eckert Creek anabranch system. The anabranch bypasses Lock 4, with several inlets into Eckert Creek above Lock 4, with a further inlet into Katarapko Creek existing downstream of Lock 4. The natural hydrological regime of the anabranch has been altered by a number of artificial banks and regulators – including a major stone weir in the upper reach of Katarapko Creek – which has contributed to ecological degradation within the floodplain.

A number of hydraulic modelling scenarios were conducted to provide hydraulic data for further assessment of proposed infrastructure options that allow managed inundation to be conducted within the floodplain. Infrastructure options involve the construction of regulators within the floodplain in combination with blocking banks to allow water to be impounded within the floodplain in a controlled manner. Three options were considered as the focus of hydraulic modelling, namely for managed inundation to heights of 13.5, 13.7 and 13.9 m AHD, with each option possessing an identical blocking bank alignment and structure placement. The scenarios were configured with varying combinations of Lock 4 level (up to 1 m raising from normal pool) and River Murray flows (up to 40 000 ML/d) to provide general hydraulic data over the area of floodplain upstream of the blocking alignment at maximum inundation heights of each option. Complementary scenarios were also developed to provide inundated area and volume data versus inundation height for a range of inundation elevations (i.e. 13 to 14 m AHD), while the impact of the blocking banks and upgraded infrastructure on natural high flows, when compared to existing floodplain conditions, was also investigated.

The hydraulic scenarios conducted do not represent an optimised control of hydraulics, but are instead intended to provide general hydraulic data over the floodplain. Designs of structures and blocking bank alignments may not correspond with final designs or alignments, while the options investigated assume that Lock 4 weir pool may be raised to the top of piers level of 14.34 m AHD. Operational limitations may restrict the maximum raising to a lower height and at lower river flows to those considered, with such restrictions potentially invalidating some or all of the options heights considered. It should also be taken into account that results from the hydraulic model are most appropriate for consideration at the floodplain scale given the outputs are accurate to a resolution of 20 m grid cell size and depend on the accuracy of digital elevation model (DEM) data, which should be considered when applying the results to any more detailed analyses.

Modelling results indicate that the concept operational level of 13.5 m AHD and Lock 4 weir pool level of 13.8 m AHD resulted in an inundated area of 1000 - 1015 ha, increasing by approximately 200 ha for each 0.2 m increase in level. The increased inundated area was typically at the fringes of the inundation extent.

Turnover rates for all scenarios considered – from 13.5 to 13.9 m AHD inundation heights and Lock 4 weir pool levels 0.3 m greater than the desired inundation height – vary from 14% up to a maximum of 20% depending on River Murray flow i.e. inflows increase as river flows are increased. Turnover rates were substantially improved by increasing the head difference between Lock 4 and floodplain level; at a 13.5 m AHD inundation height and Lock 4 pool level of 14.2 m AHD, turnover values in the order of 30% were reached, while at 13.7 m AHD inundation height and Lock 4 level of 14.2 m AHD turnover rates in the order of 22% were achieved. These results indicate that inflows and hence turnover rates are sensitive to the head difference between Lock 4 pool level and the floodplain, and of the options considered, Lock 4 levels greater than 0.3 m above the inundation height may be required during operation to generate sufficient turnover rates. Note that raising Lock 4 to the top of piers (i.e. 14.34 m AHD) has not been considered for the current modelling scenarios, and maximum Lock 4 weir pool raising for a given river flow will require confirmation for future refinement of modelling scenarios.

Velocities were greatest within the channels – particularly through the inlet channels – and at their lowest in the overbank inundated area, resulting predominantly in an increase in inundated area in the slowest velocity categories through increasing the inundation height. Bed shear stresses were modelled to be highest in the inlet channels above Lock 4 at all options considered, but overall are predominantly present below approximately 2 N/m^2, with only isolated sections of creek present above approximately 5 N/m^2. Previous literature indicates that no to low erosion risk exists within the creeks at the velocities modelled, assuming clay soils are present, however further confirmation of floodplain soil composition will be required to provide a more detailed assessment of erosion risk within the floodplain during a managed inundation event.

Modelling suggested that the blocking bank height for a 13.5 m AHD inundation height restricts natural exchange between the floodplain and River Murray below approximately 55 000 to 60 000 ML/d, while the blocking bank height at a 13.9 m AHD inundation height restricts exchange at flows up to approximately 65 000 to 70 000 ML/d. This modelling however limits flow paths through the blocking banks to the outlet regulating structures, and does not include provision for measures such ancillary structures or spillways within the blocking banks that may reduce restriction of natural high flows through the floodplain. The presence of the blocking banks is modelled to alter the natural flow paths at high flows from the majority passing through Car Park lagoon under existing conditions, to The Splash under fully upgraded floodplain conditions, indicating that measures to reduce restriction of flow through Car Park, such as via ancillary structures or spillways in the blocking banks, may require consideration.

The impact of increasing Lock 4 weir pool level during a managed inundation event results in an extension of the backwater influence of the lock upstream towards Lock 5 from typical weir pool elevation, which ultimately reduces the gradient of the river in the reach directly upstream of the lock. Conversely, river gradient increases with increasing river flow for a given weir pool elevation. These effects have implications for a potential water quality management option for the Gurra Gurra wetlands upstream of Katarapko Floodplain, to create flow-through conditions within the system, driven by river gradient. The relatively small head difference between inlets and outlets of the system may not generate sufficient flow-through conditions at 10 000 ML/d to provide water quality benefits, while operating at greater weir pool elevations also may reduce the effectiveness of this measure due to a flattening of the river reach in the vicinity of the wetland, however further modelling incorporating the wetland will be required to better assess these assertions.

1 Hydraulic model summary

Katfish Reach is a floodplain habitat of the River Murray, located on the western side of the River Murray between Berri and Loxton in South Australia, which is comprised of the Katarapko/Eckert Creek anabranch system. The anabranch bypasses Lock 4, with several inlets into Eckert Creek above Lock 4, with a further inlet into Katarapko Creek existing downstream of Lock 4. The natural hydrological regime of the anabranch has been altered by a number of artificial banks and regulators – including a major stone weir in the upper reach of Katarapko Creek – which has contributed to ecological degradation within the floodplain. The various creeks and structures (existing and proposed) within the floodplain are presented in Figure 1.1.

A description of the base 1-D/2-D coupled hydraulic model used to model the floodplain is presented in McCullough (2014), with updates to the base model covered in McCullough (2016). The model possesses inherent sources of error that may impact on the accuracy of outputs, including:

- 20 m grid cell size in the floodplain topography
- Vertical accuracy of the digital elevation model (DEM) used for the modelled floodplain topography in the order of approximately ±0.10 to 0.15 m, but may vary depending on localised characteristics within the floodplain area (e.g. dense tree coverage may reduce accuracy)
- Minimal in-stream floodplain monitoring data available for calibration/validation of the model under baseflow conditions.

Analysis of model outputs should be considered in the context of these error sources.

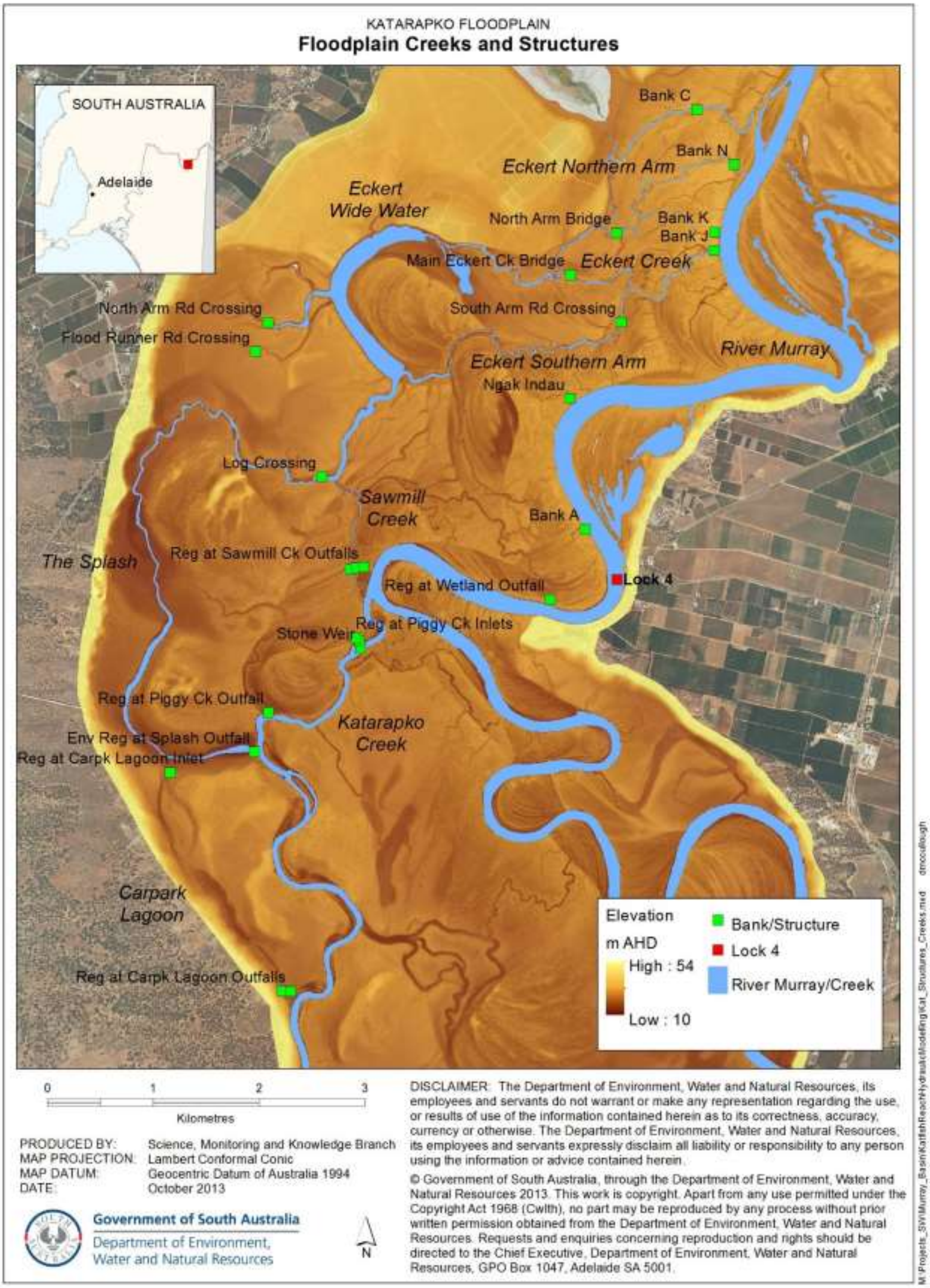

Figure 1.1 Katarapko Floodplain creeks and structures

2 Management options scenario summary

Hydraulic modelling scenarios were designed to provide data for management options development for Katarapko Floodplain. Initial scenarios were framed to investigate the maximum inundation heights for the three blocking bank options, namely 13.5, 13.7 and 13.9 m AHD. These initial scenarios were configured to provide general hydraulic data over the area of floodplain upstream of the blocking alignment, and do not reflect optimised operational hydraulics at the current stage of investigations. Note that while the maximum inundation heights were investigated in these scenarios, this does not preclude operating to inundation heights less than maximum for a given option. For instance, hydraulic characteristics of a managed inundation to 13.5 m AHD are applicable to each of the three options considered. Therefore, to complement these results, inundation extents over a range of heights, upwards of 13 m AHD, were also considered from the perspective of inundated area and volume only. The options investigated assume no restrictions on Lock 4 weir pool raising up to top of piers level (14.34 m AHD), however operational limitations may restrict maximum raising height to a lower level, and as such may invalidate some or all of the options heights considered depending on maximum height possible.

Additional modelling was subsequently conducted to assess the impact of each of the bank options on the hydraulics of natural high flows compared to existing floodplain conditions, and also some consideration given to the impacts of raising Lock 4 pool level on areas outside the blocking bank, particularly around the Gurra Gurra wetland area.

Table 2.1 shows the simulation configurations used for all scenarios tested. For each maximum inundation height considered (scenarios 1 to 5), River Murray flows upstream of Lock 4 were varied from 10 000 to 40 000 ML/d in 10 000 ML/d increments, with the model allowed to reach steady state conditions at each flow (i.e. the point at which all hydraulic parameters reach a constant level for the given model configuration). The flow of 40 000 ML/d represents the approximate maximum flow at Lock 4 before the lock is overtopped, and hence the theoretical maximum operating flow of the regulated inundation options. Confirmation of maximum allowable flows under Lock 4 weir pool raising is required to refine future investigations, however a previous investigation by Aquaterra (2009) suggests that 20 000 ML/d represents the maximum river flow at which weir pool raising may be conducted (at top of piers level). The additional scenarios designed to complement the preceding maximum inundation scenarios (i.e. scenario 6) show the progressive increase in inundated area with height, covering elevations from 13.0 to 14.0 m AHD in 0.1 m increments, with each increment in height allowed to reach steady state.

Table 2.1 Management options development steady state scenario model configurations

Scenario	Model inflow U/S Lock 4 (ML/d)	Lock 4 U/S (m AHD)	Tailwater level U/S Lock 3 (m AHD)	Inundation height (m AHD)	Modelling details
1a	10 000	13.8	9.8	13.5	Full inundation, steady state
1b	20 000	13.8	9.8	13.5	Full inundation, steady state
1c	30 000	13.8	9.8	13.5	Full inundation, steady state
1d	40 000	13.8	9.8	13.5	Full inundation, steady state
2a	10 000	14.0	9.8	13.7	Full inundation, steady state
2b	20 000	14.0	9.8	13.7	Full inundation, steady state
2c	30 000	14.0	9.8	13.7	Full inundation, steady state
2d	40 000	14.0	9.8	13.7	Full inundation, steady state
3a	10 000	14.2	9.8	13.9	Full inundation, steady state
3b	20 000	14.2	9.8	13.9	Full inundation, steady state
3c	30 000	14.2	9.8	13.9	Full inundation, steady state
3d	40 000	14.2	9.8	13.9	Full inundation, steady state
4a	10 000	14.2	9.8	13.5	Full inundation, steady state
4b	20 000	14.2	9.8	13.5	Full inundation, steady state
4c	30 000	14.2	9.8	13.5	Full inundation, steady state
4d	40 000	14.2	9.8	13.5	Full inundation, steady state
5a	10 000	14.2	9.8	13.7	Full inundation, steady state
5b	20 000	14.2	9.8	13.7	Full inundation, steady state
5c	30 000	14.2	9.8	13.7	Full inundation, steady state
5d	40 000	14.2	9.8	13.7	Full inundation, steady state

Scenario	Model inflow U/S Lock 4 (ML/d)	Lock 4 U/S (m AHD)	Tailwater level U/S Lock 3 (m AHD)	Inundation height (m AHD)	Modelling details
6	10 000	14.2	9.8	13.0-14.0	Steady state inundation in 0.1 m increments
7a	25 000 to 75 000	Variable	Variable	Variable	Existing floodplain conditions, steady state flows at 5000 ML/d increments
7b	25 000 to 75 000	Variable	Variable	Variable	13.7 m AHD blocking bank height, steady state flows at 5000 ML/d increments
7c	25 000 to 75 000	Variable	Variable	Variable	13.9 m AHD blocking bank height, steady state flows at 5000 ML/d increments
7d	25 000 to 75 000	Variable	Variable	Variable	14.1 m AHD blocking bank height, steady state flows at 5000 ML/d increments

For the purposes of the managed inundation scenarios tested, the main outflows from the floodplain were limited to The Splash and Sawmill Creek outlets, which were set to control water level at the desired inundation height while allowing the model to determine the relative flow over each regulator. No flow was passed from Piggy Creek and Car Park Lagoon outfalls, although some minor flows were modelled through the Piggy Creek outlet regulating structure in the results at an inundation height of 13.9 m AHD (Scenarios 3a to d), and at 13.7 m AHD with Lock 4 level at 14.2 m AHD (Scenarios 5a to d). Given calculation of the overall outflows from the floodplain were the main requirement for these scenarios to allow calculation of approximate turnover rates in each inundation case, the lack of optimisation of outfall regulator operations is considered acceptable. Each inlet structure at Bank J, K and N was set to fully open, as is the Ngak Indau inlet to maximise inflow to the floodplain. The structures at Log Crossing and South Arm Road Crossing were also set to a fully open state to reduce resistance to flow through the floodplain during inundation. In each managed inundation case tested, the blocking alignment was added to the bathymetric grid at a height sufficiently high to ensure no overtopping occurred at the target inundation level.

A Lock 4 pool level of 13.8 m AHD was selected for the 13.5 m AHD inundation option (Scenario 1a–d) based on the existing concept for the managed inundation solution. This head difference of 0.3 m between the inundation height and Lock 4 pool level was applied to the remaining inundation options to maintain consistency across the scenarios, resulting in 14.0 m AHD set for a maximum inundation height of 13.7 m AHD (Scenario 2a–d), and 14.2 m AHD set (i.e. 1 m rise from normal Lock 4 weir pool operating level) for a maximum inundation height of 13.9 m AHD (Scenario 3a–d). An additional set of model simulations (Scenarios 4a–d and 5a–d) were also developed to show the effect of operating at a head difference greater than 0.3 m. In these simulations, the pool level of 14.2 m AHD used for the 13.9 m AHD inundation height case was applied to the inundation heights of 13.5 m AHD (Scenario 4a–d) and 13.7 m AHD (Scenario 5 a–d). The model tailwater level at upstream Lock 3 was maintained at 9.8 m AHD for all managed inundation scenarios. Note that these modelled weir pool settings do not necessarily represent optimised hydraulics for managed inundation operation, and will require further refinement, including accounting for the maximum lock weir pool operating height for a given River Murray flow, once determined from an operational perspective. In addition, the complementary simulations (Scenario 6 set) were operated at a consistent Lock 4 level of 14.2 m AHD, with inundation height varied from 13.0 to 14.0 m AHD in 0.1 m increments. Similar to the previous managed inundation scenarios, all inlet and floodplain structures were set to fully open. Under this scenario however, Sawmill Creek regulator flow was limited to 400 ML/d, as the previous scenarios (1 to 5) yielded flows that were excessively high from an erosion perspective, and thus represented an initial attempt at some level of optimisation of regulator control.

Additional simulations were conducted to provide comparison data for assessing the potential impact of the various blocking alignment height options on inundation of the floodplain during natural high flow events. Analysis of the scenarios focus on spatial velocity distribution differences between natural flows under existing floodplain conditions (i.e. without infrastructure upgrades) and with the floodplain in a fully upgraded state, and all floodplain structures fully open. Of additional interest is whether areas of floodplain are prevented from inundating during natural high flow events by the presence of the blocking banks. Modelling data for the existing state of the floodplain was based on data extracted from previous modelled outputs produced in the work by Montazeri and McCullough (2015), based on various River Murray flows and the floodplain under existing conditions (i.e. without regulator construction). Scenarios 7a to d additionally present the impact of the blocking bank options on natural high flows through the floodplain, comparing inundation extents of existing conditions (Scenario 7a) with upgraded floodplain conditions for inundation options of 13.5 m AHD (Scenario 7b), 13.7 m AHD (Scenario 7c) and 13.9 m AHD (Scenario 7d) maximum inundations. For the upgraded floodplain conditions scenarios, all floodplain regulating structures were set to fully open, and the blocking bank height was assumed to possess a 0.2 m freeboard above the maximum height of inundation in each case.

Further work presents modelled water levels in the Lock 5 to 4 reach for weir pool heights of 13.2, 13.8, 14.0, 14.2 and 14.34 m AHD to provide an indication of the behaviour of the river upstream of the floodplain when raising weir pool levels for a managed inundation event. Note that levels at 13.8, 14.0 and 14.2 m AHD have been extracted from the modelling results in the current scenarios, while 13.2, 13.8 and 14.34 m AHD have been extracted from previous weir pool raising modelling results reported in Macky and Bloss (2012). The results from the current modelling outputs should be viewed with caution however, as the modelled River Murray reach upstream of the Katarapko Floodplain is represented in 1-D only, with no linkage to a 2-D grid, and thus will not account for any overbank flow that may occur under raised pool levels. A weir pool level of 13.8 m AHD has been presented from each set of modelling results to show where the differences in elevations lie for comparison.

The following sections present the outputs of each scenario, including water depth and spatial distribution, velocity distribution and velocity profiles within the impounded area, and targeted hydraulic data including water level, discharge, inundated area, volume, and daily turnover rate (i.e. percentage of outflow divided by impounded volume). Velocity distribution maps for a limited number of scenarios are presented in the body of the report, with the remainder contained in the Appendix. Note that no ecological advice has been provided in this technical note.

3 Hydraulic characteristics of inundation options

3.1 General Hydraulic Parameters

The modelled results for full inundation at steady state flow conditions show that the greatest maximum inflows to the floodplain are achieved predominantly through Bank J. Table 3.1 shows the discharge at each inflow and outflow structure (and total inflows and outflows), inundation area, volume and turnover rate based on the hydraulic modelling outputs. Flow through Bank J represents approximately 66 to 75% of the total inflows, while other structures at Banks K, N, Ngak Indau inlet and Bank A also contribute relatively minor additional inflows. Of note are the inflows through Ngak Indau inlet regulator, which provide similar inflows to those at Bank K when in a fully open state, especially at greater inundation (and hence Lock 4 weir pool) elevations.

For a given inundation height and all inlet structures fully open, increasing water level in the river upstream of Lock 4, either through raising river flows or Lock 4 levels, results in greater inflows to the floodplain, which in turn raises the turnover rate through the floodplain for the same impounded volume. For example, at a steady state inundation height of 13.5 m AHD, a Lock 4 pool level of 13.8 m AHD and river flow of 10 000 ML/d, the water level at Bank J is approximately 13.81 m AHD, total inflows are at approximately 1380 ML/d, inundated area is at 1000 ha and total impounded volume at approximately 9500 ML, resulting in a turnover rate of approximately 14%. When raising the river flow to 40 000 ML/d the water level at Bank J increased to approximately 13.92 m AHD, and for the same inundation height, total inflows are approximately 1740 ML/d, inundated area marginally greater at 1015 ha and impounded volume at approximately 9640 ML, resulting in a raised turnover of approximately 18%. This behaviour demonstrates that a greater turnover rate can be achieved by increasing the river level when operating the structures, subject to any operational restrictions that may be encountered with raising lock upper pool levels during higher river flows.

Turnover rate is particularly influenced by altering the Lock 4 upper pool level relative to the inundation height. The results in Table 3.1 show that for a given River Murray flow, the inflows and consequently outflows to the impounded area increase as the weir pool level is raised from 13.8 m AHD (Scenarios 1a–d) to 14.2 m AHD (Scenarios 4a–d). For example, total inflows to the floodplain at an inundation height of 13.5 m AHD, river flow of 10 000 ML/d and a Lock 4 upper pool level of 14.2 m AHD is approximately 2950 ML/d, which is over double the comparative inundation and inflows at a weir pool level of 13.8 m AHD of approximately 1380 ML/d. Turnover rates yielded between these two particular cases are 14% and 29%, respectively, highlighting the sensitivity of system operation to weir pool height. Observing the hydraulic parameters under a weir pool level of 14.2 m AHD and inundation height of 13.9 m AHD, inflows at a river flow of 10 000 ML/d are approximately 2470 ML/d, or approximately 84% of the inflows possible under the 13.5 m AHD inundation height and the same weir pool level.

These results indicate that inflows are not only influenced by the Lock 4 weir pool level, but also the head difference between weir pool level and inundation height, such that the greatest inflows can be achieved by increasing this head difference. From Table 3.1, it can be seen that a head difference of approximately 0.46 m (based on the combined impact of flow and Lock 4 level on water level at Bank J) is required to provide a turnover rate of 20% for the 13.5 m AHD and 13.7 m AHD regulator operating heights, reducing to 0.39 m for the 13.9 m AHD operating height. Note that achievable head difference is ultimately dependent on the maximum operating height of Lock 4 weir pool level, and this level will need to be established to develop more specific modelling scenarios relevant to actual operating regimes. A substantial raising of Lock 4 to close to the top of piers (maximum level physically possible) to 14.2 m AHD as well as high flows in the order of 40 000 ML/d are required to result in the head difference necessary for a 20% turnover rate for an operating height of 13.9 m AHD (Scenario 3d). It should also be noted that the inflow rates presented may be excessively high for ecological or erosion considerations, and the results should be considered as indicative only for the maximum inflows that can be achieved by manipulating hydraulics of the system. Future work will require modelling at defined limits of flows through structures to provide more realistic operational hydraulics.

Maps of inundation extent and depths of inundation are presented for inundation heights of 13.5 (Figure 3.1), 13.7 (Figure 3.2) and 13.9 m AHD (Figure 3.3) at a River Murray flow of 10 000 ML/d. Note that the blocking alignment has been included in all maps for reference purposes only, and does not differentiate between areas in the alignment that are naturally higher than the required elevation and those that require elevation through construction of banks. Note also that inundation extents are not significantly different in appearance for flows of 20 000, 30 000 and 40 000 ML/d at each inundation height (increase in area of 7–15 ha, or 0.5–1.5%), and hence have not been included as additional figures to avoid duplication. Also, only the results from scenarios with 0.3 m difference between the inundation height and Lock 4 level are presented (i.e. Scenarios 1–3), given that the differences in inundation extents between these and the higher Lock 4 levels are not sufficiently different for display purposes. The inundation extent comparison indicates that the inundated area increases with the increase in inundation height in relatively even increments, with the increase largely located at the fringes of the inundated area beyond 13.5 m AHD. Table 3.1 shows that each 0.2 m increase in inundation height results in an increase in inundated volume of approximately 200 ha. The depth maps indicate that much of the overbank floodplain area in each option is inundated at depths less than approximately 0.6 m, while in-channel depths tend to exceed approximately 1.5 to 2 m.

A comparison of inundation extents to height is presented in Figure 3.4, which includes all inundation heights (in 0.1 m increments) from 13.0 to 13.9 m AHD, with an additional step of 14.0 m AHD included for reference. A complementary plot of inundated area and volume against inundated height is also shown in Figure 3.5. Inundated area was calculated to increase from approximately 630 ha at 13.0 m AHD up to approximately 1400 ha at the maximum inundation option of 13.9 m AHD. For each 0.1 m step change, the additional area of inundation increases at a marginally greater amount below 13.5 m AHD inundation compared with heights above 13.5 m AHD i.e. increases in area for each 0.1 m step change are between 83 to 100 ha below 13.5 m AHD, and between 68 to 87 ha upwards of 13.5 m AHD.

Table 3.1 Summary of hydraulic characteristics for steady state, full inundation scenarios.

Scen.	Reg. height	Lock 4 height	Bank J height	River flow	Inlet Q						Outlet Q					Area	Volume	Turn-over*
					bank J	Bank K	Bank N	Ngak Indau inlet	Bank A	Total in-flow	Sawmill Creek	The Splash	Car Park outlet	Piggy Creek outlet	Total out-flow			
	m AHD	m AHD	m AHD	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ML/d	ha	ML	%
1a	13.5	13.8	13.81	10 000	1030	149	84	106	9	1379	507	828	0	0	1335	1000	9508	14
1b	13.5	13.8	13.83	20 000	1082	160	92	108	9	1451	530	877	0	0	1408	1006	9555	15
1c	13.5	13.8	13.87	30 000	1170	177	104	112	10	1573	575	958	0	0	1533	1010	9593	16
1d	13.5	13.8	13.92	40 000	1289	201	122	118	11	1741	641	1061	0	0	1701	1015	9639	18
2a	13.7	14.0	14.01	10 000	1280	210	116	192	37	1834	507	1193	0	0	1700	1205	11827	14
2b	13.7	14.0	14.02	20 000	1336	221	125	195	38	1915	524	1253	0	0	1777	1206	11843	15
2c	13.7	14.0	14.06	30 000	1432	240	139	202	39	2052	552	1358	0	0	1911	1208	11875	16
2d	13.7	14.0	14.10	40 000	1567	268	160	211	40	2247	592	1505	0	0	2097	1212	11916	18
3a	13.9	14.2	14.20	10 000	1625	297	163	308	78	2471	558	1607	0	243	2408	1407	14521	17
3b	13.9	14.2	14.22	20 000	1688	310	173	314	78	2563	576	1685	0	243	2504	1409	14540	17
3c	13.9	14.2	14.25	30 000	1796	332	191	324	79	2722	607	1821	0	244	2671	1411	14566	18
3d	13.9	14.2	14.29	40 000	1951	364	214	340	81	2949	648	2004	0	244	2897	1414	14606	20
4a	13.5	14.2	14.20	10 000	1971	354	196	350	79	2951	1083	1823	0	0	2906	1077	10042	29
4b	13.5	14.2	14.22	20 000	2010	364	205	354	80	3013	1106	1867	0	0	2973	1077	10063	30
4c	13.5	14.2	14.25	30 000	2083	383	220	372	81	3139	1150	1946	0	0	3096	1079	10100	31
4d	13.5	14.2	14.29	40 000	2196	412	241	373	83	3304	1216	2067	0	0	3283	1089	10166	32
5a	13.7	14.2	14.20	10 000	1857	336	186	343	79	2802	705	1917	0	1	2623	1238	12063	22
5b	13.7	14.2	14.22	20 000	1904	347	195	347	80	2874	722	1970	0	2	2694	1238	12081	22
5c	13.7	14.2	14.25	30 000	1994	368	211	355	81	3009	755	2072	0	3	2830	1241	12114	23
5d	13.7	14.2	14.29	40 000	2118	398	233	366	82	3198	801	2215	0	4	3020	1244	12161	25

* Percentage of total outflows divided by total volume in the impounded area.

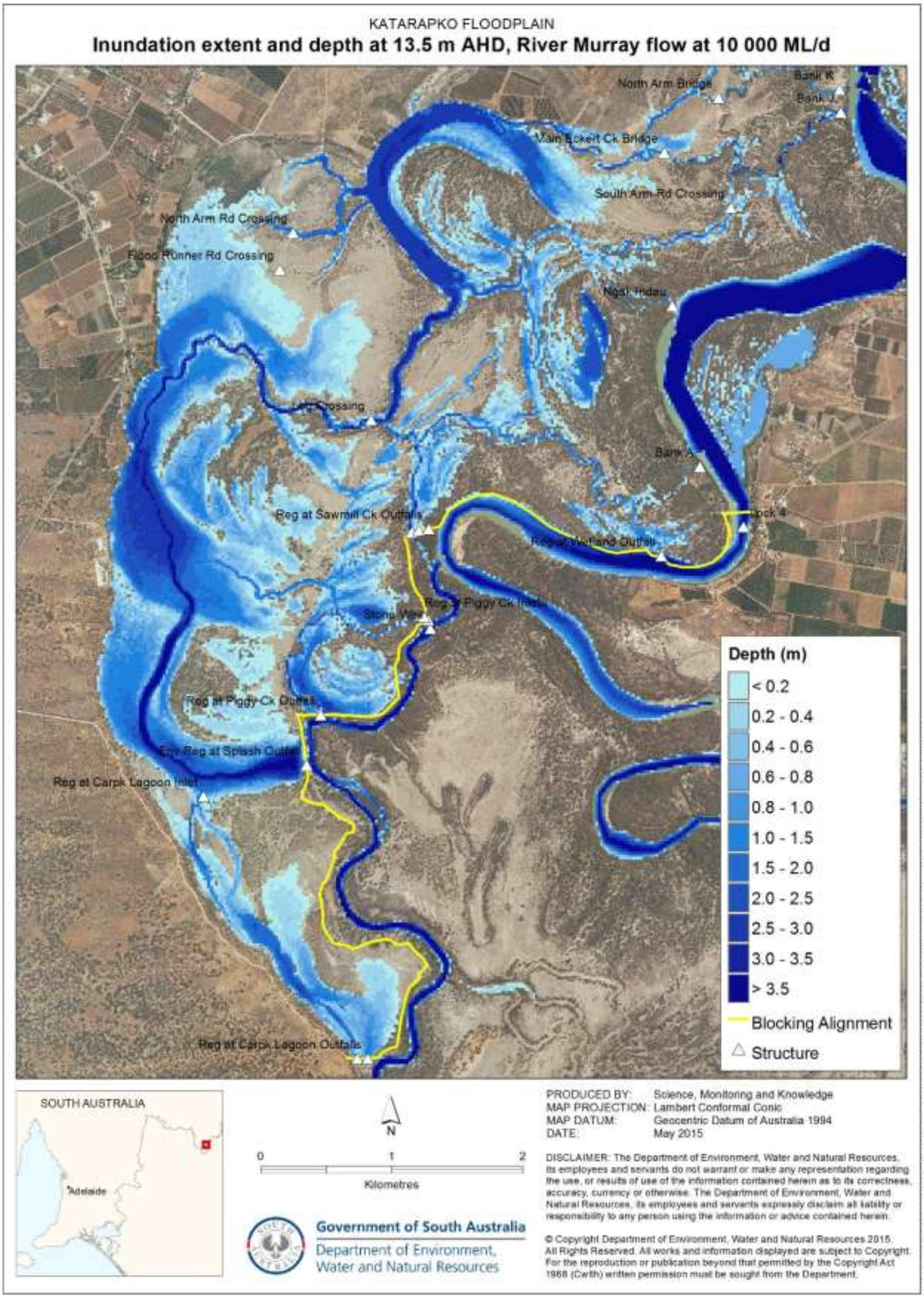

Figure 3.1 Inundation extent and depths at 13.5 m AHD inundation height, 10 000 ML/d river flow

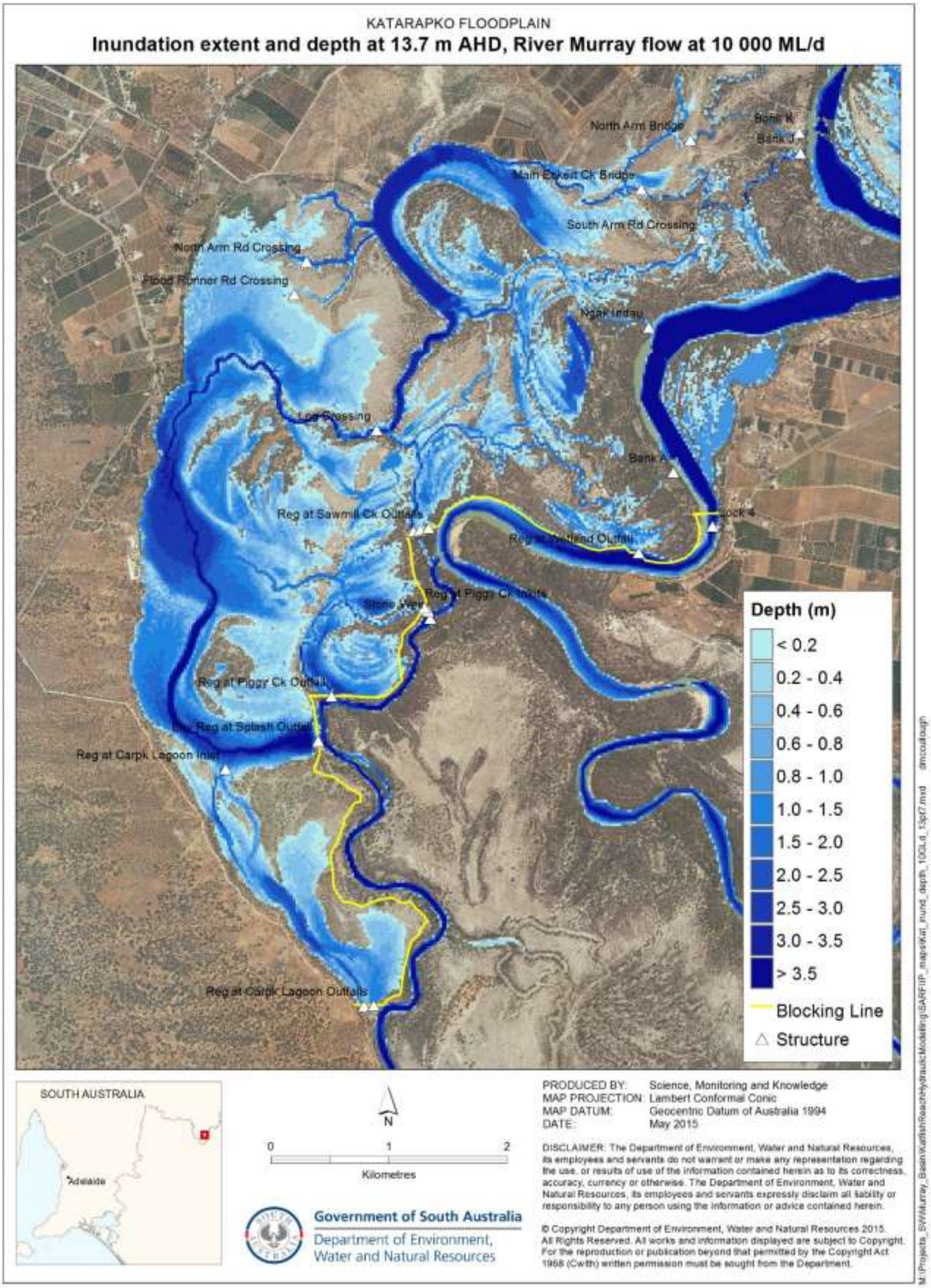

Figure 3.2 Inundation extent and depths at 13.7 m AHD inundation height, 10 000 ML/d river flow

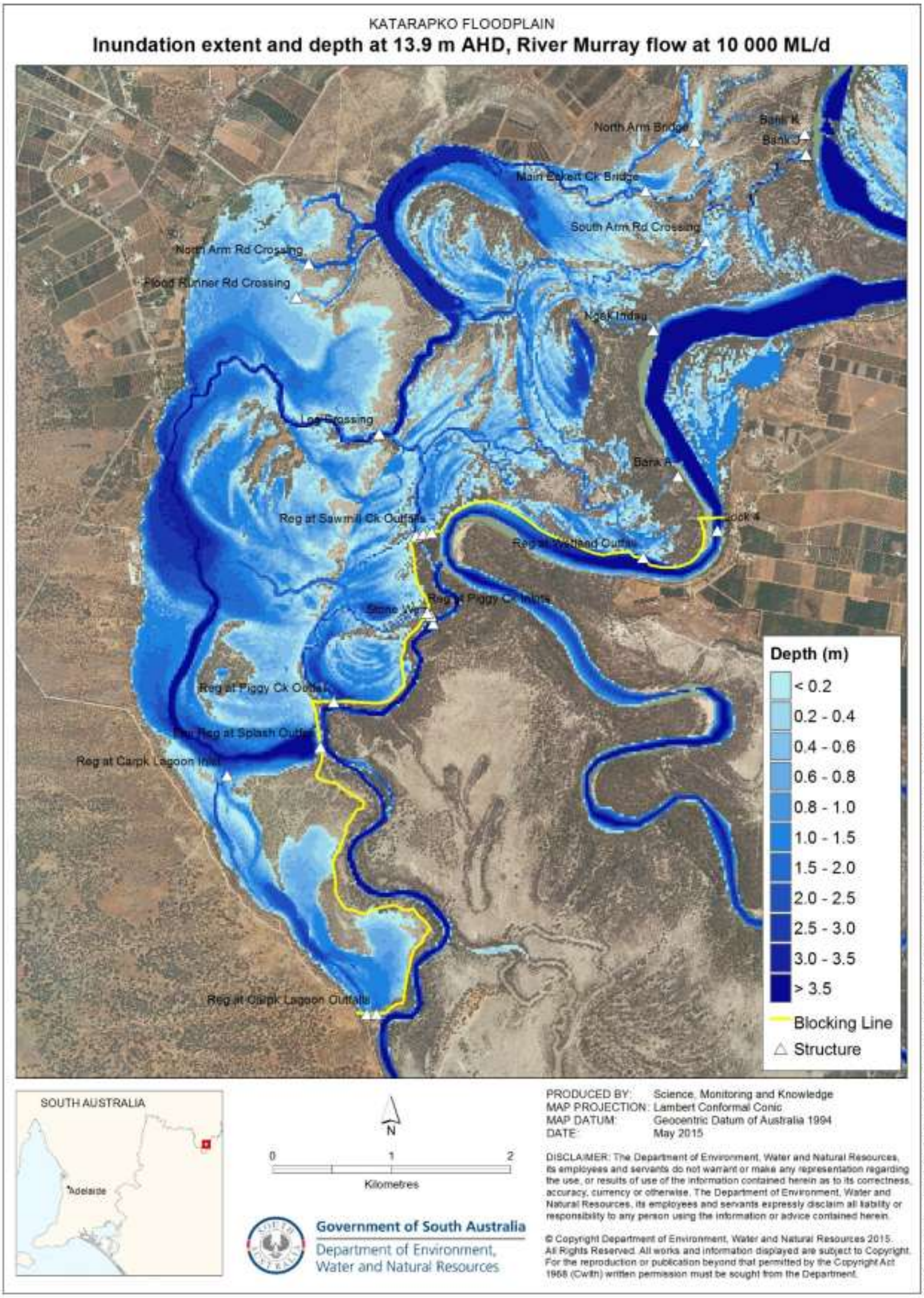

Figure 3.3 Inundation extent and depths at 13.9 m AHD inundation height, 10 000 ML/d river flow

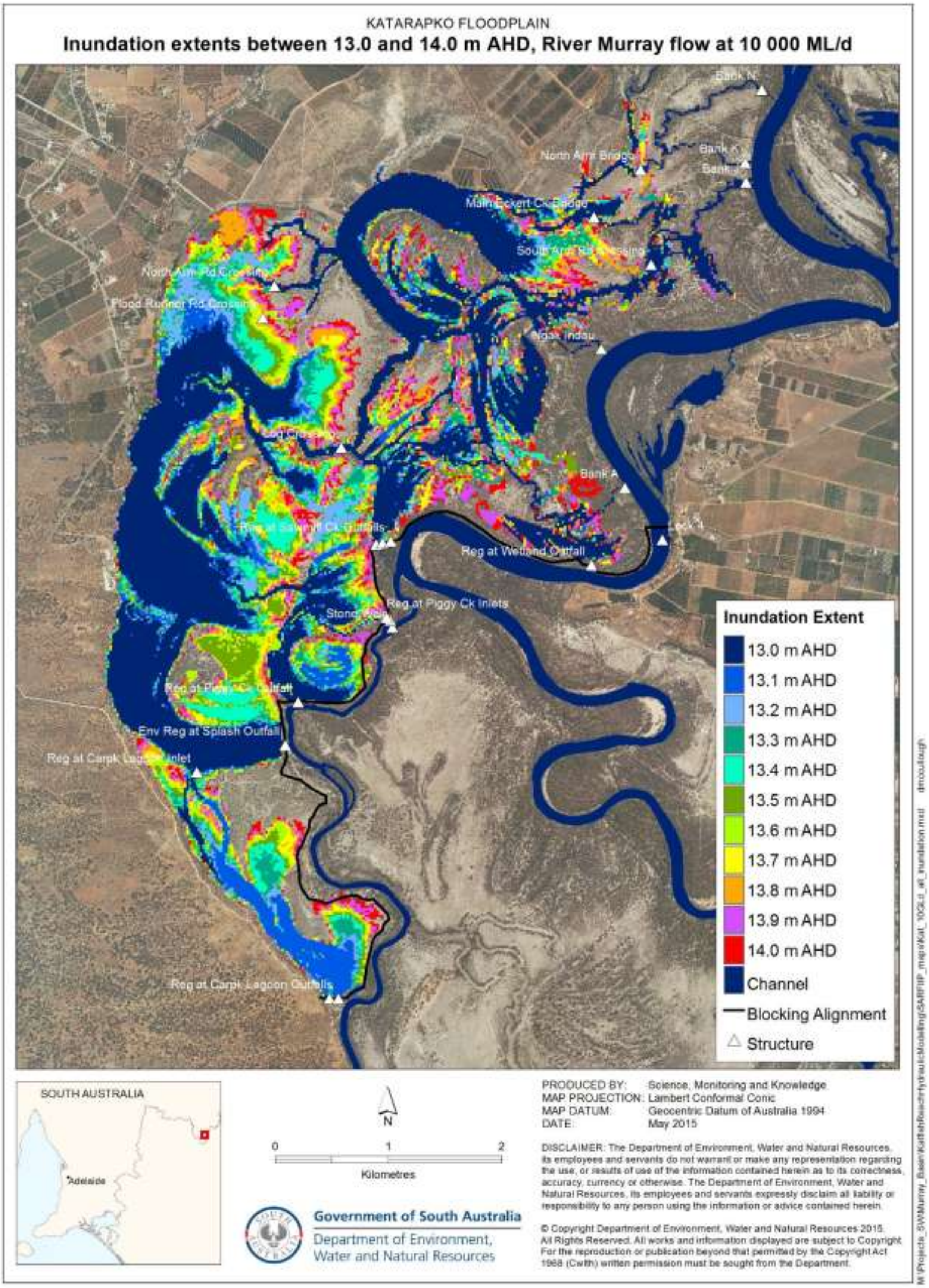

Figure 3.4 Comparison of inundation extents between inundation heights of 13.0 and 14.0 m AHD at 10 000 ML/d river flow

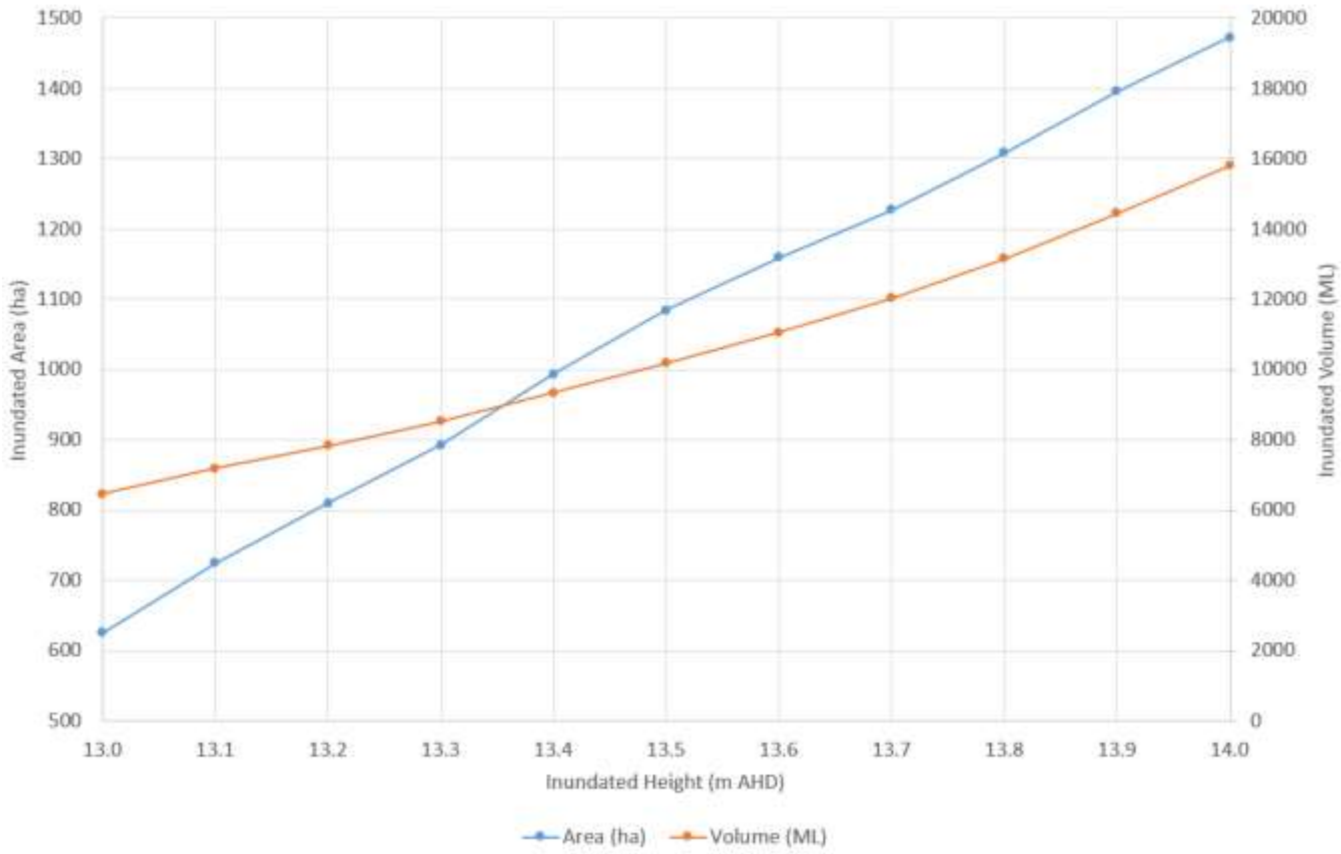

Figure 3.5 Inundated area and volume versus managed inundation height

3.2 Velocity and bed shear stress characteristics

Spatial velocity distribution maps for a River Murray flow of 10 000 ML/d and 0.3 m head difference between Lock 4 and floodplain levels are shown in Figure 3.6 (13.5 m AHD inundation with 13.8 m AHD Lock 4 weir pool level), Figure 3.7 (13.7 m AHD inundation height, 14.0 m AHD Lock 4 pool level) and Figure 3.8 (13.9 m AHD inundation height, 14.2 m AHD Lock 4 pool level). Additionally, Figure 3.9 shows the velocity distribution for the largest head difference between Lock 4 and floodplain, namely 13.5 m AHD inundation with 14.2 m AHD Lock 4 weir pool level (also at 10 000 ML/d river flow). Note that the velocity scales in each map use irregular increments, with finer ranges (0.01 m/s increments) below 0.05 m/s and coarser ranges (up to 0.5 m/s) at higher velocities, to show velocity variations with greater clarity throughout the overall velocity range. Plots of velocity by area in hectares (Figure 3.10) and by percent area (Figure 3.11) are also presented for reference, focusing on the cases of 0.3 m head difference between lock and floodplain levels.

It should be noted that velocity distributions within the floodplain are directly influenced by assumptions and simplifications made on structure configurations in the model, and refining these configurations will vary the distribution of flows, and hence velocities, across the floodplain. For instance, the Bank J inlet regulator is configured as fully open in the model for each managed inundation scenario, however manipulation of this regulator during managed inundation operations may be required in practice. Outflows were also limited to The Splash and Sawmill Creek regulators for the purposes of generating hydraulic data at the floodplain scale, however Car Park and Piggy Creek outfall regulators may also be potentially operated in practice during managed inundation. The model configurations for these scenarios have thus resulted in excessively high velocities downstream of Sawmill Creek regulator, while in practice flows would be controlled at much lower levels to avoid the potential for significant erosion that such velocities would cause. Further modelling is required using more refined structure operating configurations to further investigate velocity distributions through the floodplain.

Tabulated data for in-channel velocity and bed shear stress distributions upstream of the blocking alignment are presented for each of the scenarios conducted from Scenarios 1 to 5 (refer to Table 2.1 for scenario details). Table 3.2 to Table 3.5 present in-channel velocities by reach length and percent of reach length for each scenario, while Table 3.6 to Table 3.9 present bed shear stress data for the same scenarios. For the purposes of comparison, velocity and bed shear stress profiles for "equivalent" natural flows under existing floodplain conditions are presented in each relevant table against each set of scenarios, with equivalency based on approximately similar inundation areas in the impounded area compared to the inundation height i.e. a flow of 60 000 ML/d River Murray flow generates a similar inundated area to a 13.5 m AHD inundation height; 65 000 ML/d generates an equivalent inundated area to a 13.7 m AHD height; and 70 000 ML/d is equivalent to an inundation height of 13.9 m AHD. Velocity and bed shear stress profiles are also shown graphically in Figure 3.12 to Figure 3.21 for reference.

The results indicate that increasing the inundation height results predominantly in an increase in velocities within the no flow to very slow flow velocity category (0–0.05 m/s) when considering the inundated area as a whole, due to increasing inundation height creating an increase in inundation at the fringes (refer to Section 3.1 of this technical note). This velocity behaviour is illustrated in Figure 3.10, which shows a gradual increase in inundated area with inundation height in the very slow flow velocity category, but little difference by area that has velocities exceeding 0.10 m/s. Considering the same distributions in terms of percent of inundation (Figure 3.11), there is little difference apparent between each of the inundation options, suggesting that the increase in inundation height, and hence inundation extent, is balanced by the greater inflows modelled under the higher Lock 4 weir pool levels. Over 90% of the inundation extent at each managed inundation height is modelled to occur in the no to very slow flow velocity category.

In-channel velocities within the impounded area are modelled to be predominantly below 0.20 m/s for all cases simulated, with velocities exceeding 0.20 m/s present mainly in the inlet creeks above Lock 4. Under a head difference of 0.3 m between Lock 4 level and inundated level, approximately 80 to 86% of stream length is present in the 0 to 0.20 m/s range for 13.5 m AHD maximum inundation, 79 to 84% for 13.7 m AHD inundation, and 78 to 82% for 13.9 m AHD. When increasing the head difference greater than 0.3 m, in the case of 13.5 m AHD inundation height and Lock 4 at 14.2 m AHD, approximately 61 to 69% of stream length is below 0.20 m/s, while at 13.7 m AHD inundation and Lock 4 at 14.2 m AHD, approximately 72 to 75% of stream length is below 0.20 m/s. These results indicate that increasing the head difference between Lock 4 and the inundation height causes velocities to tend towards higher velocities through the floodplain, while a relatively smaller impact is modelled when raising inundation height for a given head difference between the river and floodplain.

Considering in-channel bed shear stresses, the majority of shear stresses through the floodplain are present below 2 N/m^2. Under a 0.3 m head difference between Lock 4 and the floodplain level, 97 to 98% of stream length is present below 2 N/m^2 at

13.5 and 13.7 m AHD inundation levels, and 95 to 97% at 13.9 m AHD. When considering greater head differences between Lock 4 and the floodplain, at 13.5 m AHD inundation and 14.2 m AHD Lock 4 level, approximately 86–88% of streams contain shear stresses less than 2 N/m^2, while at 13.7 m AHD inundation and 14.2 m AHD Lock 4 level approximately 91–93% of stream length is present with shear stresses below 2 N/m^2. In all cases with the 0.3 m head difference, overall bed shear stresses are generally present below 5 N/m^2, with only isolated parts of streams present up to 7 N/m^2. The highest shear stresses are modelled in the extreme case of 13.5 m AHD and 14.2 m AHD Lock 4 level, however less than 1% of the streams at each river flow tested are present with bed shear stresses above 6 N/m^2, and only in isolated sections. Gippel et al. (2008) states that for clay banks, 11 N/m^2 represents a critical shear stress value below which erosion risk is considered negligible, with a low erosion risk considered between 11 and 17 N/m^2, suggesting that risk of erosion in all managed inundation scenarios tested (particularly with optimised hydraulic control methodologies) may low to negligible, assuming clay channels throughout the floodplain. Local investigation of soil types is necessary to improve the assumption of thresholds to avoid erosion risks.

Comparing each inundation height to the equivalent natural flows under existing floodplain conditions (i.e. 60 000, 65 000 and 70 000 ML/d for inundation heights of 13.5, 13.7 and 13.9 m AHD, respectively), velocities and shear stresses by length of creek tend to be skewed towards higher categories above 0.15 m/s under the existing floodplain case when compared to scenarios with a 0.3 m head difference between Lock 4 and the floodplain, while also possessing greater lengths of creek in the very slow velocity category. Comparing the scenario with 13.5 m AHD inundation height and 14.2 m AHD Lock 4 level to the equivalent 60 000 ML/d natural flooding scenario, velocities by stream length are present in similar distributions above 0.15 m/s, while a greater stream length is present in the very slow category for the case of natural flooding. In terms of bed shear stress for this managed inundation scenario however, greater lengths of stream are present in shear stress categories upwards of 2 N/m^2. Comparing the scenario of 13.7 m AHD inundation and 14.2 m AHD Lock 4 height to a natural equivalent flood of 65 000 ML/d, velocity distributions are similar above 0.15 m/s and tend towards the very low velocity category below 0.15 m/s, while shear stress distributions are similar throughout the range. While the comparison results should be treated with caution given the difference in flooding mechanism in each case, the results indicate that erosion processes in the floodplain may be lessened or may not be considerably different for managed inundation when compared to an equivalent natural flood (by inundated area), depending on operations of the floodplain.

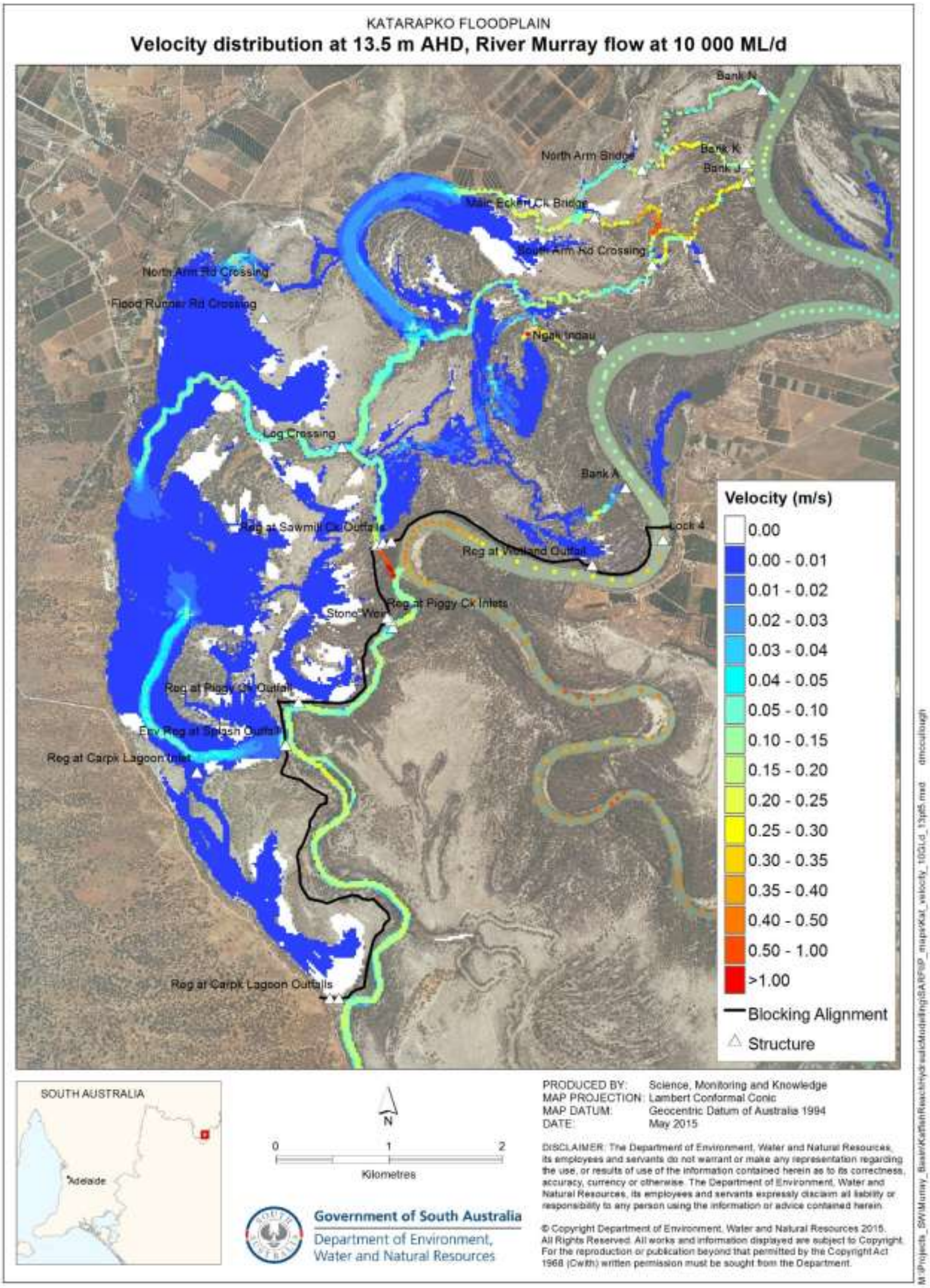

Figure 3.6 Velocities in the floodplain at an inundation height of 13.5 m AHD (Lock 4 weir pool 13.8 m AHD), river flow 10 000 ML/d

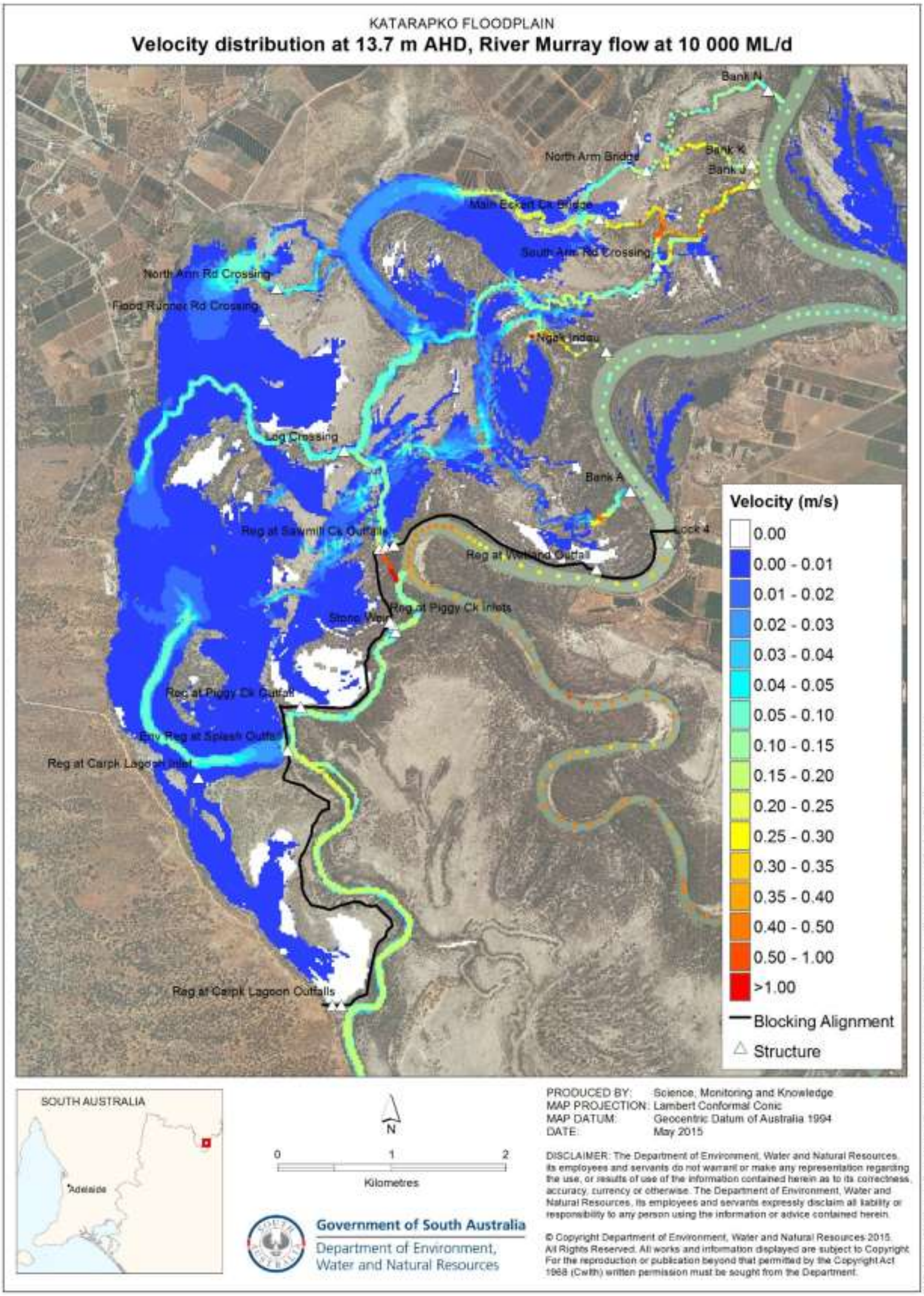

Figure 3.7 Velocities in the floodplain at an inundation height of 13.7 m AHD (Lock 4 weir pool 14.0 m AHD), river flow 10 000 ML/d

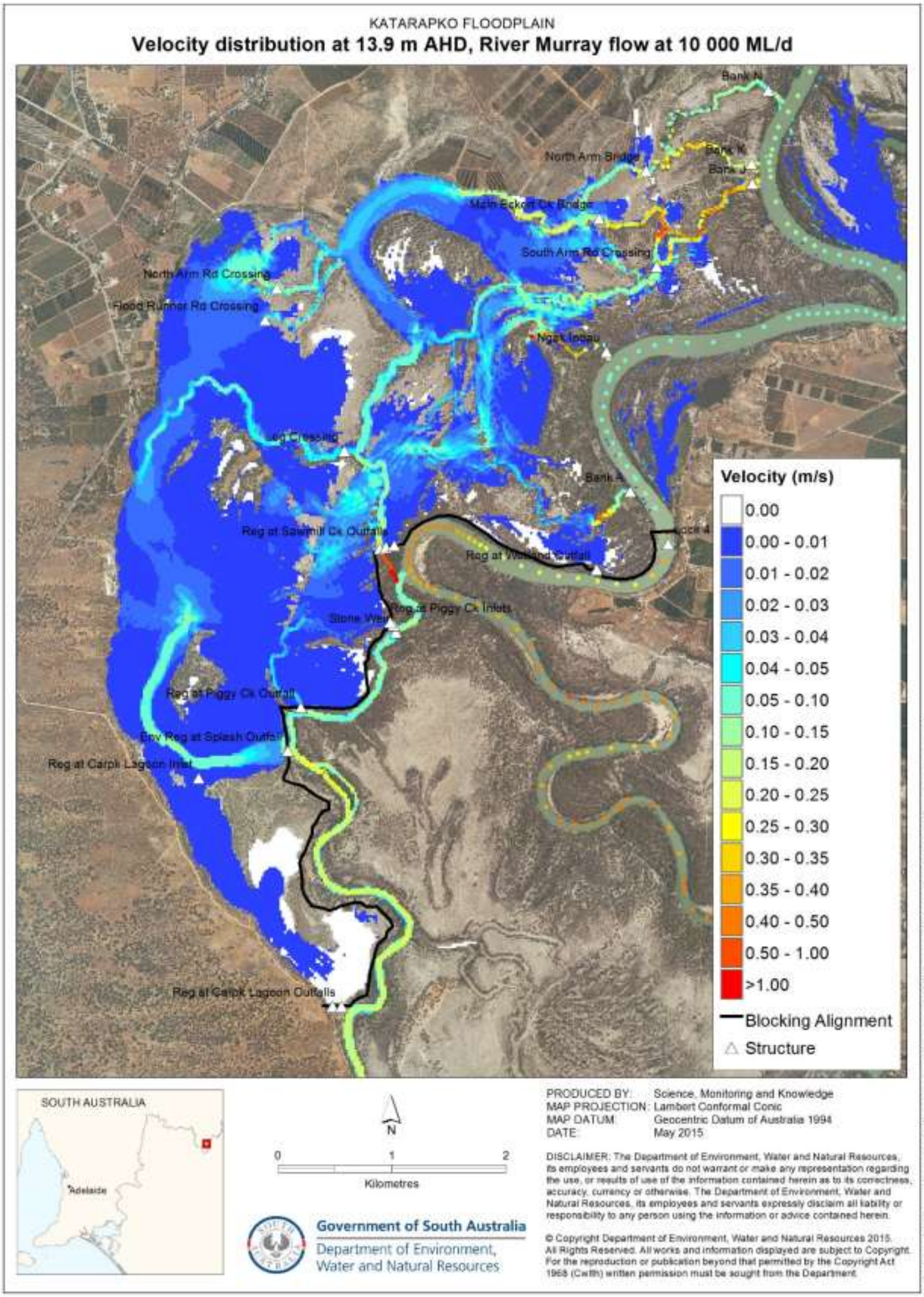

Figure 3.8 Velocities in the floodplain at an inundation height of 13.9 m AHD (Lock 4 weir pool 14.2 m AHD), river flow 10 000 ML/d

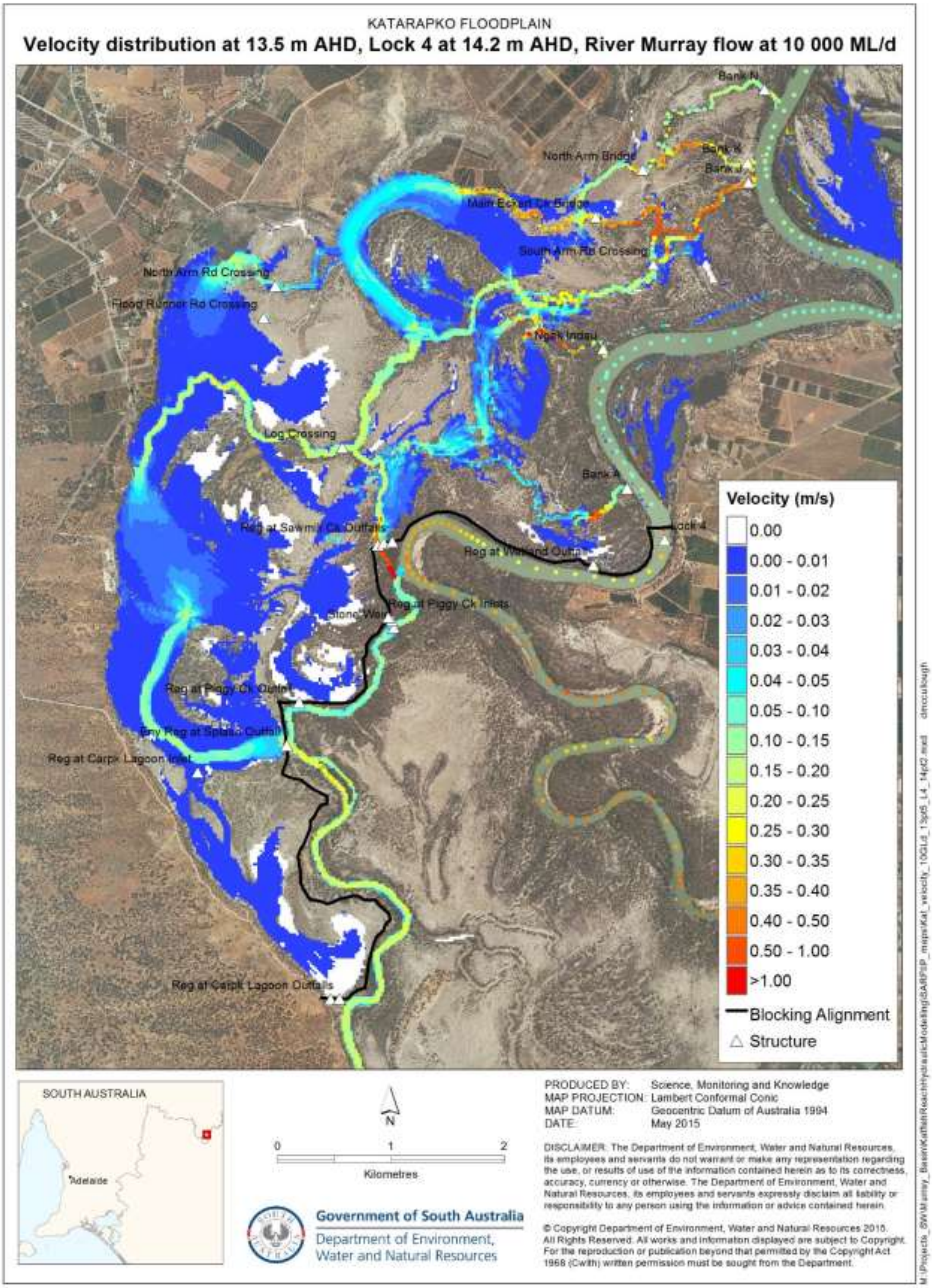

Figure 3.9 Velocities in the floodplain at an inundation height of 13.5 m AHD (Lock 4 weir pool at 14.2 m AHD), river flow 10 000 ML/d

Table 3.2 Length of reach under specified velocity ranges for 13.5 m AHD (1a–d), 13.7 m AHD (2a–d) and 13.9 m AHD (3a–d) inundation scenarios, including equivalent natural flows based on inundated area

Velocity range (m/s)	Length of reach														
	Sc1a (m)	Sc1b (m)	Sc1c (m)	Sc1d (m)	60 GL/d (m)	Sc2a (m)	Sc2b (m)	Sc2c (m)	Sc2d (m)	65 GL/d (m)	Sc3a (m)	Sc3b (m)	Sc3c (m)	Sc3d (m)	70 GL/d (m)
0.00–0.05	7367	7227	6603	6120	11414	6319	6171	6033	5839	10454	7865	7613	6541	5916	12062
0.05–0.10	11250	10649	10193	8897	1810	12702	12654	12042	10057	2906	10494	10460	6308	6487	1623
0.10–0.15	5640	5953	6429	7297	2656	4563	4558	4944	6211	3726	4870	4761	9378	9178	4589
0.15–0.20	2848	2984	2860	2892	5183	2625	2413	2220	2797	4839	2418	2433	2615	2790	3785
0.20–0.25	1648	1685	1990	2308	4162	2049	2148	2408	1897	3079	1927	2090	2152	2088	3478
0.25-0.30	1086	1241	1492	1432	1020	1163	1211	1276	1694	1567	1009	1061	1163	1471	1394
0.30-0.35	747	656	546	952	1409	719	870	930	1032	1075	1124	1211	1071	937	836
0.35-0.40	363	406	569	598	1454	680	811	629	713	1225	713	640	887	988	1069
0.40-0.45	71	229	321	443	1027	175	161	468	654	951	358	489	510	463	998
0.45-0.50	76	43	26	62	651	122	47	60	107	814	254	288	241	495	776
0.50-0.55	145	166	192	63	151	103	192	142	63	232	108	108	262	217	348
0.55-0.60	0	7	17	173	85	11	0	84	163	240	14	4	33	111	178
0.60-0.65	0	0	7	0	170	3	3	3	10	79	0	10	0	18	71
0.65-0.70	21	21	0	0	27	7	0	0	3	49	11	0	10	10	5
0.70-0.75	38	14	34	7	0	25	7	7	0	22	21	21	21	0	26
0.75-0.80	0	25	0	34	30	14	34	21	7	0	0	0	0	21	67
0.80-0.85	0	0	25	0	0	0	0	14	21	21	0	0	0	0	0
0.85-0.90	0	0	0	0	3	25	0	0	14	0	0	0	0	0	0
0.90-0.95	0	0	0	25	28	0	25	0	0	30	18	14	0	0	3
0.95-1.00	59	59	59	59	0	59	59	84	59	0	59	59	73	59	0
>1.00	12	12	12	12	98	12	12	12	37	67	114	114	114	128	67
Total	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376

Table 3.3 Percent length of reach under specified velocity ranges for 13.5 m AHD (1a–d), 13.7 m AHD (2a–d) and 13.9 m AHD (3a–d) inundation scenarios, including equivalent natural flows based on inundated area

Velocity	Percent length of reach														
range	Sc1a	Sc1b	Sc1c	Sc1d	60 GL/d	Sc2a	Sc2b	Sc2c	Sc2d	65 GL/d	Sc3a	Sc3b	Sc3c	Sc3d	70 GL/d
(m/s)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
0.00–0.05	23	23	21	20	36	20	20	19	19	33	25	24	21	19	38
0.05–0.10	36	34	32	28	6	40	40	38	32	9	33	33	20	21	5
0.10–0.15	18	19	20	23	8	15	15	16	20	12	16	15	30	29	15
0.15–0.20	9	10	9	9	17	8	8	7	9	15	8	8	8	9	12
0.20–0.25	5	5	6	7	13	7	7	8	6	10	6	7	7	7	11
0.25-0.30	3	4	5	5	3	4	4	4	5	5	3	3	4	5	4
0.30-0.35	2	2	2	3	4	2	3	3	3	3	4	4	3	3	3
0.35-0.40	1	1	2	2	5	2	3	2	2	4	2	2	3	3	3
0.40-0.45	0	1	1	1	3	1	1	1	2	3	1	2	2	1	3
0.45-0.50	0	0	0	0	2	0	0	0	0	3	1	1	1	2	2
0.50-0.55	0	1	1	0	0	0	1	0	0	1	0	0	1	1	1
0.55-0.60	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1
0.60-0.65	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0.65-0.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.70-0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.75-0.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.80-0.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.85-0.90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.90-0.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.95-1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 3.4 Length of reach under specified velocity ranges for 13.5 m AHD (4a–d) and 13.7 m AHD (5a–d) inundation scenarios, at Lock 4 weir pool level of 14.2 m AHD, including equivalent natural flows based on inundated area

Velocity range (m/s)	Length of reach Sc4a (m)	Sc4b (m)	Sc4c (m)	Sc4d (m)	60 GL/d (m)	Sc5a (m)	Sc5b (m)	Sc5c (m)	Sc5d (m)	65 GL/d (m)
0.00–0.05	5274	2582	2582	2582	11414	5498	5494	5510	5448	10454
0.05–0.10	1828	4468	4006	3897	1810	3903	3293	2456	1647	2906
0.10–0.15	8584	8167	8122	7339	2656	10855	11219	11606	11227	3726
0.15–0.20	6070	6368	6256	5416	5183	3206	3302	3637	4330	4839
0.20–0.25	2437	2559	3078	4582	4162	1714	1771	1786	2165	3079
0.25-0.30	1582	1525	1364	1366	1020	1979	1870	1634	1302	1567
0.30-0.35	1119	1223	1367	1430	1409	1195	1324	1498	1673	1075
0.35-0.40	1498	1469	1452	1476	1454	908	968	781	900	1225
0.40-0.45	1017	1046	1093	917	1027	855	713	976	955	951
0.45-0.50	708	575	581	712	651	666	754	737	623	814
0.50-0.55	715	864	788	758	151	107	198	285	505	232
0.55-0.60	74	34	192	383	85	100	62	52	136	240
0.60-0.65	83	123	104	116	170	198	241	195	240	79
0.65-0.70	122	122	85	96	27	27	17	74	56	49
0.70-0.75	84	74	113	113	0	0	10	10	17	22
0.75-0.80	37	36	27	17	30	0	0	0	10	0
0.80-0.85	0	0	26	36	0	18	7	7	7	21
0.85-0.90	0	0	0	0	3	0	0	0	0	0
0.90-0.95	0	0	0	0	28	21	21	0	0	30
0.95-1.00	66	66	66	66	0	59	59	80	80	0
>1.00	78	74	74	74	98	69	53	53	53	67
Total	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376

Table 3.5 Percent length of reach under specified velocity ranges for 13.5 m AHD (4a–d) and 13.7 m AHD (5a–d) inundation scenarios, at Lock 4 weir pool level of 14.2 m AHD, including equivalent natural flows based on inundated area

Velocity range (m/s)	Percent length of reach									
	Sc4a (%)	Sc4b (%)	Sc4c (%)	Sc4d (%)	60 GL/d (%)	Sc5a (%)	Sc5b (%)	Sc5c (%)	Sc5d (%)	65 GL/d (%)
0.00–0.05	17	8	8	8	36	18	18	18	17	33
0.05–0.10	6	14	13	12	6	12	10	8	5	9
0.10–0.15	27	26	26	23	8	35	36	37	36	12
0.15–0.20	19	20	20	17	17	10	11	12	14	15
0.20–0.25	8	8	10	15	13	5	6	6	7	10
0.25-0.30	5	5	4	4	3	6	6	5	4	5
0.30-0.35	4	4	4	5	4	4	4	5	5	3
0.35-0.40	5	5	5	5	5	3	3	2	3	4
0.40-0.45	3	3	3	3	3	3	2	3	3	3
0.45-0.50	2	2	2	2	2	2	2	2	2	3
0.50-0.55	2	3	3	2	0	0	1	1	2	1
0.55-0.60	0	0	1	1	0	0	0	0	0	1
0.60-0.65	0	0	0	0	1	1	1	1	1	0
0.65-0.70	0	0	0	0	0	0	0	0	0	0
0.70-0.75	0	0	0	0	0	0	0	0	0	0
0.75-0.80	0	0	0	0	0	0	0	0	0	0
0.80-0.85	0	0	0	0	0	0	0	0	0	0
0.85-0.90	0	0	0	0	0	0	0	0	0	0
0.90-0.95	0	0	0	0	0	0	0	0	0	0
0.95-1.00	0	0	0	0	0	0	0	0	0	0
>1.00	0	0	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100

Table 3.6 Length of reach under specified bed shear stress ranges for 13.5 m AHD (1a–d), 13.7 m AHD (2a–d) and 13.9 m AHD (3a–d) inundation scenarios, including equivalent natural flows based on inundated area

Bed shear stress	Length of reach														
range (N/m^2)	Sc1a (m)	Sc1b (m)	Sc1c (m)	Sc1d (m)	60 GL/d (m)	Sc2a (m)	Sc2b (m)	Sc2c (m)	Sc2d (m)	65 GL/d (m)	Sc3a (m)	Sc3b (m)	Sc3c (m)	Sc3d (m)	70 GL/d (m)
0-1	29398	28855	27910	27519	23349	28426	28013	27584	27392	23709	27915	27862	27022	25950	24348
1-2	1431	2041	2778	3052	5414	2346	2601	3014	3023	5021	2417	2541	3121	3906	4581
2-3	492	442	480	563	1365	460	632	612	598	1207	826	741	824	1110	1415
3-4	39	39	207	242	504	36	92	127	324	744	56	141	318	212	510
4-5	0	0	0	0	444	70	0	0	0	250	36	36	36	157	76
5-6	0	0	0	0	0	0	0	0	0	199	0	0	15	0	199
6-7	0	0	0	0	177	39	39	39	39	0	124	54	39	39	0
7-8	0	0	0	0	19	0	0	0	0	207	0	0	0	0	246
8-9	0	0	0	0	65	0	0	0	0	0	0	0	0	0	0
9-10	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0
>10	0	0	0	0	0	0	0	0	0	39	1	1	1	1	0
Total	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376

Table 3.7 Percent length of reach under specified bed shear stress ranges for 13.5 m AHD (1a–d), 13.7 m AHD (2a–d) and 13.9 m AHD (3a–d) inundation scenarios, including equivalent natural flows based on inundated area

Bed shear stress range (N/m^2)	Percent length of reach														
	Sc1a (%)	Sc1b (%)	Sc1c (%)	Sc1d (%)	60 GL/d (%)	Sc2a (%)	Sc2b (%)	Sc2c (%)	Sc2d (%)	65 GL/d (%)	Sc3a (%)	Sc3b (%)	Sc3c (%)	Sc3d (%)	70 GL/d (%)
0-1	94	92	89	88	74	91	89	88	87	76	89	89	86	83	78
1-2	5	7	9	10	17	7	8	10	10	16	8	8	10	12	15
2-3	2	1	2	2	4	1	2	2	2	4	3	2	3	4	5
3-4	0	0	1	1	2	0	0	0	1	2	0	0	1	1	2
4-5	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0
5-6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
6-7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7-8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
8-9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 3.8 Length of reach under specified bed shear stress ranges for 13.5 m AHD (4a–d) and 13.7 m AHD (5a–d) inundation scenarios, at Lock 4 weir pool level of 14.2 m AHD, including equivalent natural flows based on inundated area

Bed shear stress	Length of reach									
range (N/m²)	Sc4a (m)	Sc4b (m)	Sc4c (m)	Sc4d (m)	60 GL/d (m)	Sc5a (m)	Sc5b (m)	Sc5c (m)	Sc5d (m)	65 GL/d (m)
0-1	22551	22621	22563	22175	23349	25052	24825	24602	24391	23709
1-2	5113	4919	4872	4949	5414	4247	4360	4497	4023	5021
2-3	2166	2212	2051	2132	1365	1168	1351	1418	1765	1207
3-4	675	823	947	1177	504	428	295	173	510	744
4-5	511	399	504	342	444	329	462	604	447	250
5-6	208	320	291	453	0	35	35	35	192	199
6-7	0	0	65	65	177	9	9	9	9	0
7-8	35	35	35	35	19	0	0	0	0	207
8-9	70	0	0	0	65	70	0	0	0	0
9-10	47	47	9	9	39	39	39	39	39	0
>10	0	0	39	39	0	0	0	0	0	39
Total	31376	31376	31376	31376	31376	31376	31376	31376	31376	31376

Table 3.9 Percent length of reach under specified bed shear stress ranges for 13.5 m AHD (4a–d) and 13.7 m AHD (5a–d) inundation scenarios, at Lock 4 weir pool level of 14.2 m AHD, including equivalent natural flows based on inundated area

Bed shear stress range (N/m^2)	Percent length of reach									
	Sc4a (%)	Sc4b (%)	Sc4c (%)	Sc4d (%)	60 GL/d (%)	Sc5a (%)	Sc5b (%)	Sc5c (%)	Sc5d (%)	65 GL/d (%)
0-1	72	72	72	71	74	80	79	78	78	76
1-2	16	16	16	16	17	14	14	14	13	16
2-3	7	7	7	7	4	4	4	5	6	4
3-4	2	3	3	4	2	1	1	1	2	2
4-5	2	1	2	1	1	1	1	2	1	1
5-6	1	1	1	1	0	0	0	0	1	1
6-7	0	0	0	0	1	0	0	0	0	0
7-8	0	0	0	0	0	0	0	0	0	1
8-9	0	0	0	0	0	0	0	0	0	0
9-10	0	0	0	0	0	0	0	0	0	0
>10	0	0	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100

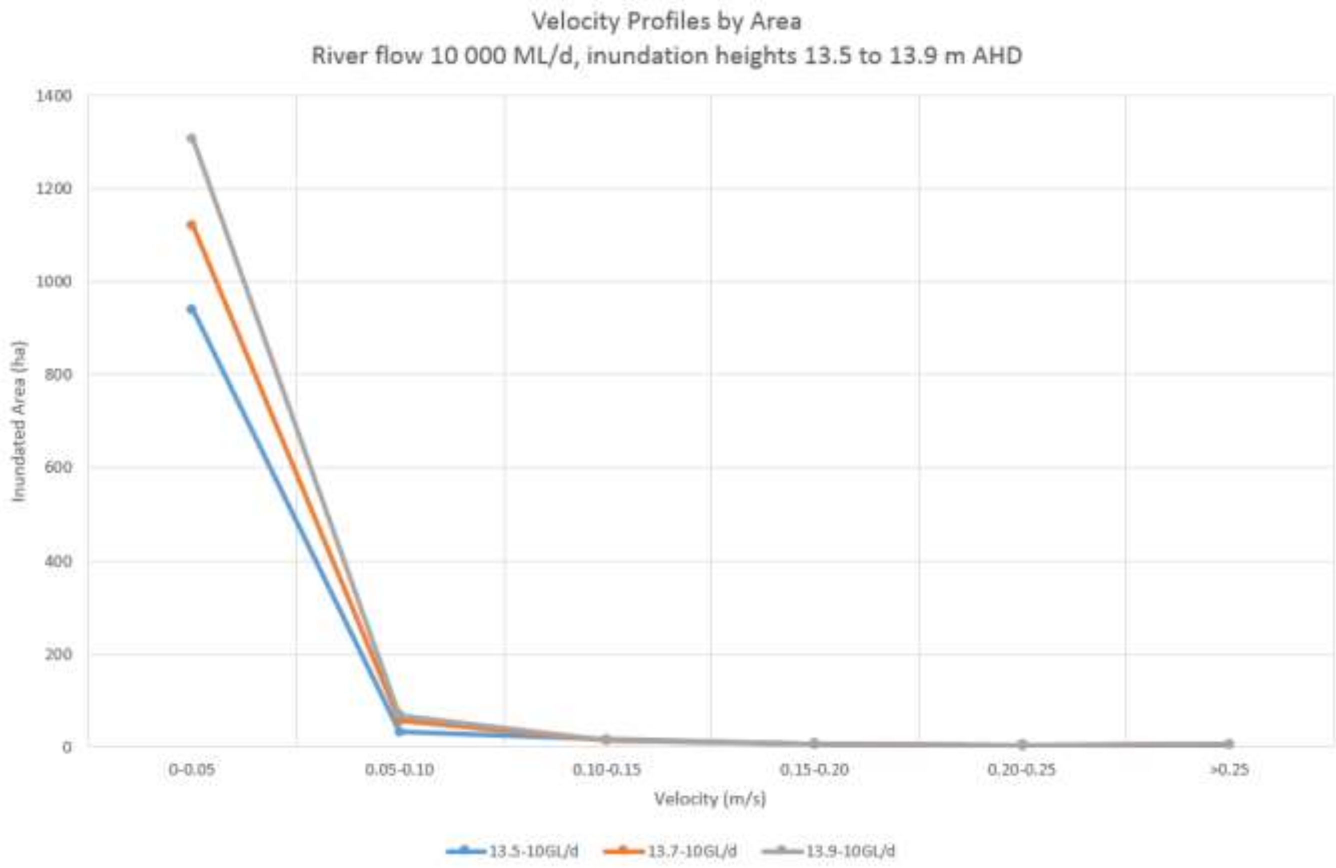

Figure 3.10 Velocity profiles by area of inundation for 13.5 to 13.9 m AHD, river flow at 10 000 ML/d

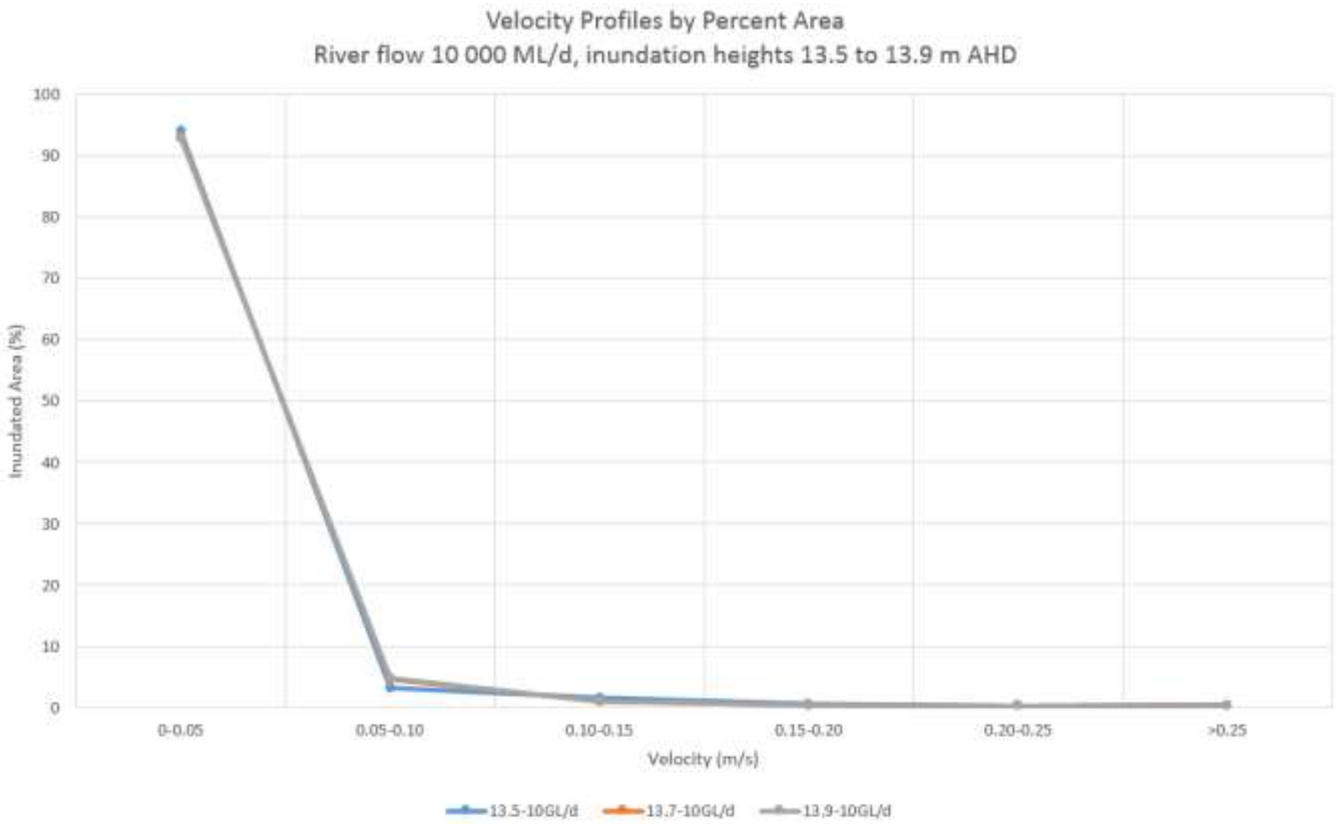

Figure 3.11 Velocity profiles by percent area of inundation for 13.5 to 13.9 m AHD, river flow at 10 000 ML/d

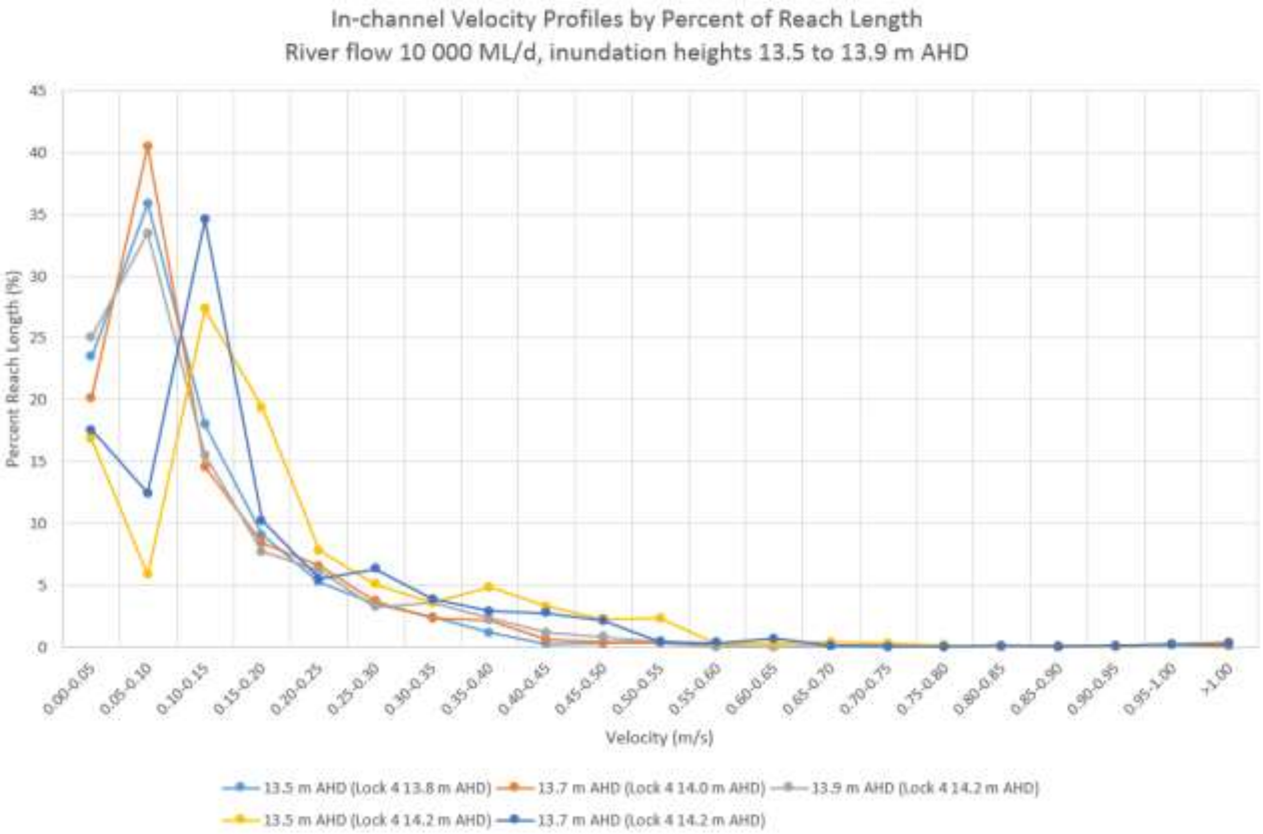

Figure 3.12 Velocity profiles of channels by percent reach length for inundation for 13.5 to 13.9 m AHD, river flow at 10 000 ML/d, various Lock 4 elevations

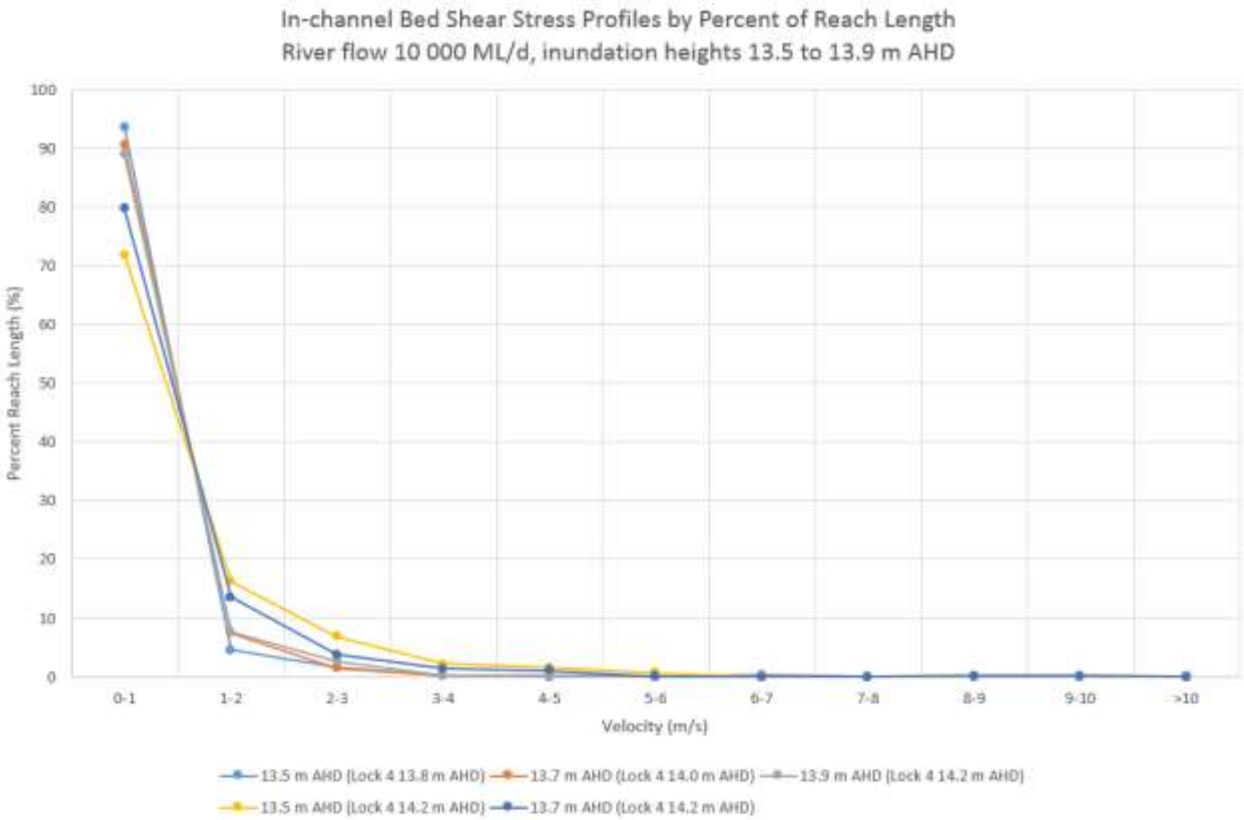

Figure 3.13 Bed shear stress profiles of channels by percent reach length for inundation for 13.5 to 13.9 m AHD, river flow at 10 000 ML/d, various Lock 4 elevations

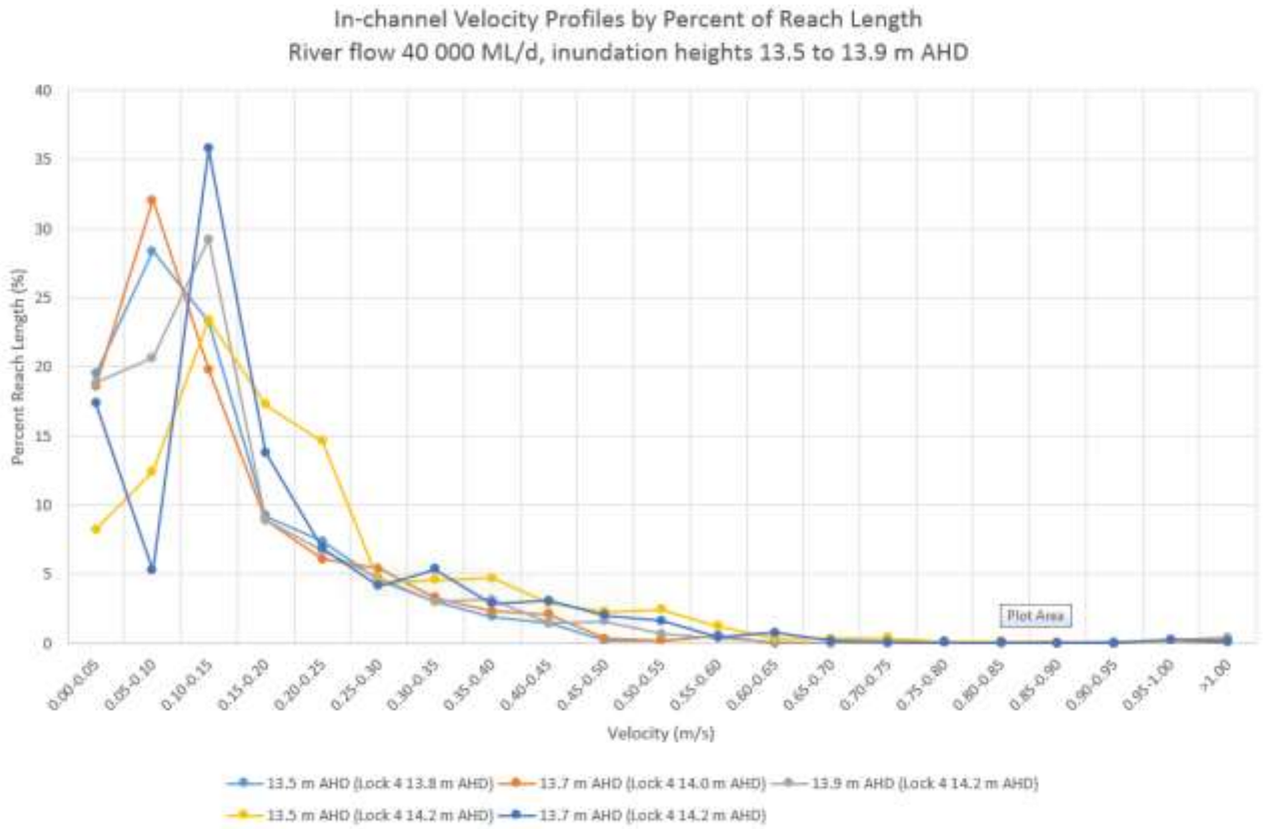

Figure 3.14 Velocity profiles of channels by percent reach length for inundation for 13.5 to 13.9 m AHD, river flow at 40 000 ML/d, various Lock 4 elevations

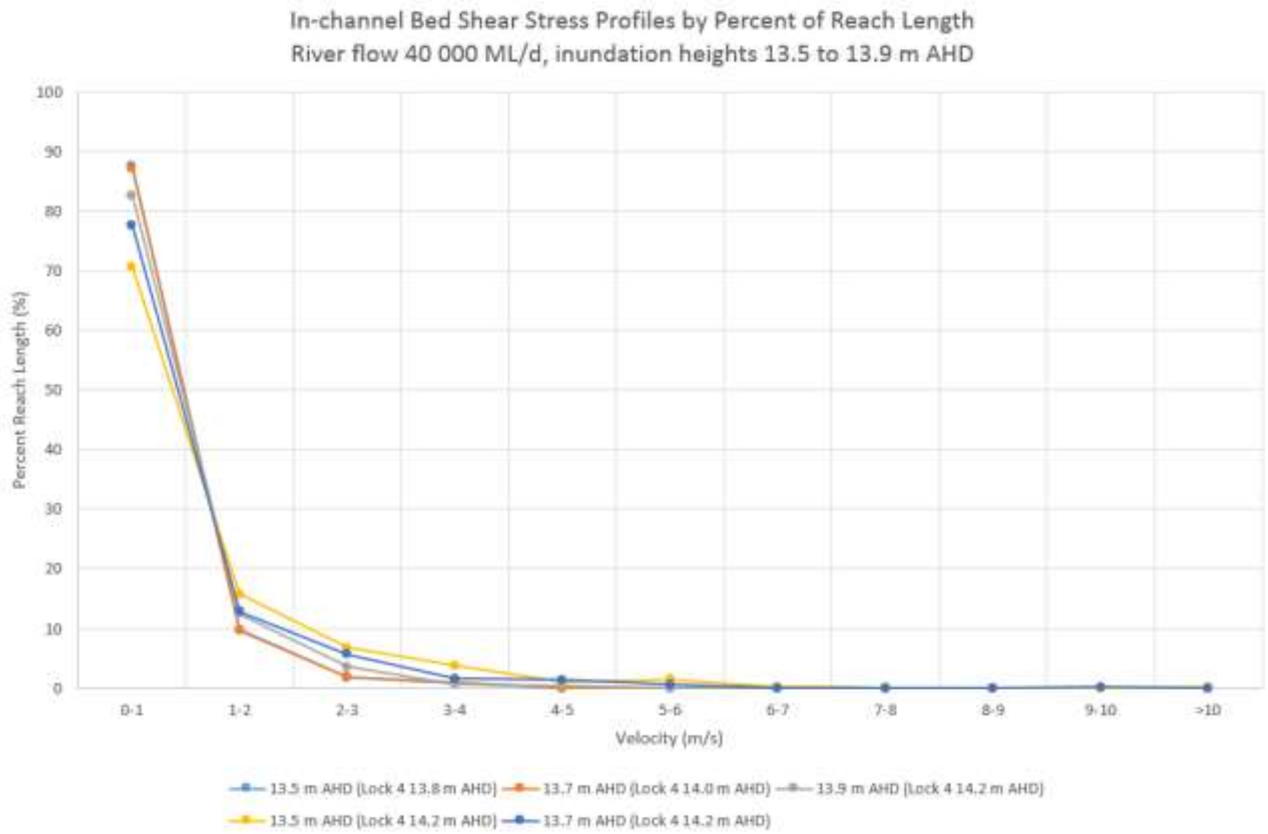

Figure 3.15 Bed shear stress profiles of channels by percent reach length for inundation for 13.5 to 13.9 m AHD, river flow at 40 000 ML/d, various Lock 4 elevations

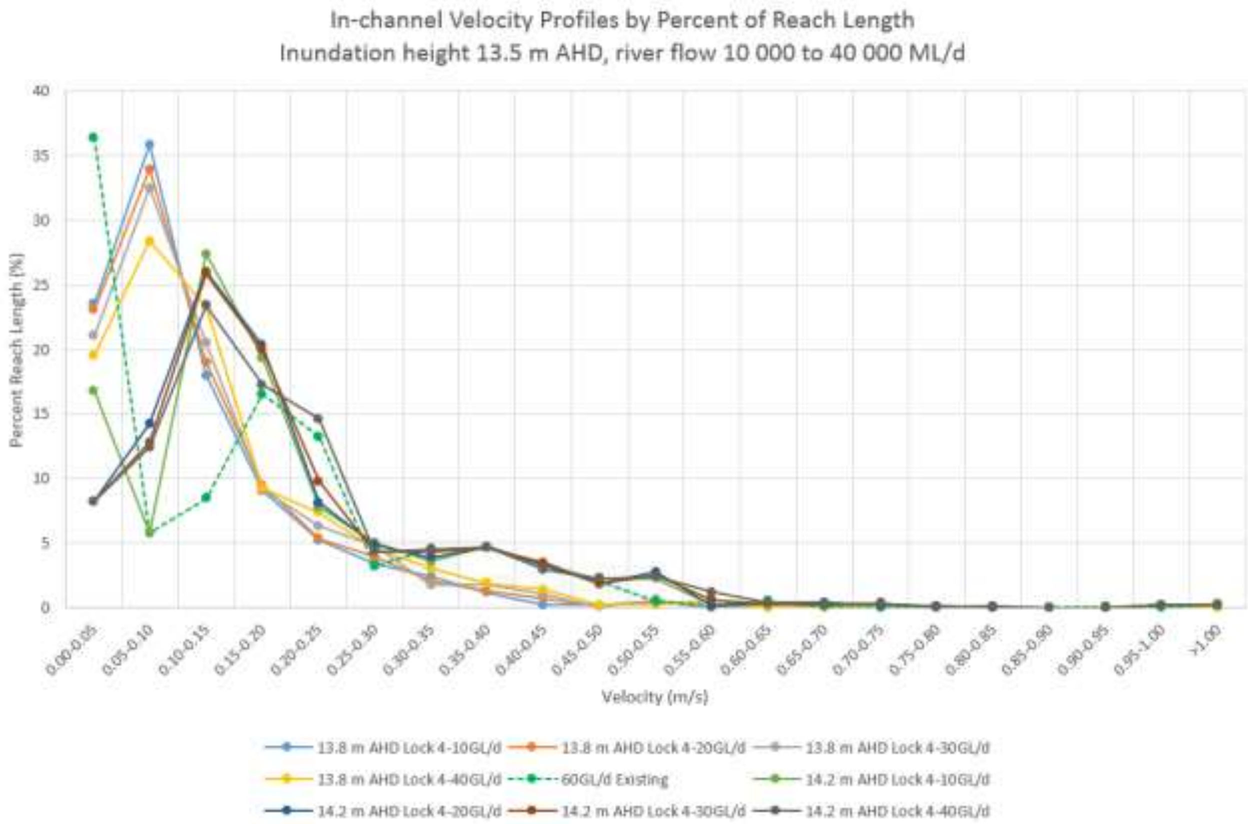

Figure 3.16 Velocity profiles of channels by percent reach length for inundation at 13.5 m AHD, river flow from 10 000 to 40 000 ML/d, Lock 4 levels of 13.8 and 14.2 m AHD (comparison to 60 GL/d natural flow)

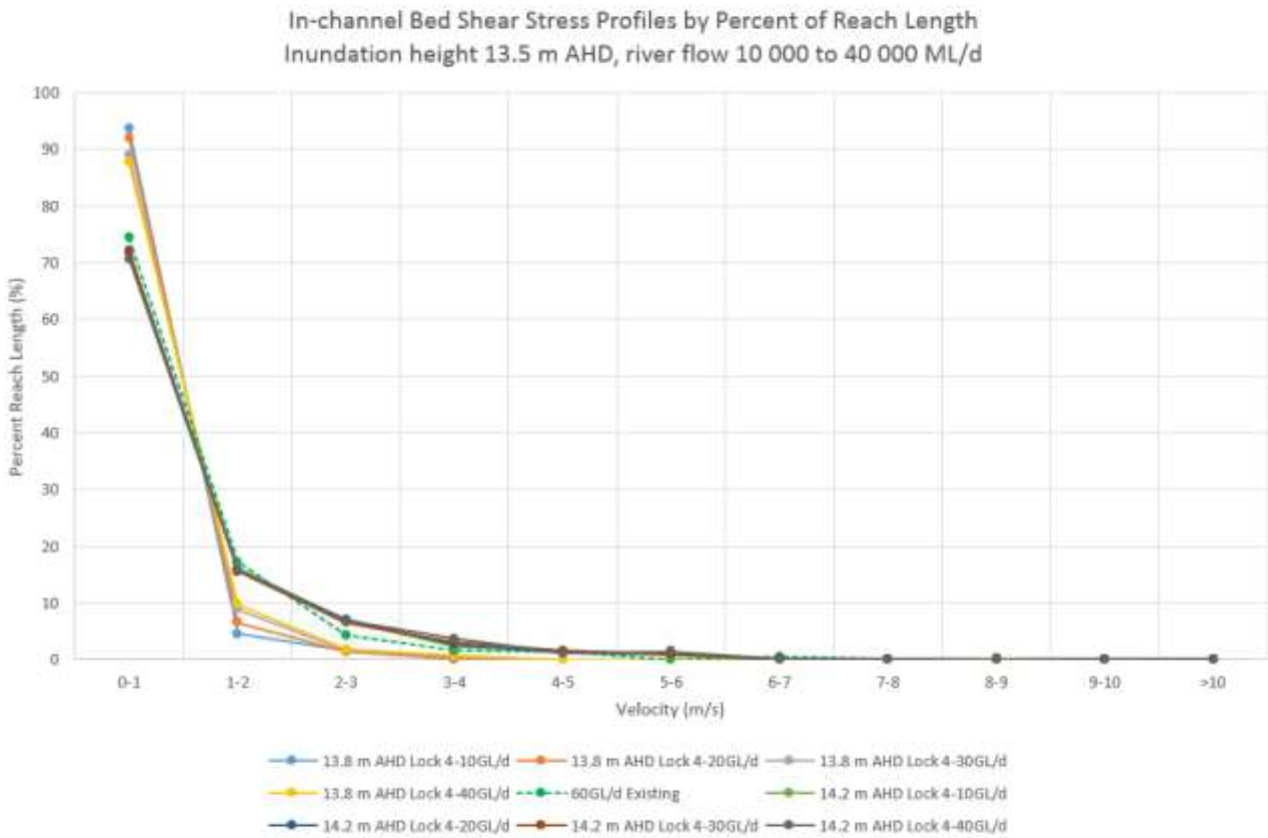

Figure 3.17 Bed shear stress channel profiles by percent reach length for inundation at 13.5 m AHD, river flow from 10 000 to 40 000 ML/d, Lock 4 levels of 13.8 and 14.2 m AHD (60 GL/d natural flow comparison)

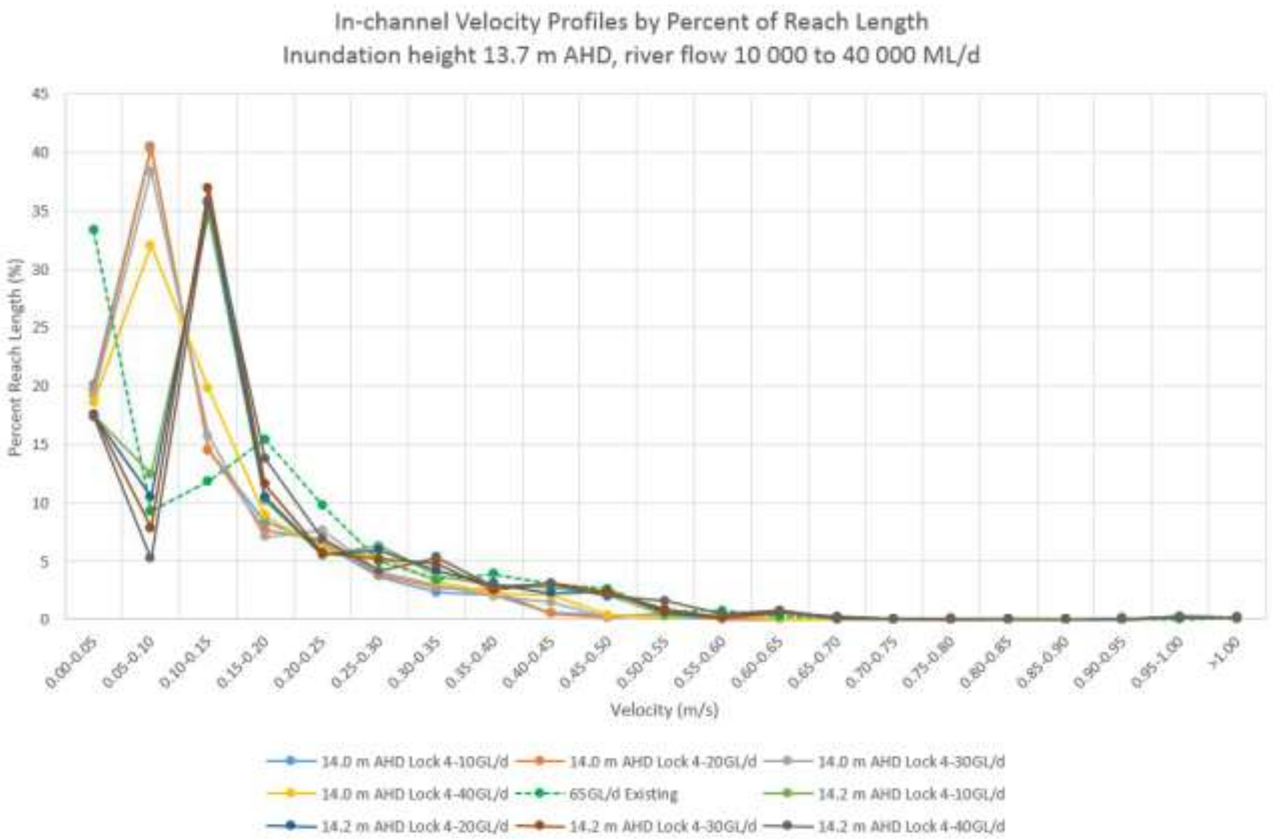

Figure 3.18 Velocity profiles of channels by percent reach length for inundation at 13.7 m AHD, river flow from 10 000 to 40 000 ML/d, Lock 4 levels of 14.0 and 14.2 m AHD (comparison to 65 GL/d natural flow)

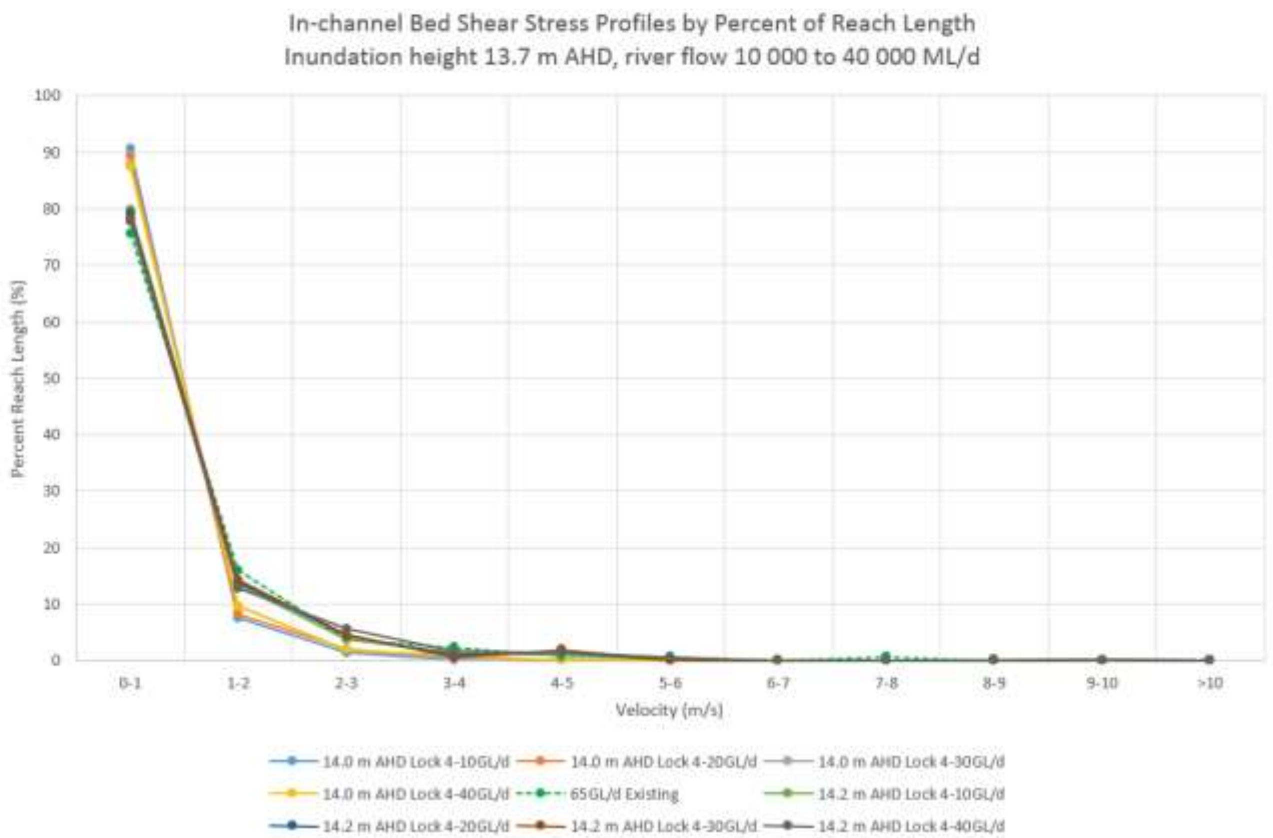

Figure 3.19 Bed shear stress channel profiles by percent reach length for inundation at 13.7 m AHD, river flow from 10 000 to 40 000 ML/d, Lock 4 levels of 14.0 and 14.2 m AHD (65 GL/d natural flow comparison)

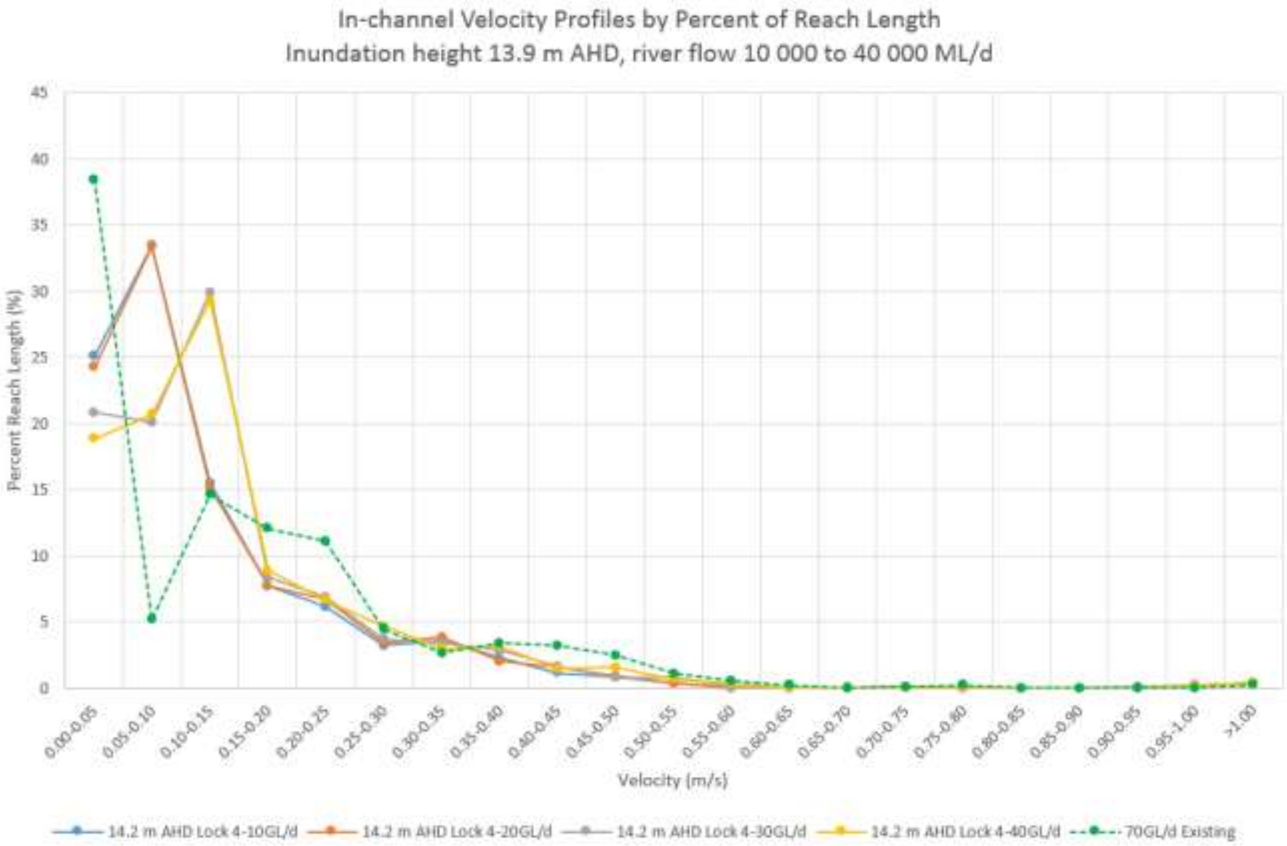

Figure 3.20 Velocity profiles of channels by percent reach length for inundation at 13.9 m AHD, river flow from 10 000 to 40 000 ML/d, Lock 4 level of 14.2 m AHD (comparison to 70 GL/d natural flow)

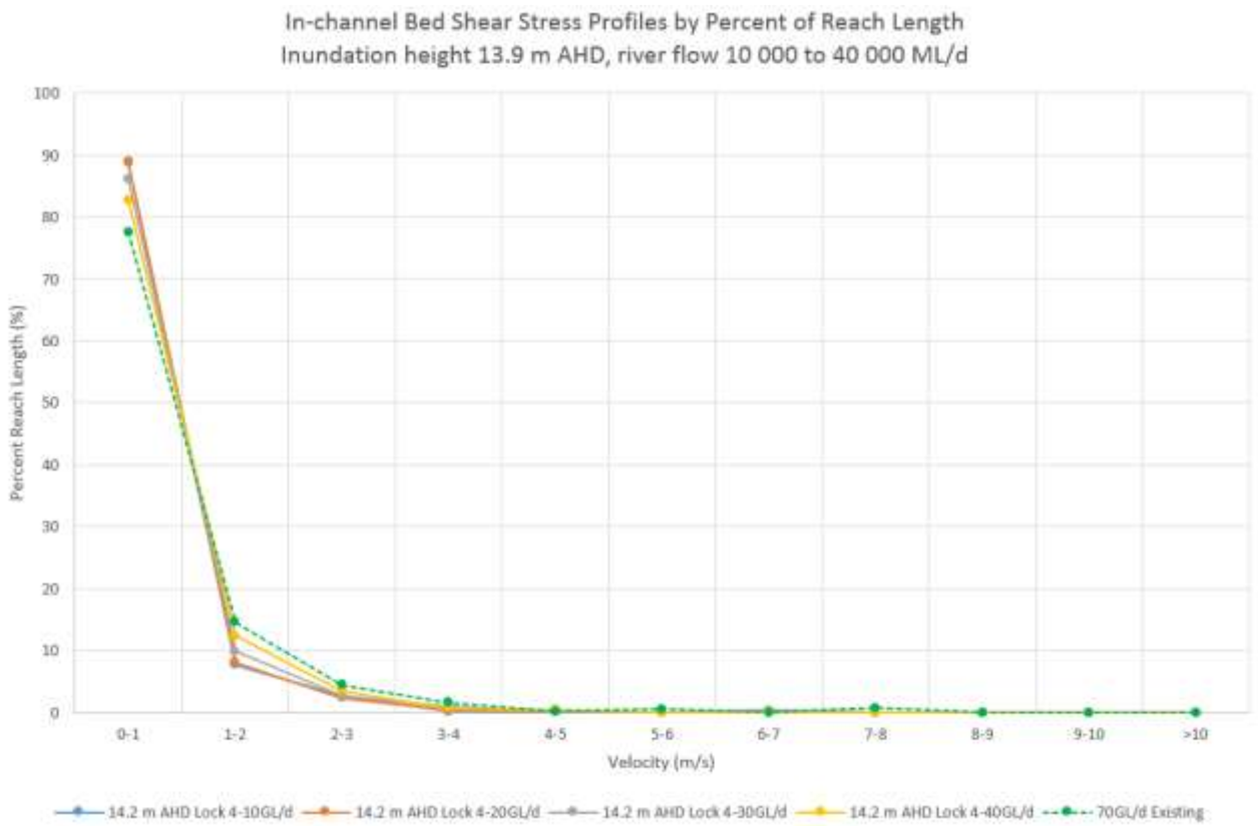

Figure 3.21 Bed shear stress channel profiles by percent reach length for inundation at 13.9 m AHD, river flow from 10 000 to 40 000 ML/d, Lock 4 level of 14.2 m AHD (70 GL/d natural flow comparison)

3.3 Blocking bank interaction with natural flows

Water levels in the River Murray and Katarapko Creek under various flow and weir pool conditions are presented to provide an indication of the impacts of implementing managed inundation schemes to the river system outside of the impounded area, noting the limitations with the data discussed in Section 0 of this technical note.

Figure 3.22 shows water levels at relevant flows in the section of River Murray between Lock 4 and the Katarapko Creek inlet, and Figure 3.23 shows the water levels in the section of Katarapko Creek between the inlet and Car Park Lagoon outlet. These sections of streams are adjacent to the blocking alignment and as such are the most relevant to determining the flows up to which the blocking banks may prevent passage of natural high flows. River levels upstream of Lock 4 have not been considered in this analysis given the blocking alignment terminates at Lock 4.

Assuming that the height of the blocking bank includes 0.2 m of freeboard above the design inundation height, it is apparent that for an inundation height of 13.5 m AHD (blocking bank height assumed at 13.7 m AHD), the blocking banks may prevent flow exchange between the river and floodplain within a flow range of approximately 55 000 to 60 000 ML/d, and between approximately 60 000 to 65 000 ML/d between Katarapko Creek and the adjacent floodplain in the absence of auxiliary structures within the blocking bank. For a 13.7 m AHD managed inundation (13.9 m AHD blocking bank height), exchange may be impacted between 60 000 to 65 000 ML/d between the river and floodplain, and 65 000 to 70 000 ML/d between Katarapko Creek and the floodplain. When considering an inundation height of 13.9 m AHD (blocking bank height at 14.1 m AHD), this flow threshold for exchange increases to between approximately 65 000 to 70 000 ML/d from the River Murray to the floodplain, and between approximately 70 000 to 75 000 ML/d from Katarapko Creek. Note however that these results do not distinguish between artificial banks and natural elevations above the blocking alignment height, and as such only provide an indication of interaction of the blocking banks with natural flows.

Further modelling was conducted to provide a comparison of spatial velocity distributions between existing floodplain conditions (i.e. prior to infrastructure upgrades or blocking bank construction) and upgraded floodplain conditions under high River Murray flows. In these scenarios, the only flow paths through each blocking bank option are at the regulating structures, and no provision of measures such as minor ancillary structures or spillways within the blocking banks are considered that may act to reduce resistance to flow from that modelled.

Considering the spatial velocity distributions for existing floodplain conditions, the results indicate that flows tend to exit the floodplain to Katarapko Creek through The Splash at low to medium flows, but shift towards Car Park lagoon at high flows. At a River Murray flow of 25 000 ML/d (refer to Figure 3.24), flows remain in channel, with The Splash acting as the main outlet point. Note that higher velocities are observed in Sawmill Creek compared to The Splash in this case, with Sawmill acting as an inlet to the floodplain under existing floodplain conditions. At a flow of 50 000 ML/d under existing floodplain conditions (Figure 3.26), Car Park is acting as an outlet in addition to The Splash, with Sawmill Creek continuing to act as an inlet. Velocities are similar between The Splash and Car Park outlets, up to approximately 0.05 m/s. At River Murray flows of 65 000 ML/d (Figure 3.28) and 70 000 ML/d (Figure 3.31), velocities in the outlets are highest through Car Park lagoon, up to approximately 0.25 m/s, compared to velocities in The Splash existing below 0.01 m/s, suggesting that the natural flow path passes through Car Park to Katarapko Creek at these high flows (note that Sawmill Creek continues to act as an inlet at this river flow).

A comparison of the velocity distributions between existing floodplain conditions and the fully upgraded floodplain (including all inlet and outlet structures fully open) indicates that the presence of the blocking bank acts to redirect flow paths away from Car Park towards The Splash as flows increase, up to the height of the blocking bank crest. Under the upgraded floodplain condition at flows of 25 000 ML/d (Figure 3.25) and 50 000 ML/d (Figure 3.27), spatial velocity distributions are the same for all managed inundation options given that the floodplain inundation level remains below the top of blocking banks in all cases, and therefore only the 13.5 m AHD option results are presented to avoid duplication. Note that the characteristics of structures are all modelled to be identical, with the exception of the maximum elevation changing to match the blocking bank height between options. The greater inflows possible under upgraded compared to existing floodplain conditions at all river flows results in higher velocities through the inlet creeks, while also creates a higher water level in the floodplain such that Sawmill acts as a floodplain outlet at 25 000 ML/d due to head difference between the floodplain and river, differing from the existing conditions case (note that for River Murray flows above 30 000 ML/d in the upgraded cases, the river level increases sufficiently to reverse the flow direction in Sawmill Creek, thereby causing the creek to act as a floodplain inlet, as encountered under existing conditions). At approximately 65 000 ML/d, the blocking banks for the 13.5 m AHD option overtop along Katarapko

Creek (Figure 3.29), and velocities through Car Park correspondingly increase. At this flow, inundation height remains below the blocking bank height for 13.7 and 13.9 m AHD options, and hence possess reduced velocities through Car Park and higher velocities exiting The Splash compared to the 13.5 m AHD option (refer to Figure 3.30 for velocity distribution of the 13.7 m AHD option; the 13.9 m AHD option contains an identical velocity distribution at this flow, and hence is not shown to avoid duplication). At 70 000 ML/d river flow, the greatest difference in velocity distributions are observed between the three options; at the 13.5 m AHD option blocking bank is overtopped, and velocities through Car Park approach that of the existing floodplain condition case for the same flow; at 13.7 m AHD, the banks in Car Park are also overtopping, but not to the same extent of the 13.5 m AHD inundation option, and hence has reduced velocities through Car Park compared to that option; and for the 13.9 m AHD inundation option, the bank in Car Park has not yet overtopped, and hence possesses lower velocities in this area compared to the other options, with more of the flow, and increased hence velocities, directed toward the Splash. As flows reach 75 000 ML/d, all bank options are overtopped, and hence velocities approach those of the existing floodplain conditions.

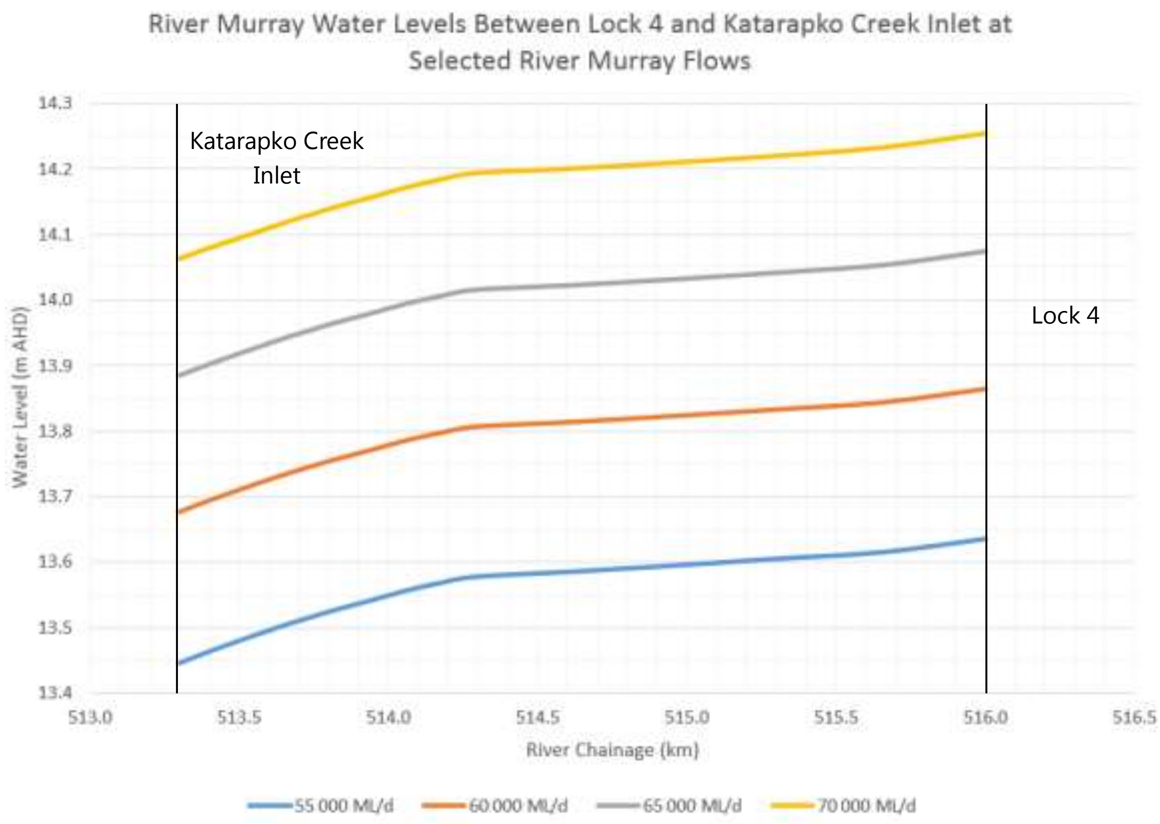

Figure 3.22 River Murray water levels between Lock 4 and Katarapko Creek inlet at River Murray flows of 55 000 to 70 000 ML/d under upgraded floodplain conditions

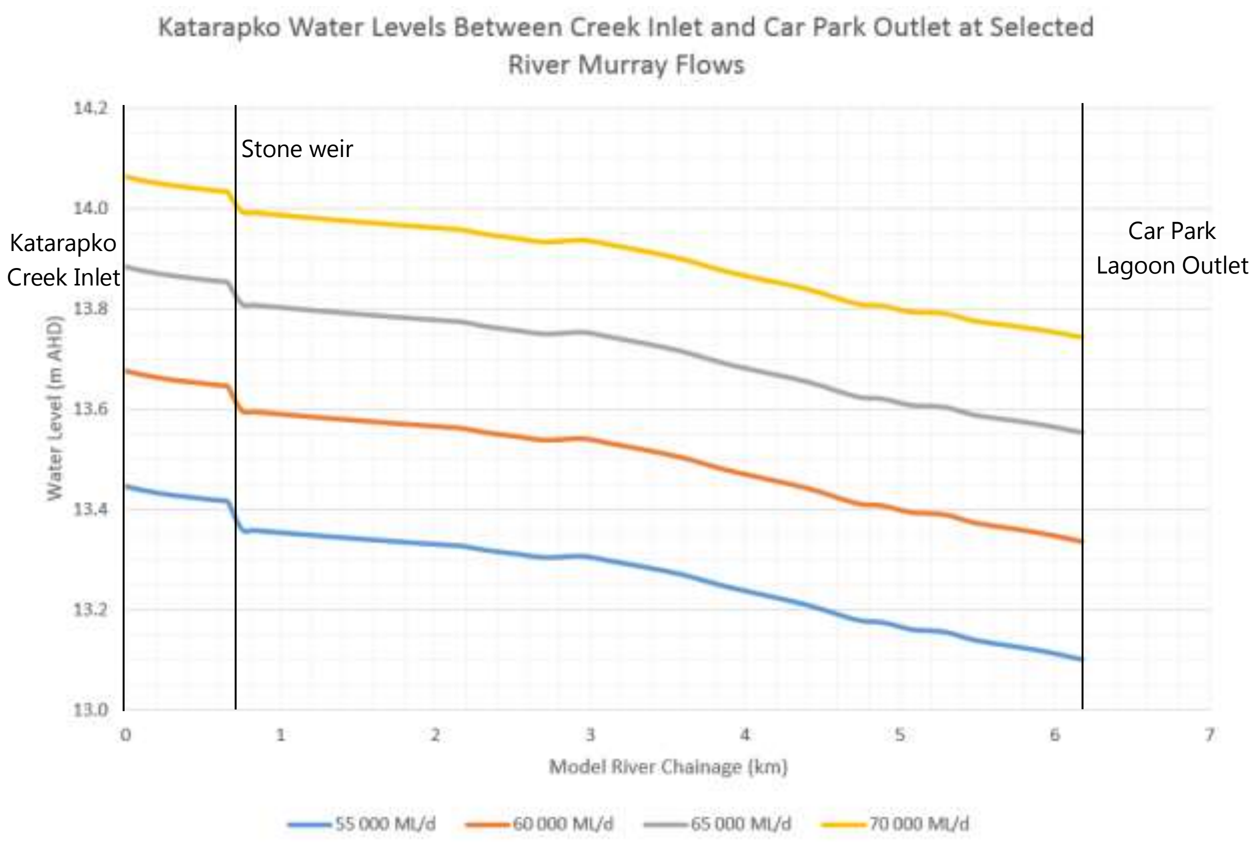

Figure 3.23 Katarapko Creek water levels between Katarapko Creek inlet and Car Park lagoon outlet at River Murray flows of 55 000 to 70 000 ML/d under upgraded floodplain conditions

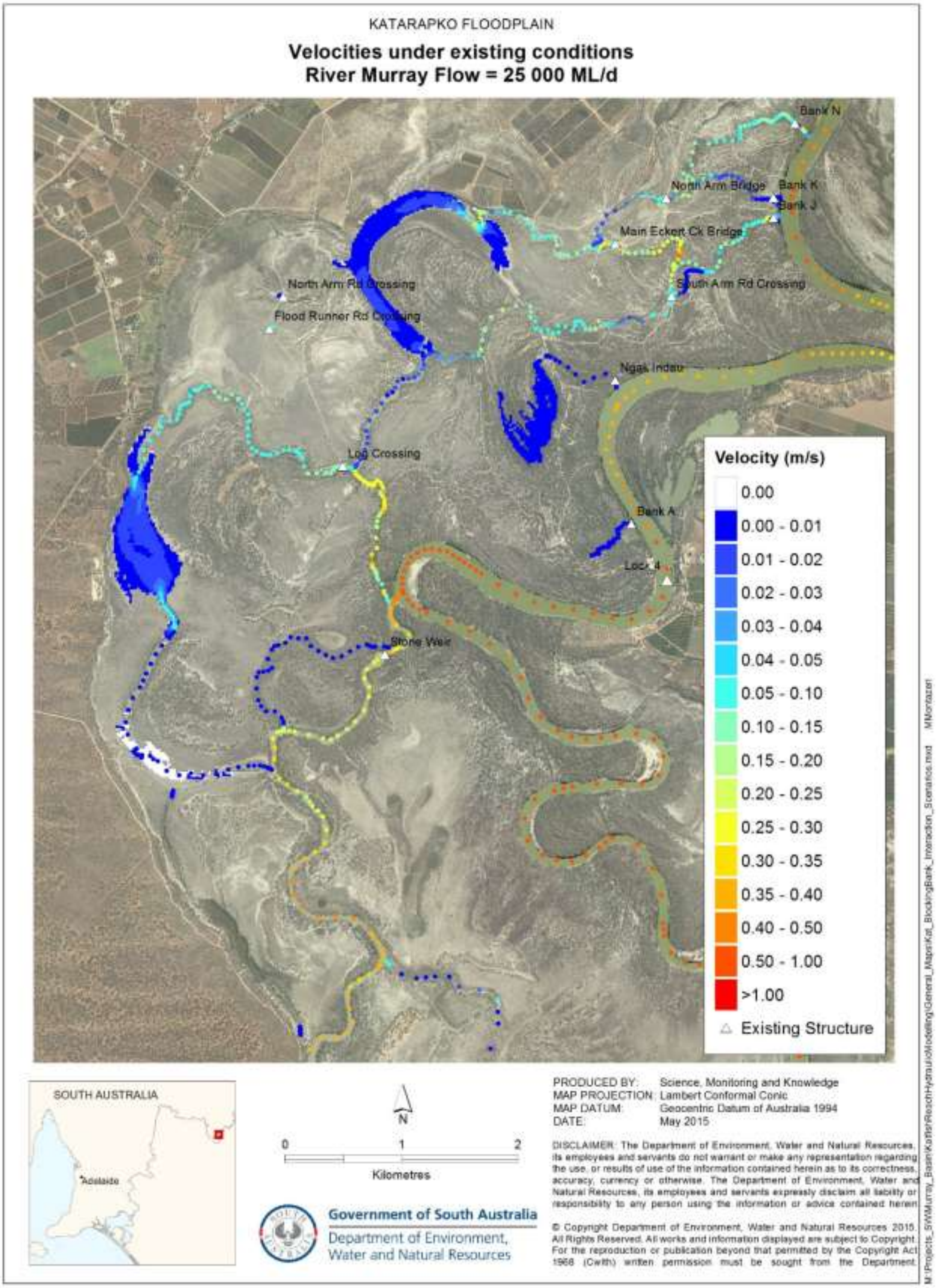

Figure 3.24 Velocity distribution at 25 000 ML/d flow upstream of Lock 4 under existing floodplain conditions

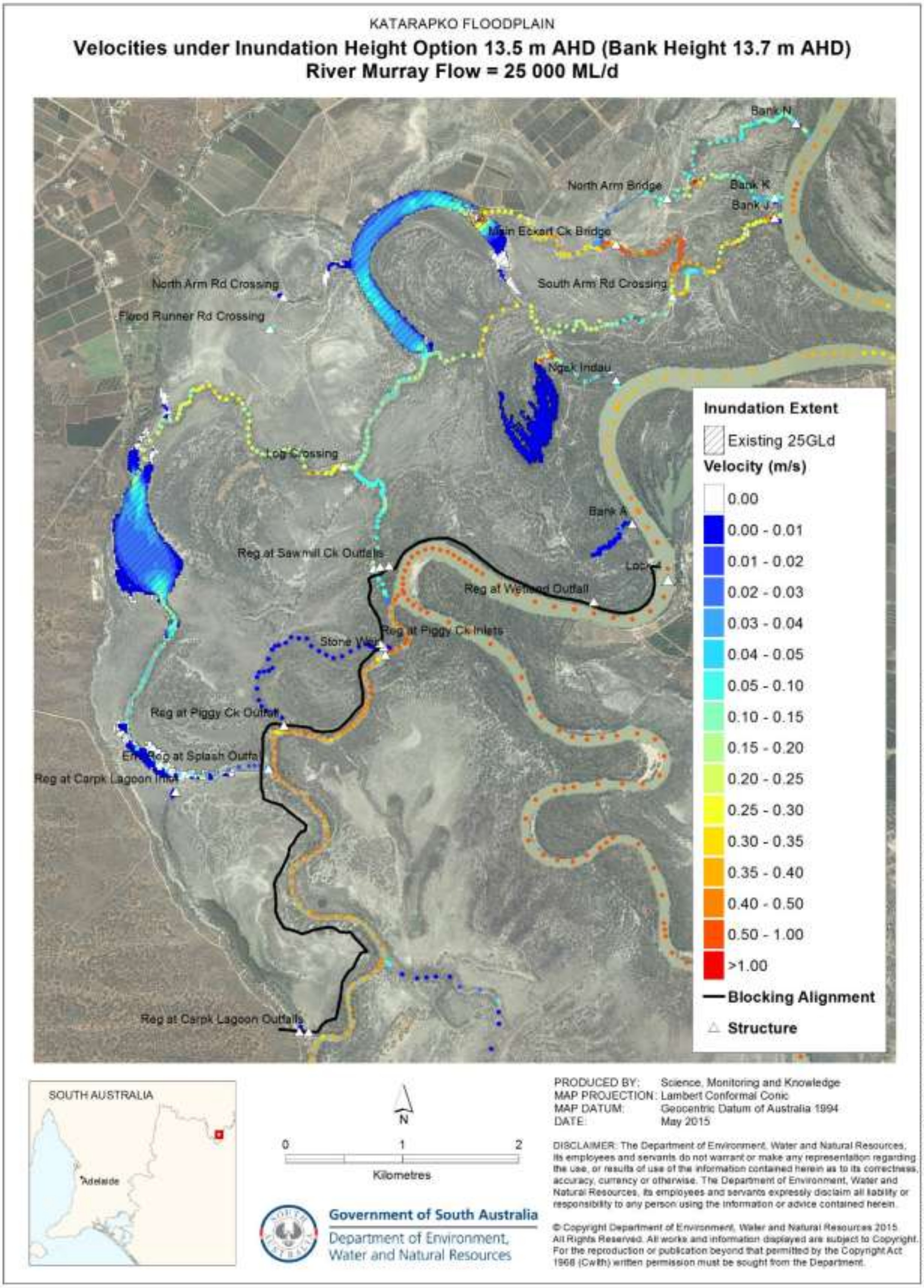

Figure 3.25 Velocity distribution at 25 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.5 m AHD inundation option (bank height at 13.7 m AHD)

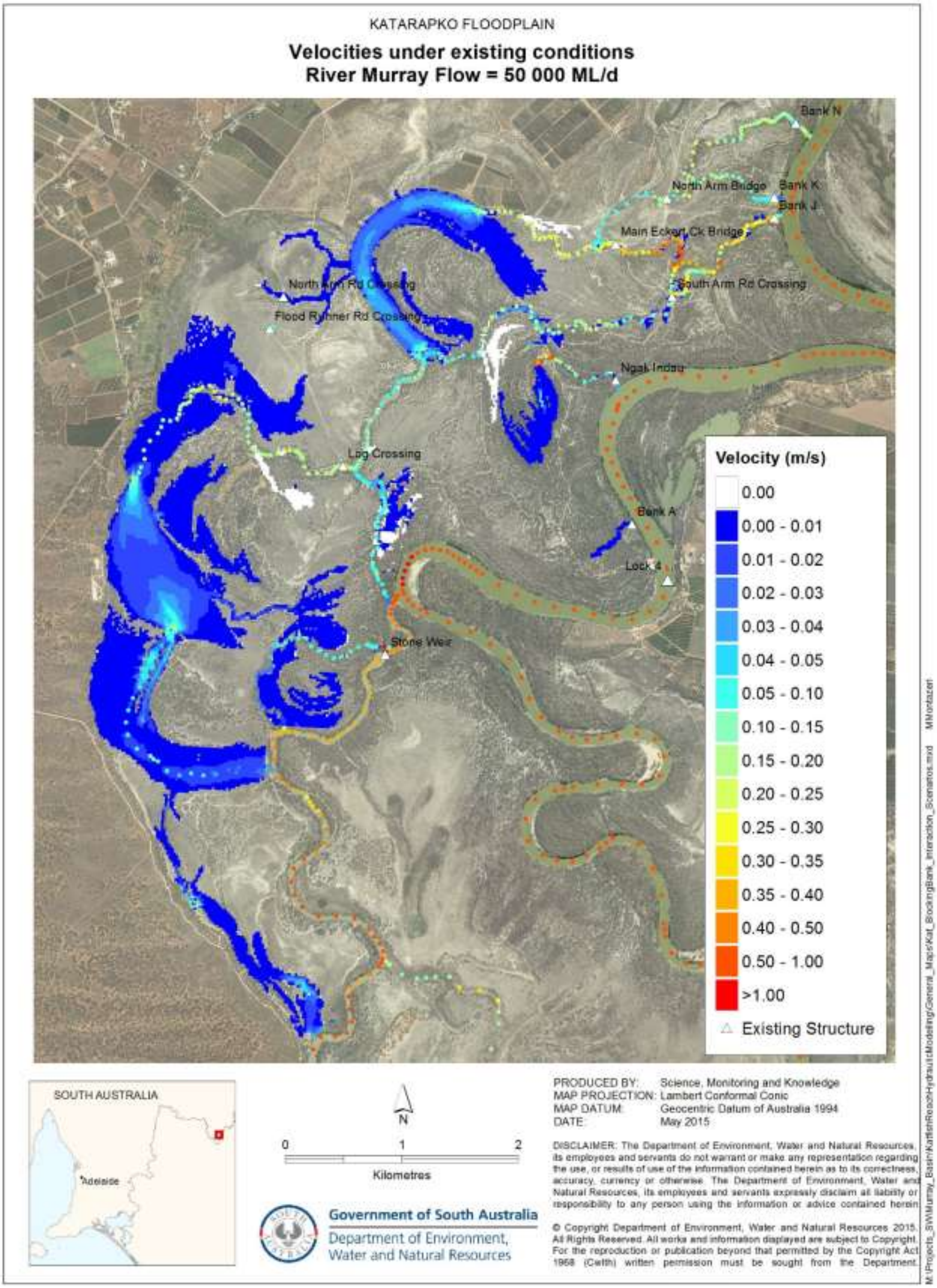

Figure 3.26 Velocity distribution at 50 000 ML/d flow upstream of Lock 4 under existing floodplain conditions

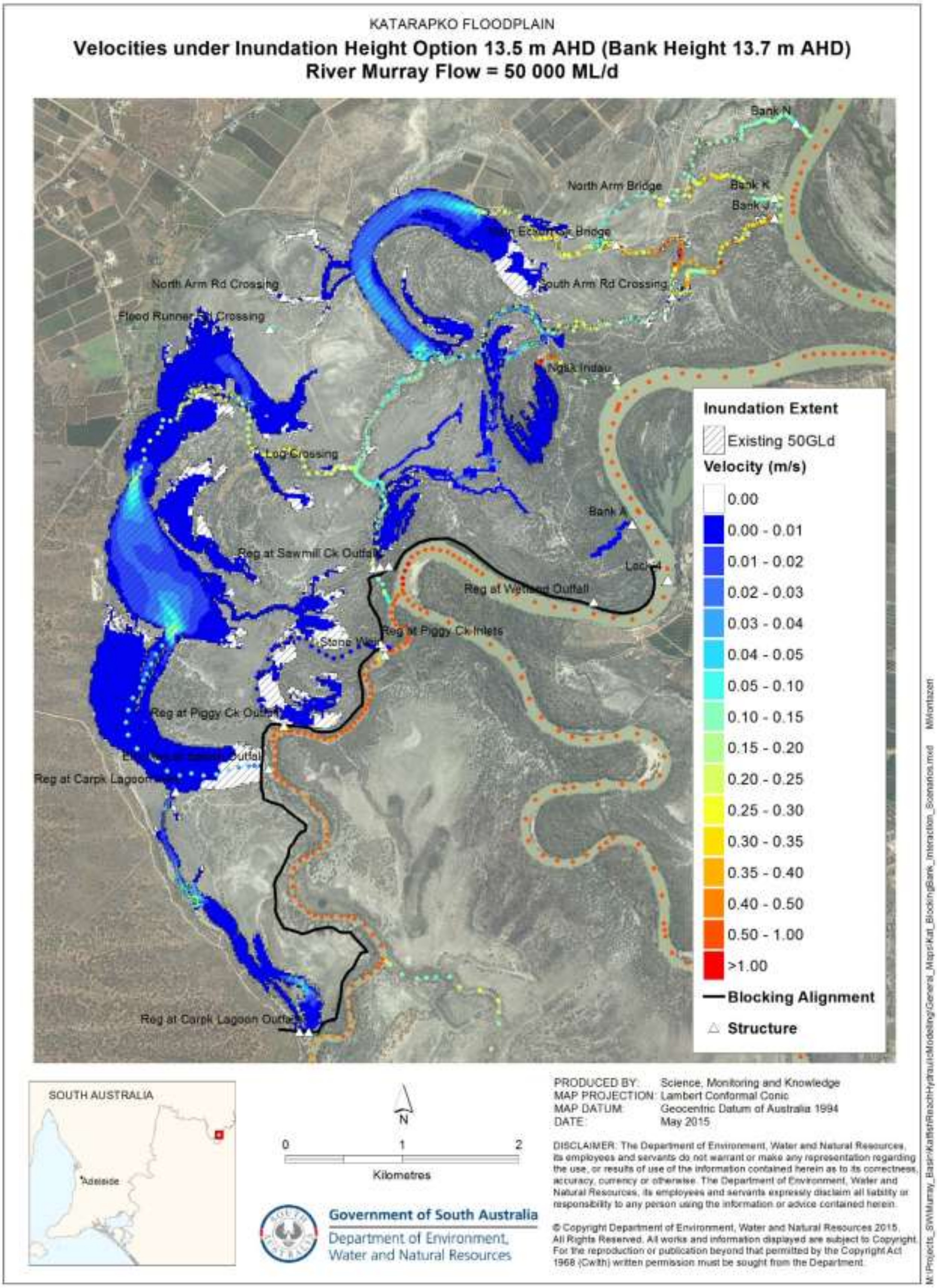

Figure 3.27 Velocity distribution at 50 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.5 m AHD inundation option (bank height at 13.7 m AHD)

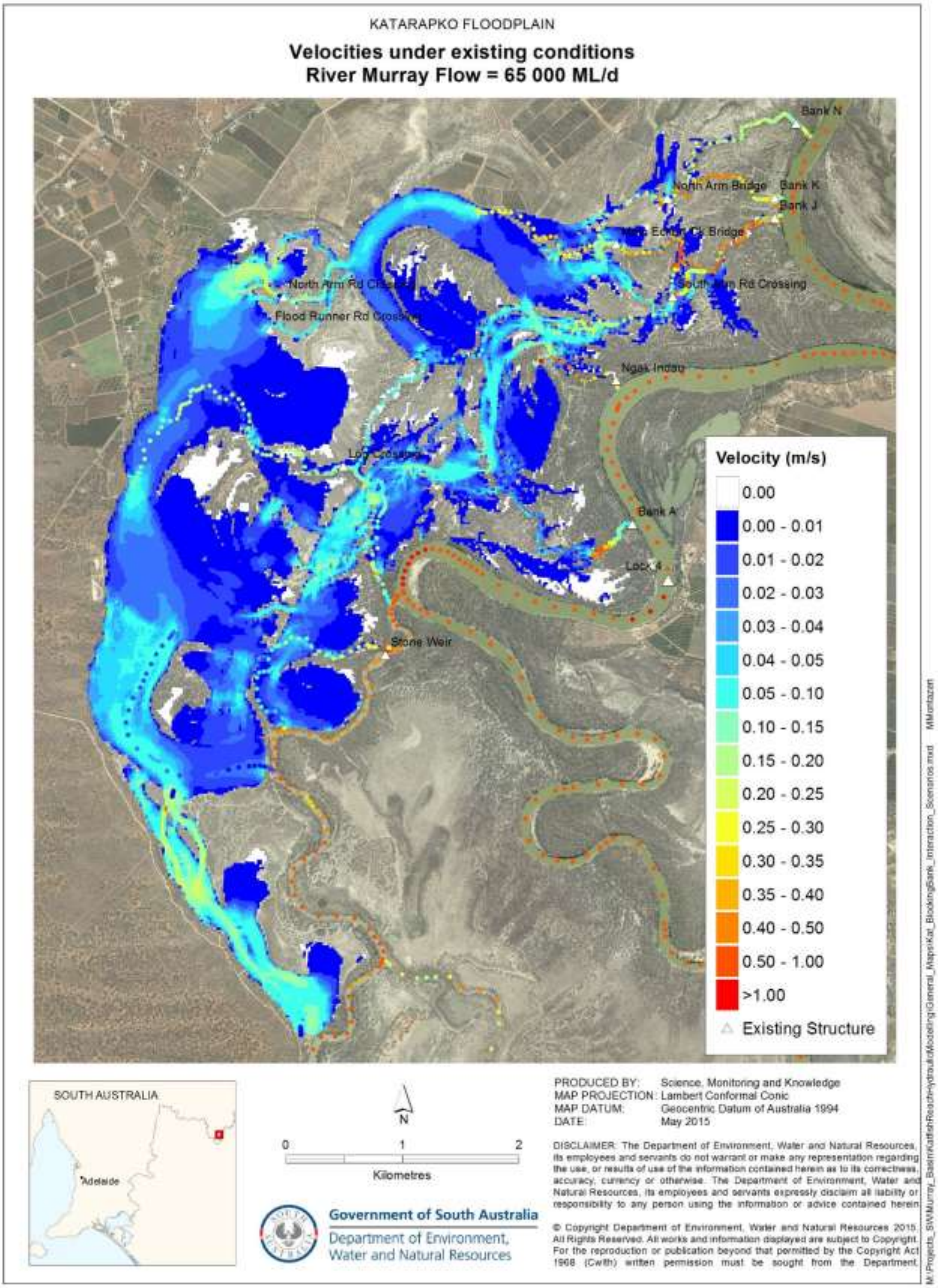

Figure 3.28 Velocity distribution at 65 000 ML/d flow upstream of Lock 4 under existing floodplain conditions

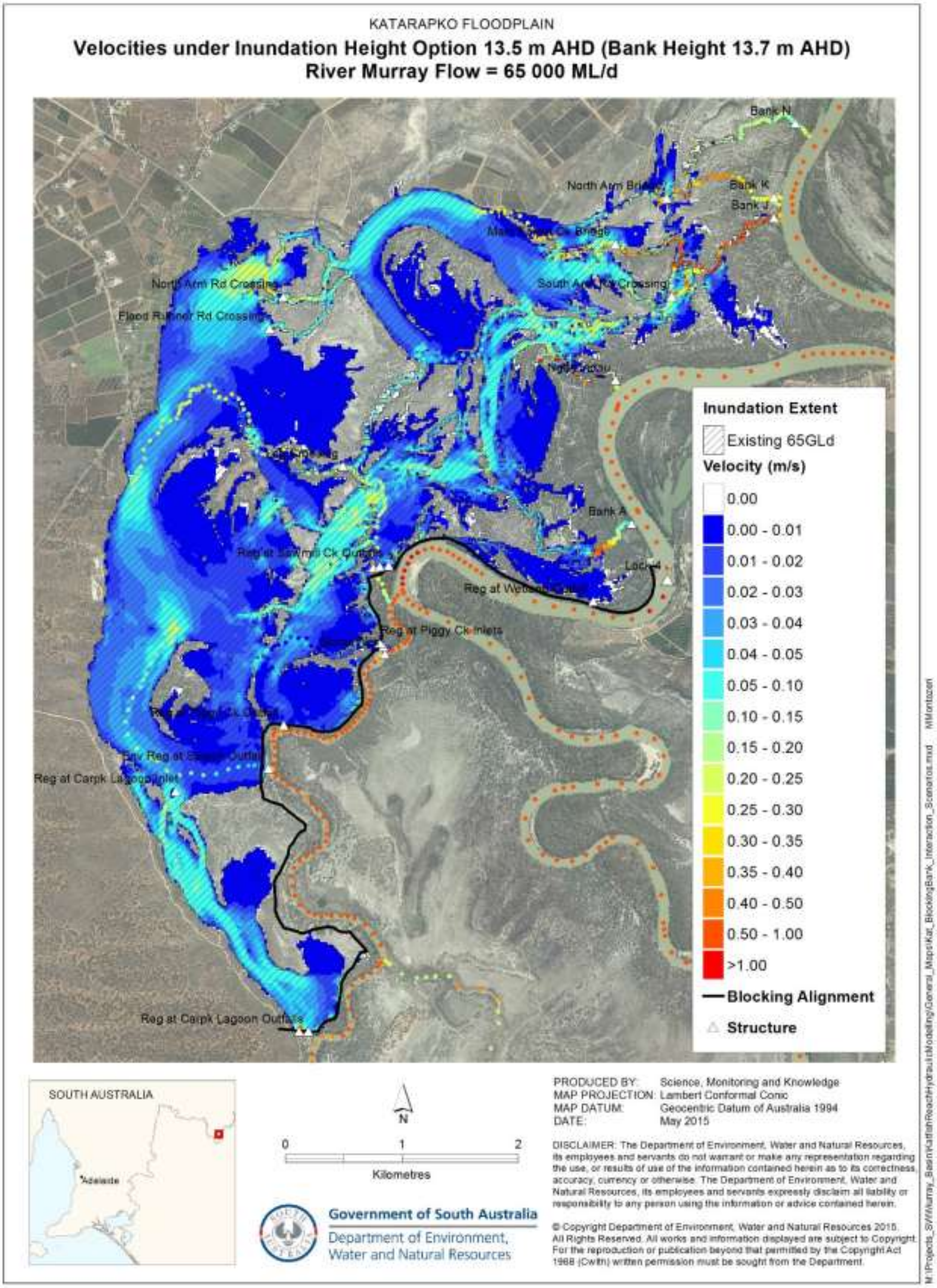

Figure 3.29 Velocity distribution at 65 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.5 m AHD inundation option (bank height at 13.7 m AHD)

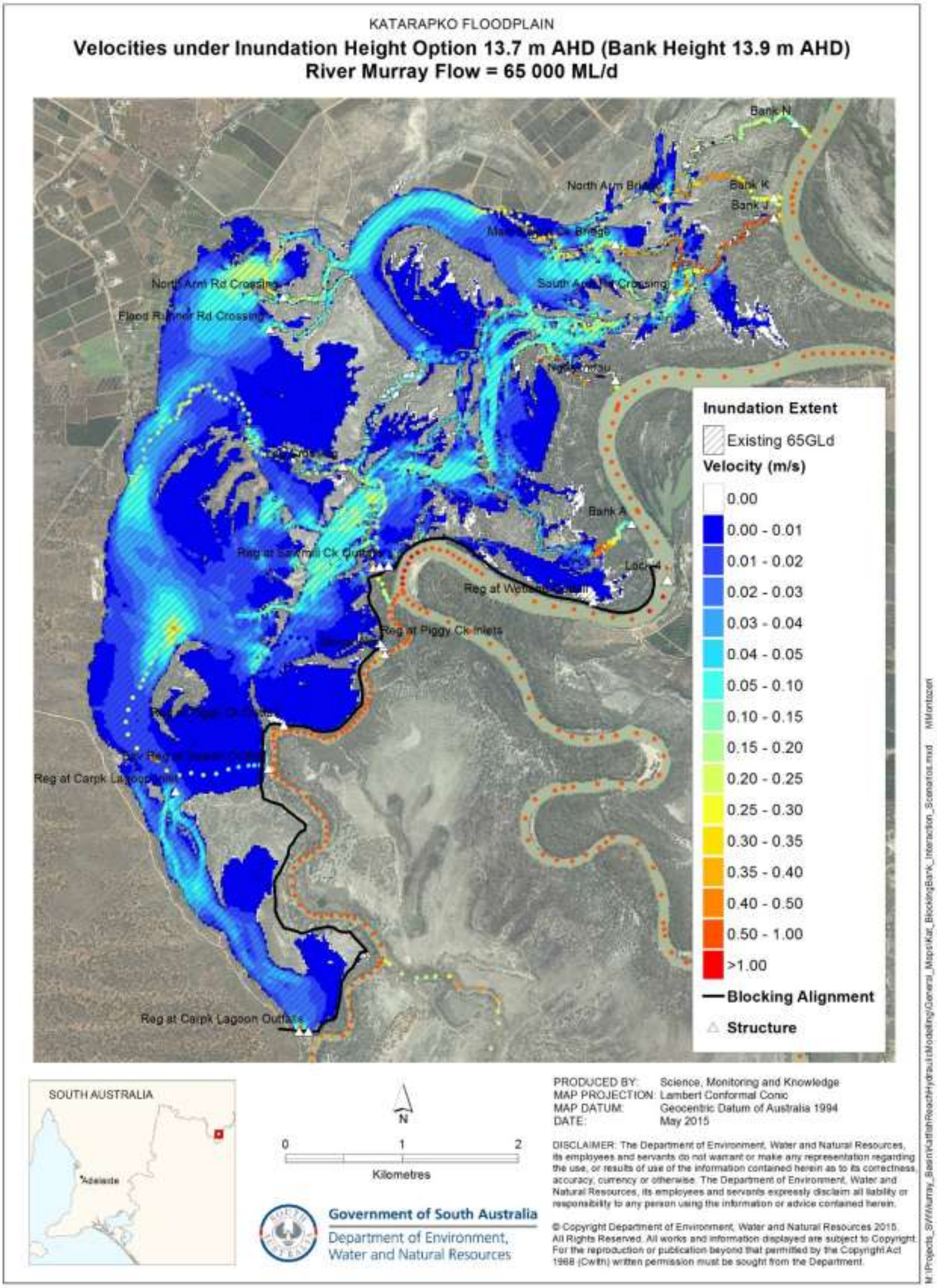

Figure 3.30 Velocity distribution at 65 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.7 m AHD inundation option (bank height at 13.9 m AHD)

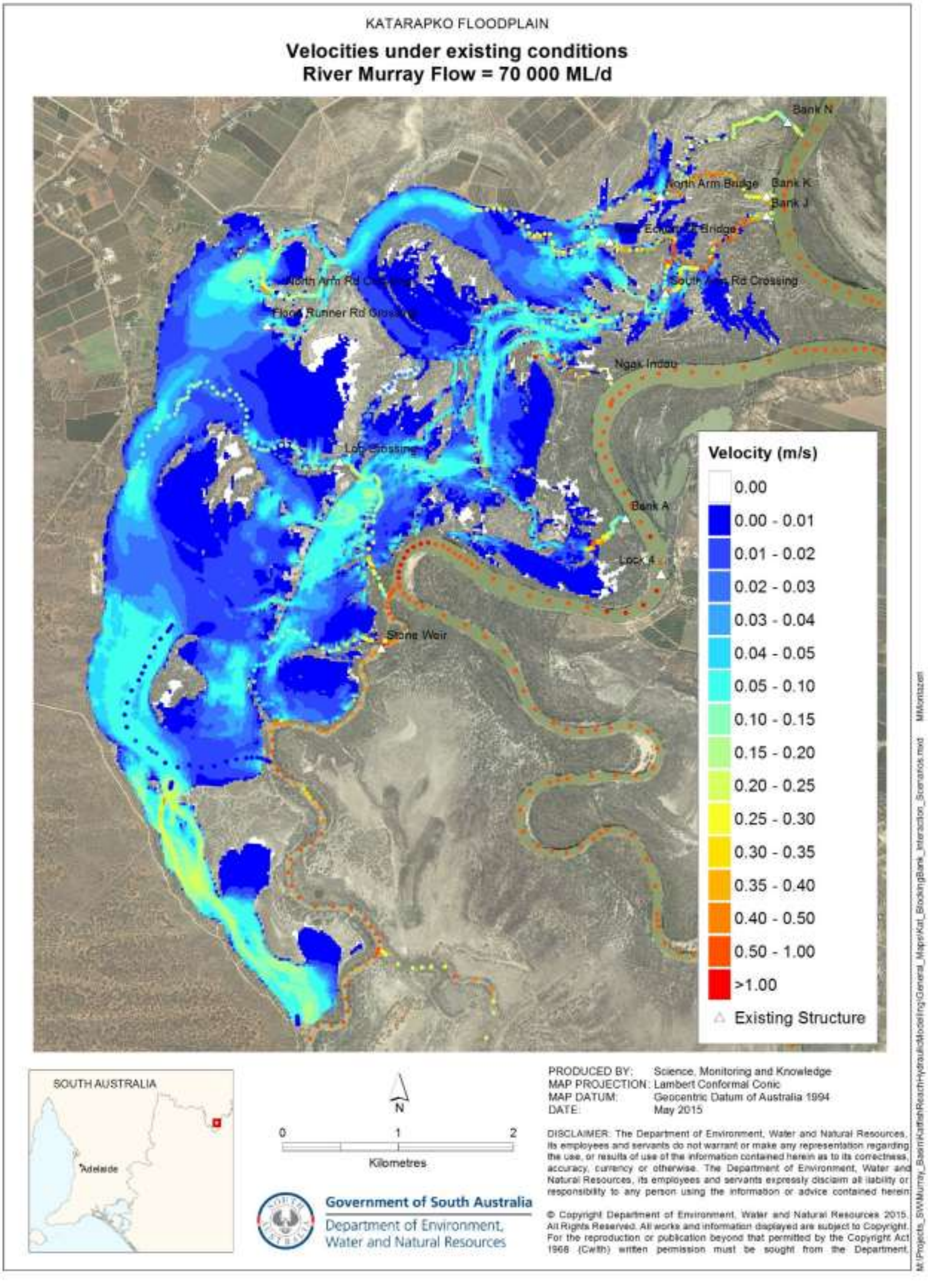

Figure 3.31 Velocity distribution at 70 000 ML/d flow upstream of Lock 4 under existing floodplain conditions

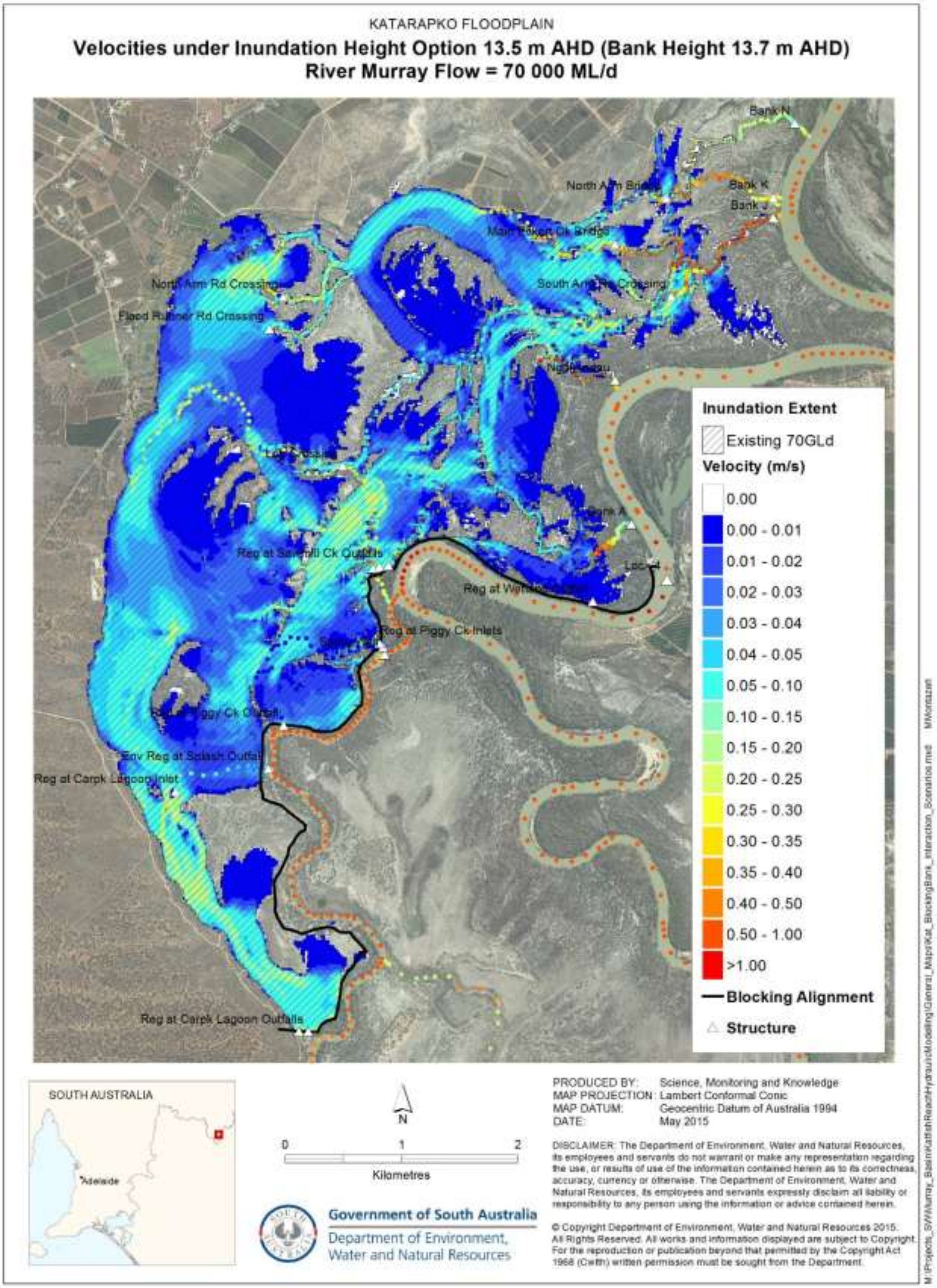

Figure 3.32 Velocity distribution at 70 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.5 m AHD inundation option (bank height at 13.7 m AHD)

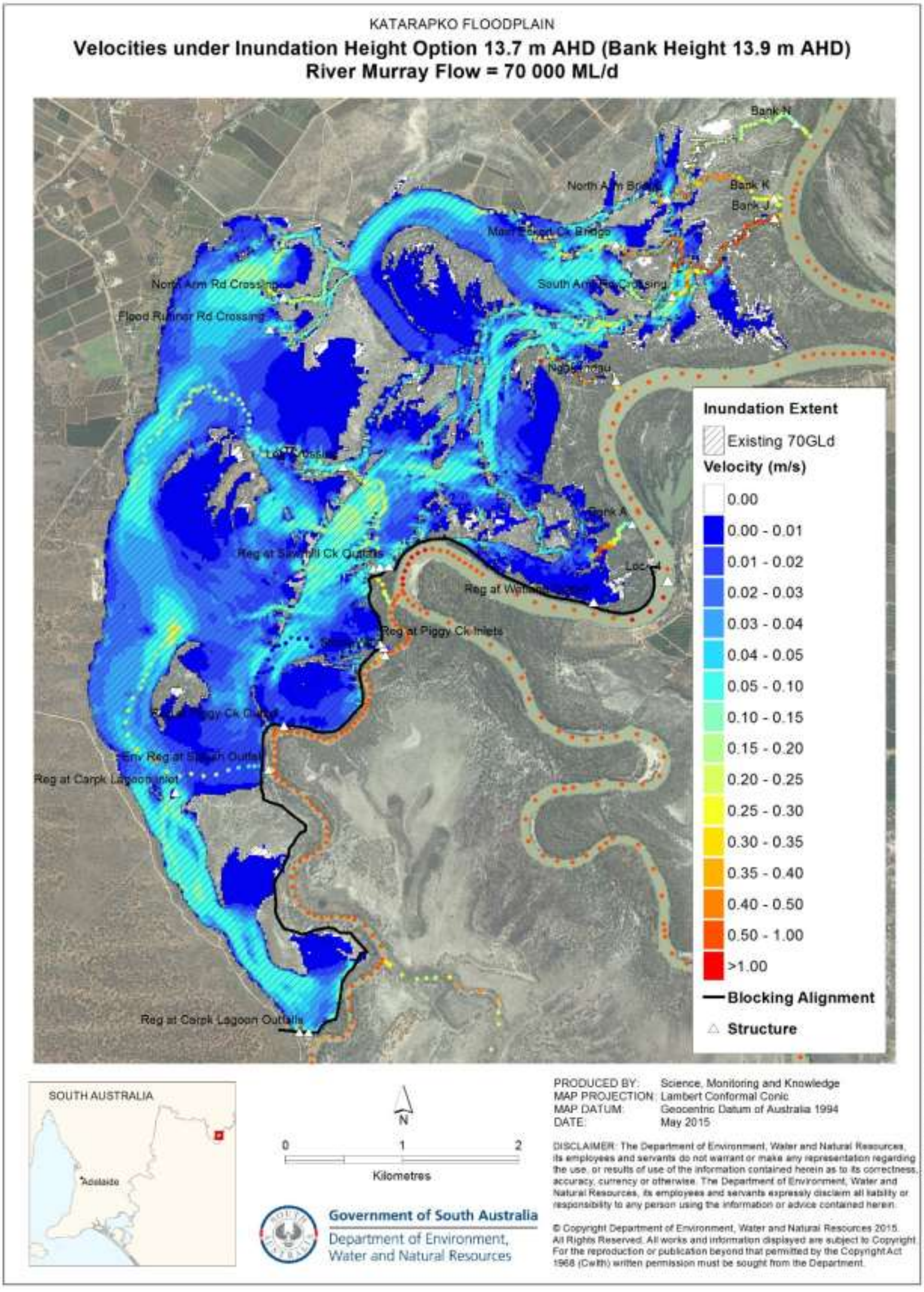

Figure 3.33 Velocity distribution at 70 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.7 m AHD inundation option (bank height at 13.9 m AHD)

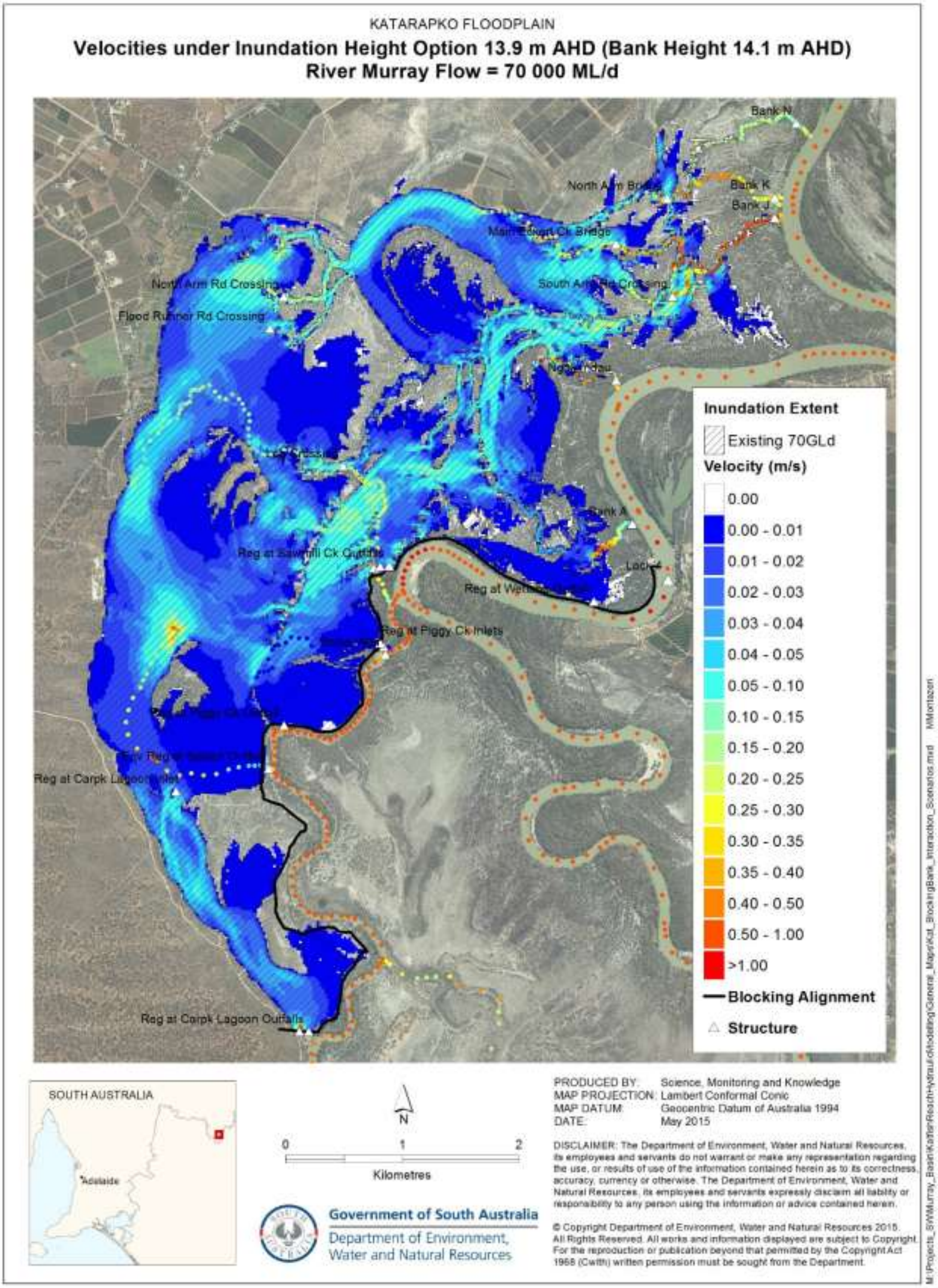

Figure 3.34 Velocity distribution at 70 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.9 m AHD inundation option (bank height at 14.1 m AHD)

3.4 Additional considerations outside impounded area

River Murray elevations in the Lock 5 to 4 reach for Lock 4 weir pool levels of 13.2, 13.8, 14.0, 14.2, and 14.34 m AHD are presented for 10 000 ML/d (Figure 3.35), 20 000 ML/d (Figure 3.36), 30 000 ML/d (Figure 3.37) and 40 000 ML/d (Figure 3.38) River Murray flow. The results presented include 1-D results extracted from the current scenarios as well as results from previous 2–D modelling by Macky and Bloss (2012) for comparison. The results indicate that raising Lock 4 weir pool for a given river flow results in a decrease in the river gradient up to a river kilometre mark of approximately 545 km. This can be attributed to the increase in backwater influence from Lock 4 as weir pool level is increased under controlled flow conditions. Conversely, an increase in River Murray flow for a given weir pool elevation results in an increase in the river gradient in the same length of reach, resulting from a decrease in Lock 4 backwater influence. Note that water levels calculated within 1-D and 2-D models at a 13.8 m AHD weir pool height are relatively similar up to a river chainage of approximately 545 to 555 km (Figure 3.35 and Figure 3.36), where the water levels from the 2-D results depart from the 1-D modelled water levels to a maximum difference of approximately 0.08 m directly downstream of Lock 5. This departure can be attributed firstly to the River Murray being represented only in 1-D above Eckert Northern Arm, with no coupling to 2-D bathymetry, and hence no overbank flow is being accounted for, while the influence of Pike Floodplain on the water level profile of the river is also not being considered. Additionally, the river in this section of the model is more coarsely represented given that it is outside the main area of interest of the model – for instance, the river chainages listed above (i.e. 545 to 555 km), at which the water level profile departure from the previous 2-D results occurs, are adjacent to Pike Floodplain, and correspond to an area where a bend in the river is partially bypassed by small connecting flow paths. Not including these small bypass connections may be exacerbating the head difference in this section of river, and thus the water level profiles from the 1-D modelling should be considered as indicative only.

Water levels of particular interest during weir pool manipulation are located in the vicinity of the Gurra Gurra wetlands. This wetland area is sensitive to river level changes, whereby raised water levels have previously shown to create high salinity issues within the wetlands, and hence create significant impacts on local irrigation. This also creates a potential barrier for artificially raising Lock 4 pool level for managed inundation, requiring options to mitigate any potential salinity impacts in Gurra Gurra.

Modelled water levels at the wetlands inlet, directly downstream of the Lyrup ferry crossing (i.e. river km approximately 537 km), are shown in Table 3.10. The commence to flow level in the vicinity of the inlet appears to be approximately 13.8 m AHD based on the DEM, however confirmation through on-ground survey would be required to confirm the actual minimum elevation for flow entering the wetland. Assuming this commence to flow level, Lock 4 pool levels above 13.8 m AHD appear to be conducive to allowing flow-through conditions from the inlet to the outlet of the wetlands (river km of approximately 520 km). Benefit of operating at increased river flows is apparent in this case however, with a head difference between inlet and outlet locations modelled at 0.02-0.03 m for a Lock 4 pool level of 13.8 m AHD and flow of 10 000 ML/d, whereas operating at a flow of 20 000 ML/d at this pool level results in a head difference of approximately 0.09 m, and hence a higher hydraulic gradient over the wetland.

One alternative Gurra Gurra wetlands management option being considered is to lower the sill level of an identified upstream flood runner connecting the wetlands to the River Murray (river km approximately 529 km), thereby creating some flow through from the river to the wetlands inlet/outlet connection at typical pool level (i.e. approximately river km 520 km), although the viability of this option will depend on the head difference between the two river km markers of interest. The results in Table 3.10 suggest similar conclusions as above, namely that the difference between the flood runner location and the typical inlet/outlet connection increases with increasing river flow for a given weir pool elevation, and with decreasing weir pool for a given river flow. For instance, at the concept design elevation of 13.8 m AHD, the head difference increases from less than 0.02 m at 10 000 ML/d to approximately 0.20 m at 40 000 ML/d. Conversely, at a river flow of 20 000 ML/d, the head difference decreases from approximately 0.06 m at a typical pool level of 13.2 m AHD to 0.04 m at a maximum weir pool level of 14.34 m AHD. Based on the results presented, it appears that a river flow of 10 000 ML/d will not allow a significant head difference between the two river locations identified to be achieved for generating sufficient flow through conditions in the wetlands area, with less than 0.02 m as the maximum difference achieved, at a 13.8 m AHD weir pool level. It therefore may not be a viable management option below 20 000 ML/d for managing water quality in Gurra Gurra, and other alternatives may need to be considered.

Further modelling of the Gurra Gurra wetlands is required to properly assess the ability for creating flow through conditions within the system by manipulating river hydraulic conditions, which will require the development of a new model, including topographic and/or bathymetric surveys of the wetlands and associated waterways.

Table 3.10 River elevations at river chainages relevant to Gurra Gurra wetlands management at various Lock 4 weir pool elevations and River Murray flows

River flow ML/d	River Chainage km	Lock 4 weir pool elevation (1-D or 2-D model simulation) 13.2 m AHD (2-D)	13.8 m AHD (1-D)	13.8 m AHD (2-D)	14.0 m AHD (1-D)	14.2 m AHD (1-D)	14.34 m AHD (2-D)
10 000	520	13.198	13.804	13.808	14.003	14.202	14.328
	529	13.217	13.816	13.822	14.014	14.212	14.338
	537	13.233	13.826	13.836	14.023	14.220	14.350
Head	529-520	0.018	0.013	0.015	0.011	0.010	0.011
difference	537-520	0.035	0.023	0.028	0.020	0.017	0.023
20 000	520	13.220	13.816	13.805	14.014	14.212	14.339
	529	13.275	13.868	13.852	14.060	14.252	14.375
	537	13.322	13.906	13.893	14.093	14.282	14.408
Head	529-520	0.055	0.052	0.047	0.046	0.040	0.036
difference	537-520	0.102	0.089	0.088	0.079	0.070	0.069
30 000	520	-	13.838	-	14.033	14.228	-
	529	-	13.953	-	14.134	14.318	-
	537	-	14.032	-	14.206	14.382	-
Head	529-520	-	0.115	-	0.101	0.090	-
difference	537-520	-	0.194	-	0.173	0.154	-
40 000	520	-	13.868	-	14.060	14.252	-
	529	-	14.064	-	14.234	14.407	-
	537	-	14.195	-	14.353	14.515	-
Head	529-520	-	0.196	-	0.175	0.155	-
difference	537-520	-	0.327	-	0.293	0.263	-

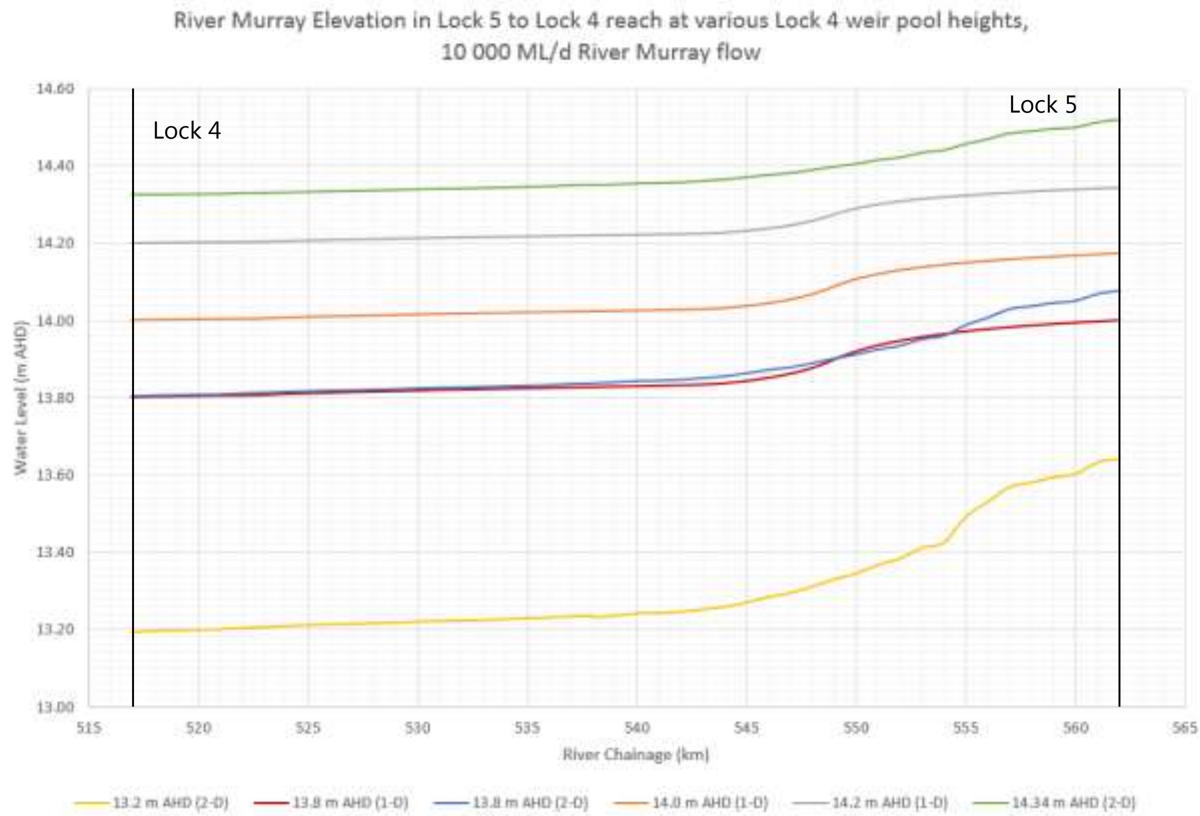

Figure 3.35 River Murray elevation at River Murray flow of 10 000 ML/d and various Lock 4 weir pool heights, from 1-D (current modelling) and 2-D (Macky and Bloss, 2012) modelled results

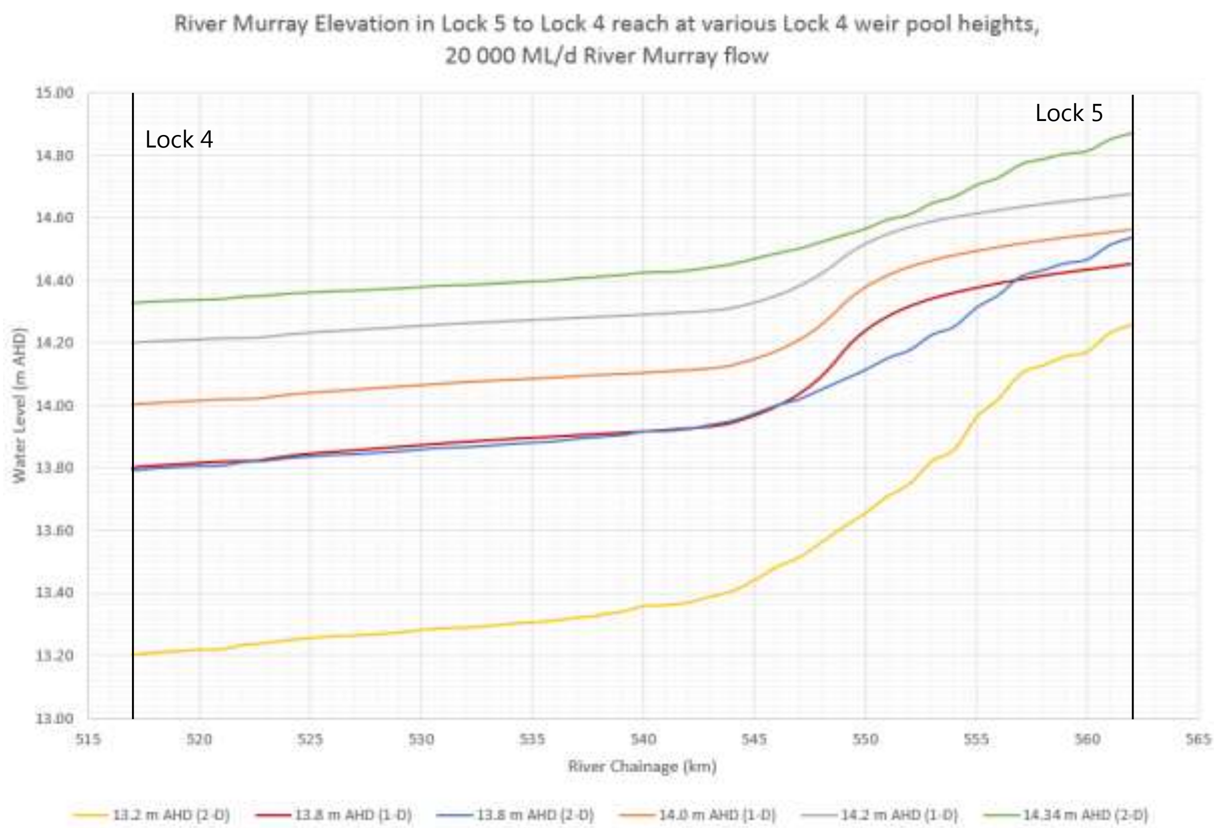

Figure 3.36 River Murray elevation at River Murray flow of 20 000 ML/d and various Lock 4 weir pool heights, from 1-D (current modelling) and 2-D (Macky and Bloss, 2012) modelled results

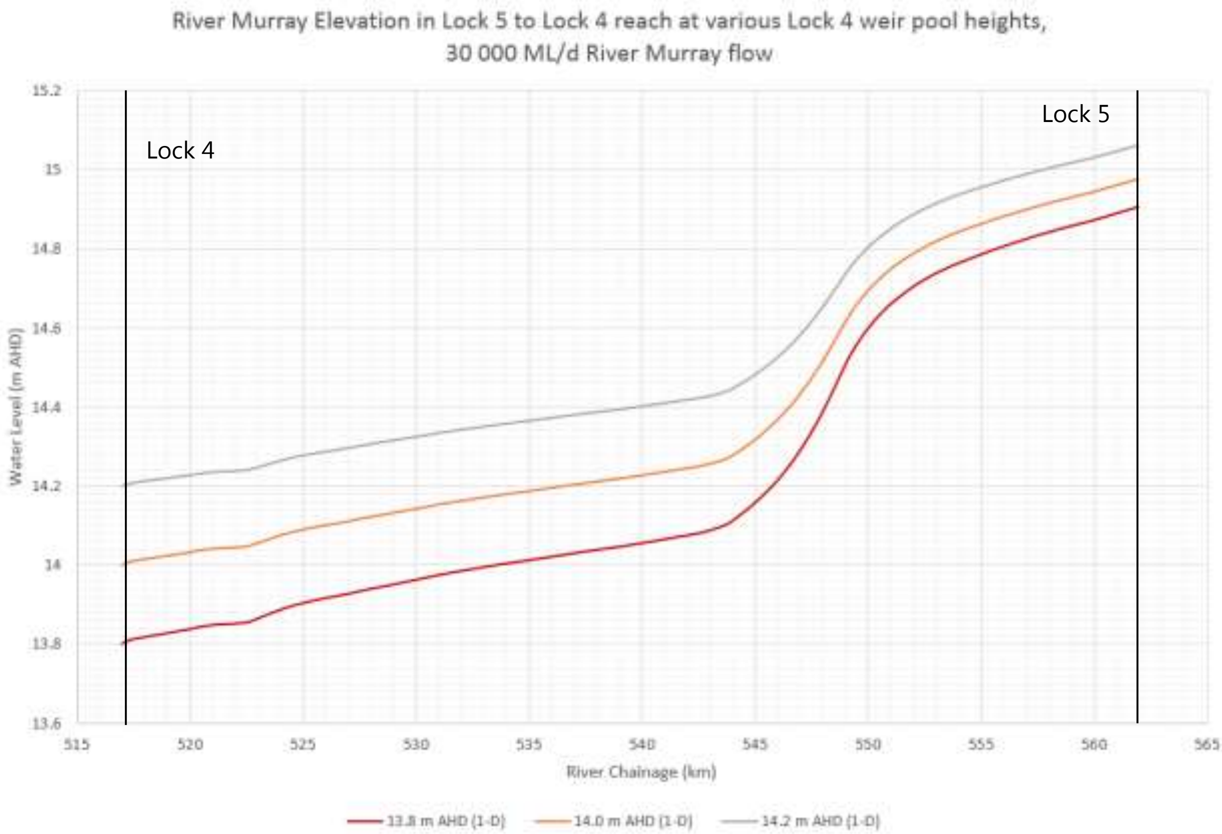

Figure 3.37 River Murray elevation at River Murray flow of 30 000 ML/d and various Lock 4 weir pool heights, from 1-D (current modelling) results

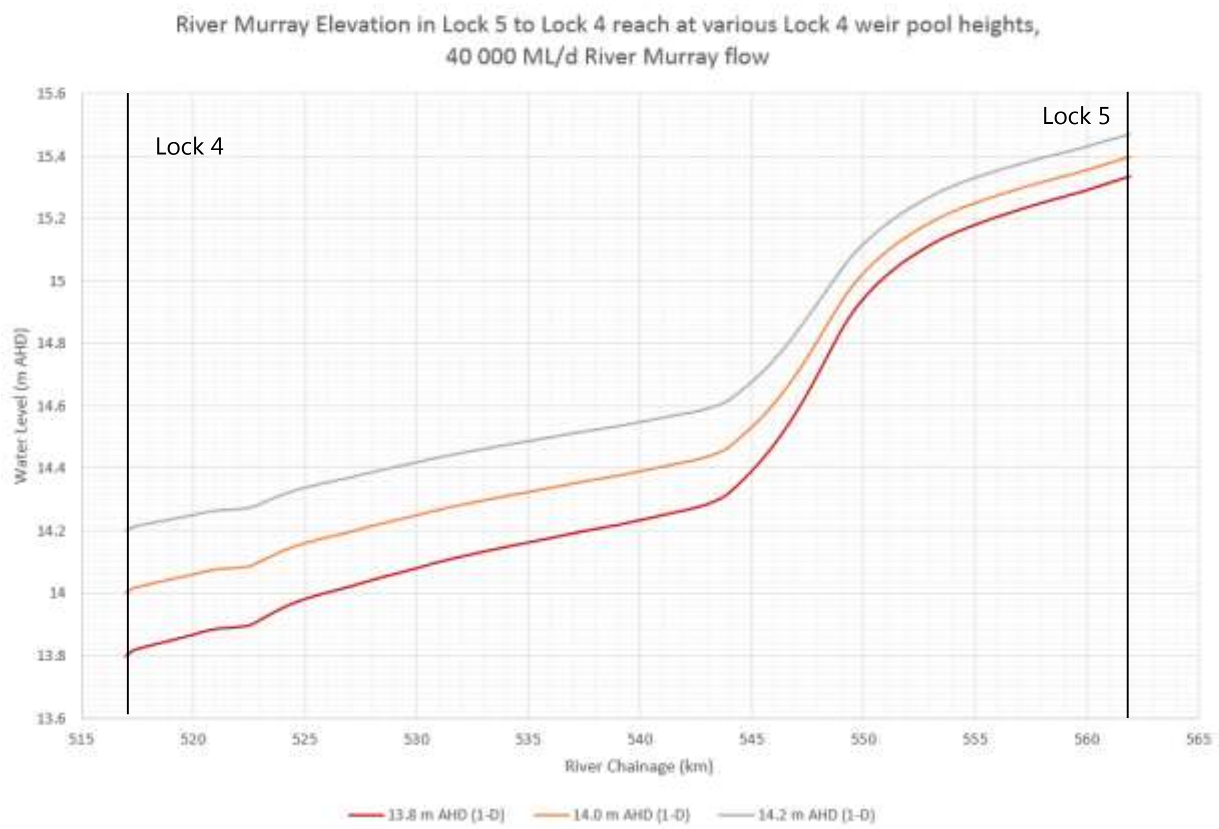

Figure 3.38 River Murray elevation at River Murray flow of 40 000 ML/d and various Lock 4 weir pool heights, from 1-D (current modelling) modelled results

4 Conclusion

Results from the scenarios considered include:

- The operational level of 13.5 m AHD and Lock 4 weir pool level of 13.8 m AHD resulted in an inundated area of 1000–1015 ha, increasing by approximately 200 ha for each 0.2 m increase in level above this operational level. The increased inundated area was typically at the fringes of the inundation extent.
- Turnover rates for all scenarios considered – from 13.5–13.9 m AHD inundation heights and Lock 4 weir pool levels 0.3 m greater than the desired inundation height – vary from 14% up to a maximum of 20% depending on River Murray flow i.e. inflows increase as river flows are increased. Turnover rates were substantially improved by increasing the head difference between Lock 4 and floodplain level; at a 13.5 m AHD inundation height and Lock 4 pool level of 14.2 m AHD, turnover values in the order of 30% were reached, while at 13.7 m AHD inundation height and Lock 4 level of 14.2 m AHD turnover rates in the order of 22% were achieved. These results indicate that inflows and hence turnover rates are sensitive to the head difference between Lock 4 pool level and the floodplain, and of the options considered, Lock 4 levels greater than 0.3 m above the inundation height may be required during operation to maintain sufficient turnover rates.
- Velocities are greatest within the channels – particularly through the inlet channels – and at their lowest in the overbank inundated area, resulting predominantly in an increase in inundated area in the slowest velocity categories through increasing the inundation height. Velocity results at the downstream end of the impounded area are influenced by the assumptions regarding the distribution of outflow across the outlet regulators, and these results will be refined in further work.
- Bed shear stresses are modelled to be highest in the inlet channels above Lock 4 at all options considered, but overall are predominantly present below approximately 2 N/m^2, with only isolated sections of creek present above approximately 5 N/m^2. Previous literature indicates that no to low erosion risk exists within the creeks at the velocities modelled assuming clay soils, however further confirmation of floodplain soil composition is required to provide a more detailed assessment of erosion risk within the floodplain during a managed inundation event.
- Modelling suggested that the blocking bank height for a 13.5 m AHD inundation height restricts natural exchange between the floodplain and River Murray below approximately 55 000 to 60 000 ML/d, while the blocking bank height at a 13.9 m AHD inundation height restricts exchange at flows up to approximately 65 000 to 70 000 ML/d. However, this modelling does not include provision for measures such ancillary structures or spillways within the blocking banks that may reduce restriction of natural high flows through the floodplain.
- With fully open structures, the presence of the blocking banks was modelled to alter the natural flow paths at high flows from the majority passing through Car Park lagoon under existing conditions, to The Splash under fully upgraded floodplain conditions.
- The impact of increasing Lock 4 weir pool level during a managed inundation event results in an extension of the backwater influence of the lock upstream towards Lock 5 from typical weir pool elevation, which ultimately reduces the gradient of the river in the reach directly upstream of the lock. Conversely, river gradient increases with increasing river flow for a given weir pool elevation. These effects have implications for potential water quality management options for the Gurra Gurra wetlands upstream of Katarapko Floodplain, to create flow through conditions within the system, driven by river gradient. It appears that an insufficient head difference exists to generate flow through conditions at 10 000 ML/d when considering an option of lowering the sill level of a flood runner located between the inlet and outlet of the wetlands, while operating at greater weir pool elevations also reduces the effectiveness of this measure. Further modelling is recommended to better investigate the aforementioned management option.

5 References

Aquaterra, 2009, *South Australian Weir Pool Manipulation Compilation Report*, Aquaterra Report reference A86B/R001e, prepared for SA Murray-Darling Basin NRM Board, Berri, December

Gippel, CJ and Anderson, BG and Andersen, S, 2008, *Evaluation of the impacts of operating proposed infrastructure on geomorphology of the Chowilla Floodplain*, Fluvial Systems Pty Ltd, Stockton, for Department of Water, Land and Biodiversity Conservation, Berri, June

Macky, G, Bloss, C, 2012, *Riverine Recovery Weir Pool Hydraulic Modelling*, DEWNR Technical Note, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide

McCullough DP, 2014, *Riverine Recovery Katfish Reach Hydraulic Modelling 2012–13*, DEWNR Technical Note, Government of South Australia, through Department of Environment, Water and Natural Resources, Berri

McCullough DP, 2016, *Katarapko Floodplain Hydraulic Model Setup and Review,* DEWNR Technical Note 2016/06, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide

Montazeri M, McCullough DP, 2015, *SARFIIP – Kararapko Floodplain Hydraulic Modelling, Natural, Current and Basin Plan Flow Scenarios*, DEWNR Technical Note 2016/08, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide

Appendix – Velocity profiles and distribution

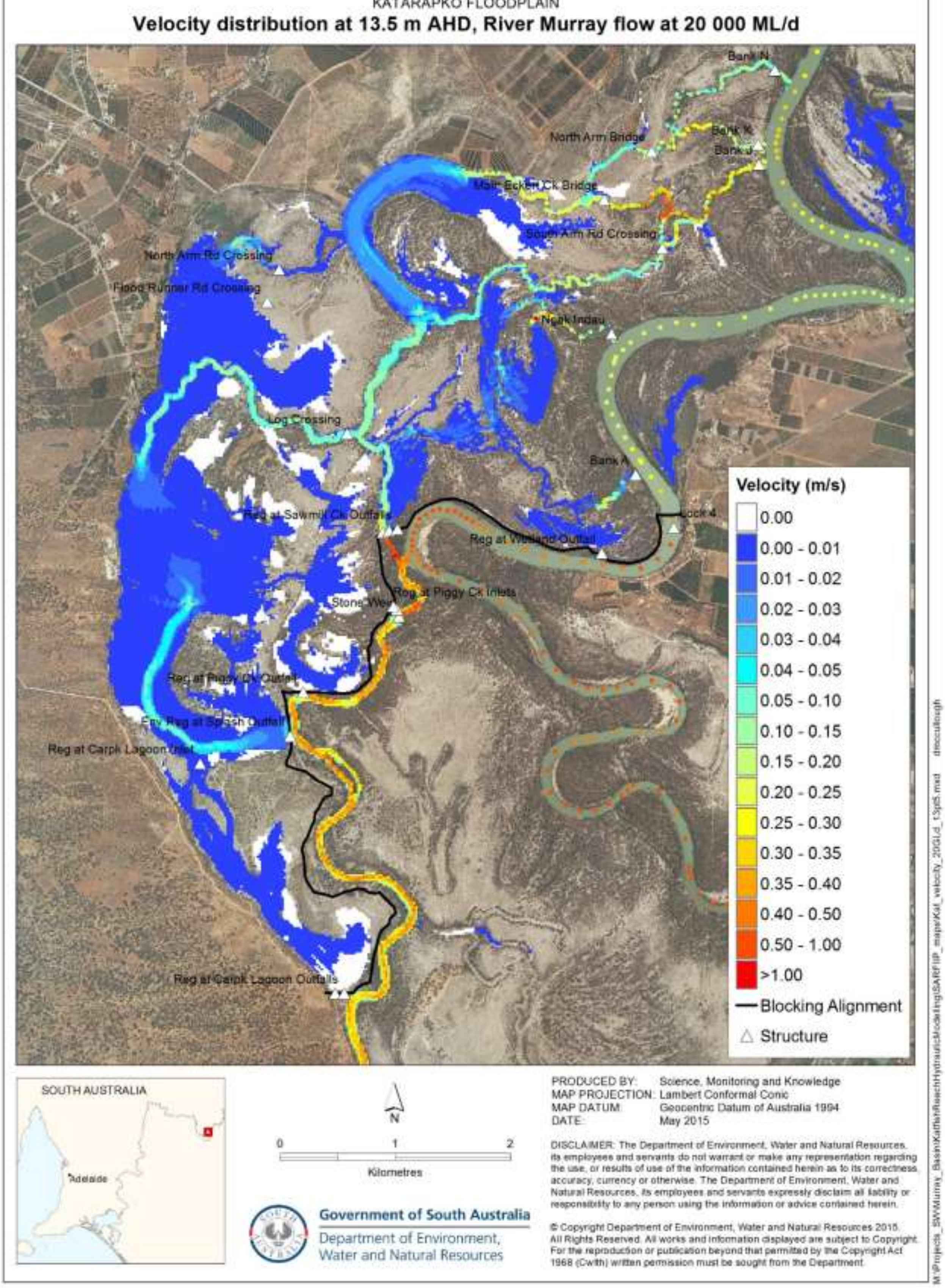

Figure A.1 Velocity distribution at 13.5 m AHD inundation height (Lock 4 weir pool 13.8 m AHD), River Murray flow at 20 000 ML/d

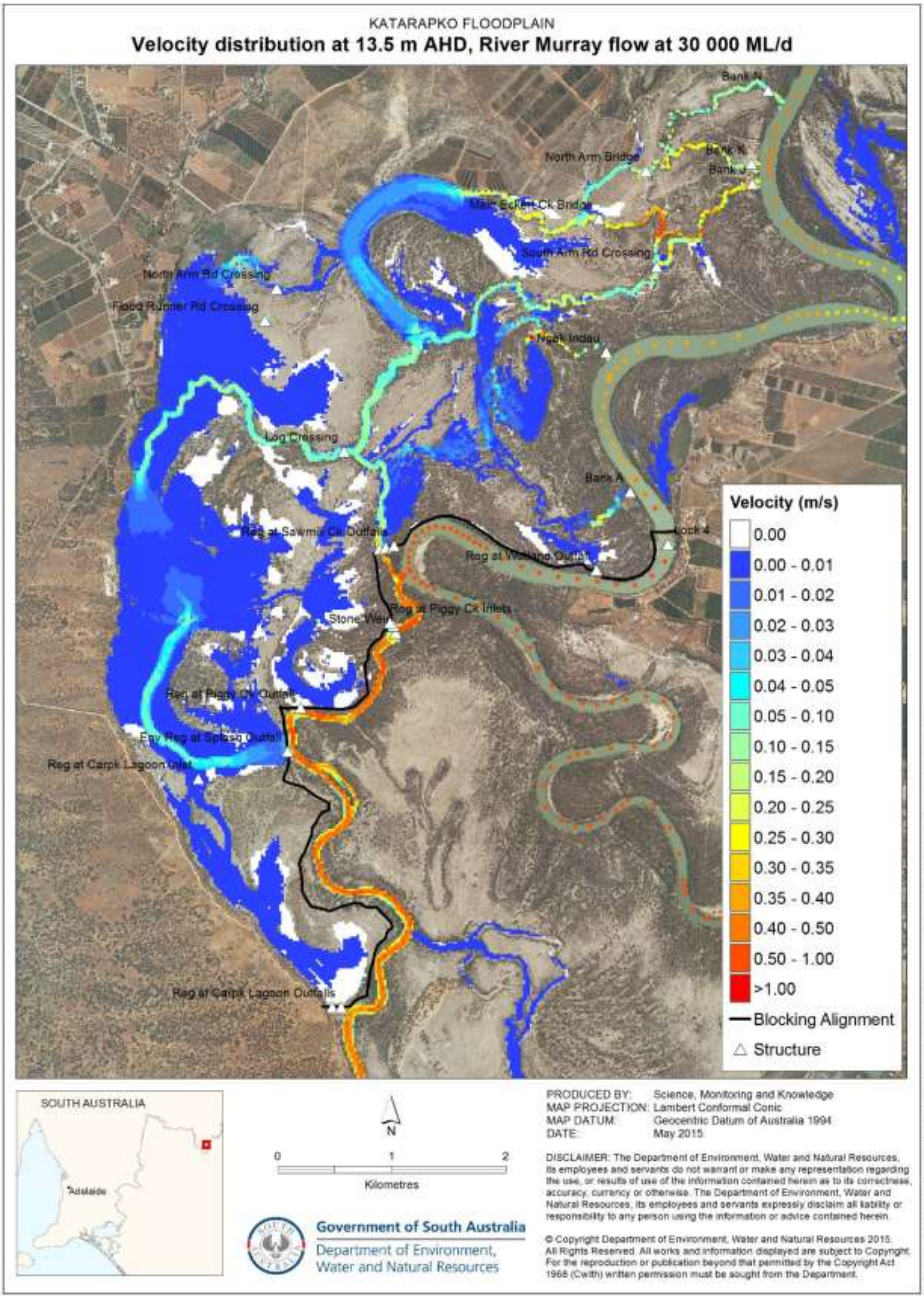

Figure A.2 Velocity distribution at 13.5 m AHD inundation height (Lock 4 weir pool 13.8 m AHD), River Murray flow at 30 000 ML/d

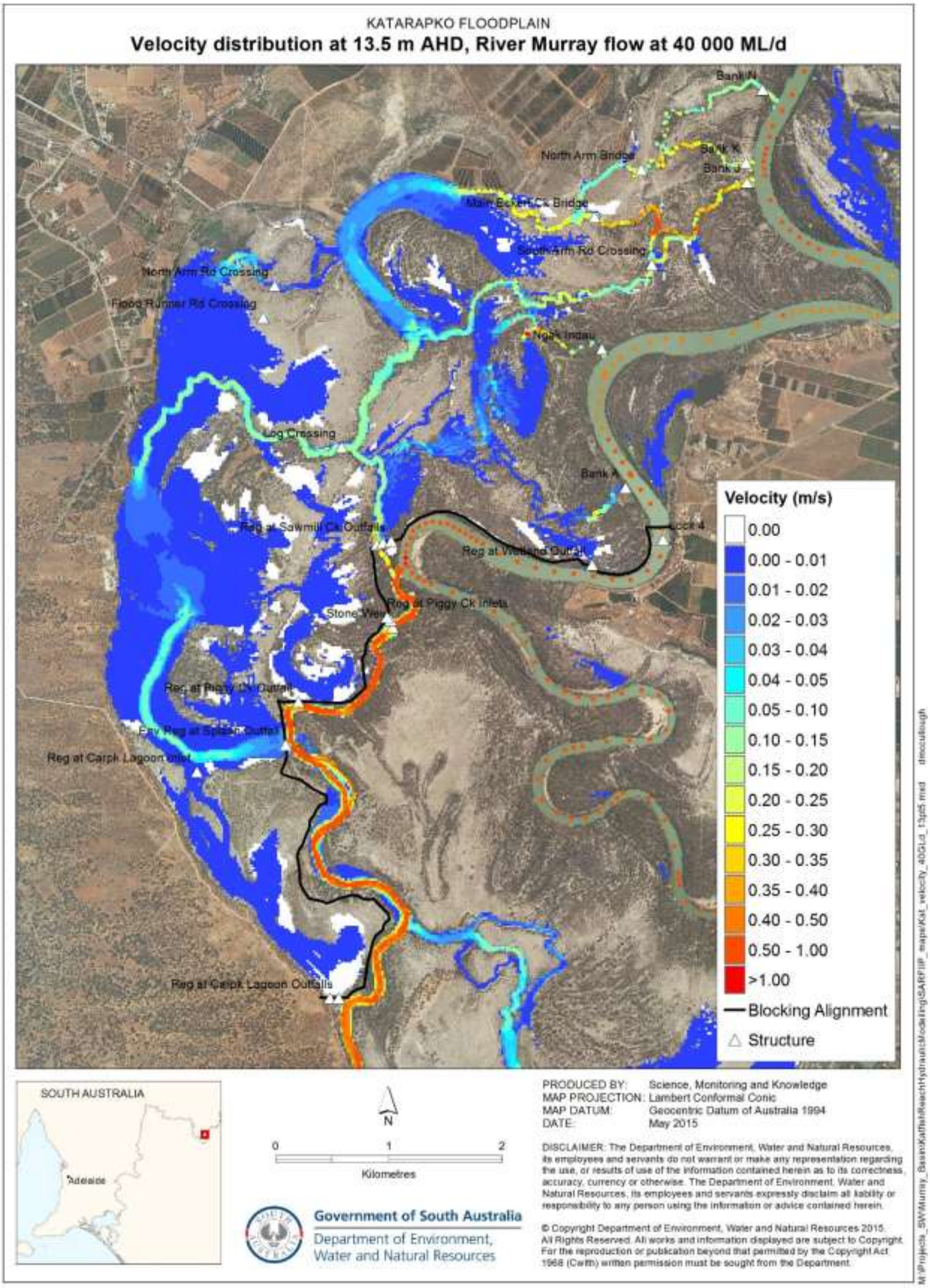

Figure A.3 Velocity distribution at 13.5 m AHD inundation height (Lock 4 weir pool 13.8 m AHD), River Murray flow at 40 000 ML/d

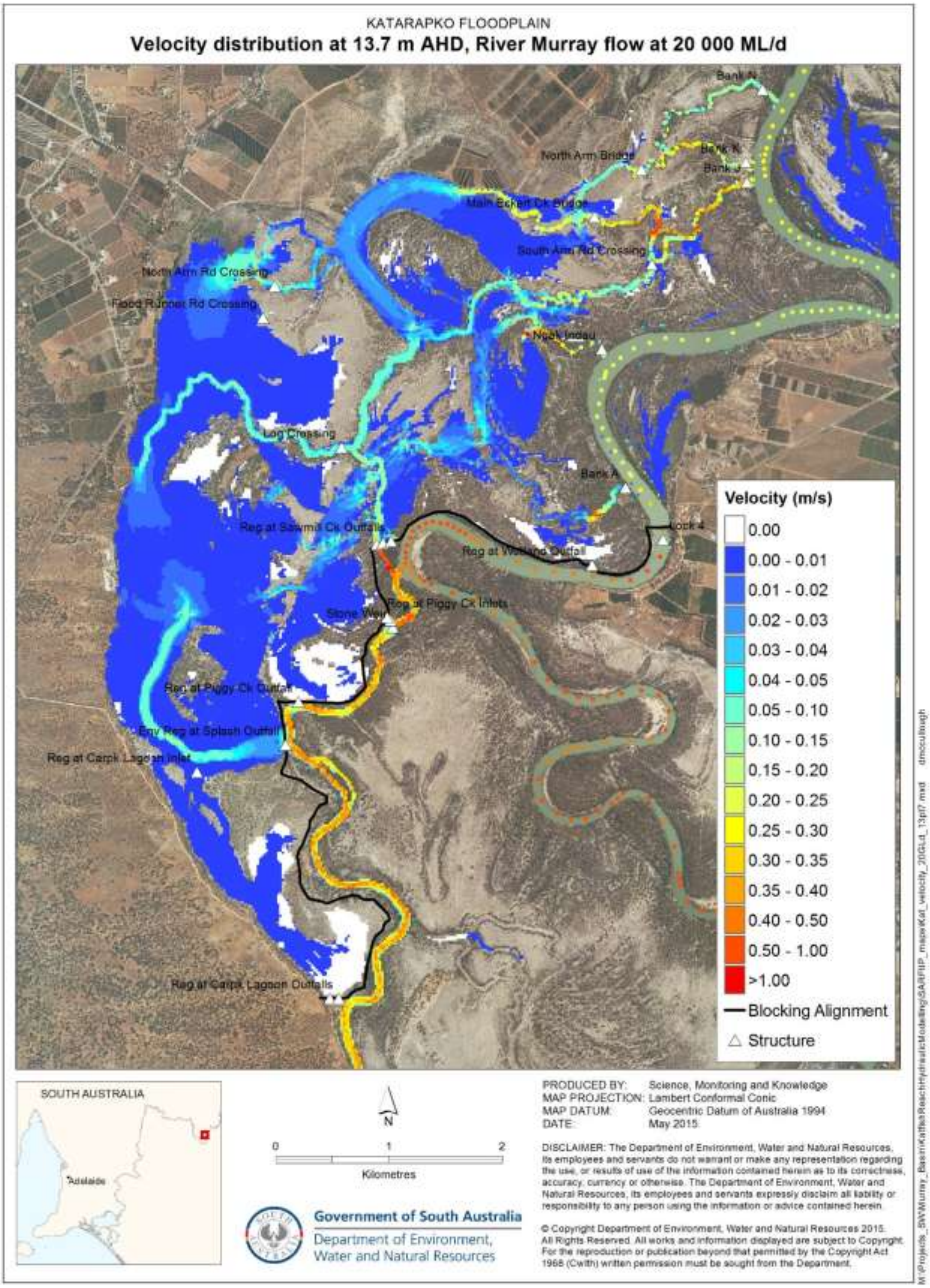

Figure A.4 Velocity distribution at 13.7 m AHD inundation height (Lock 4 weir pool 14.0 m AHD), River Murray flow at 20 000 ML/d

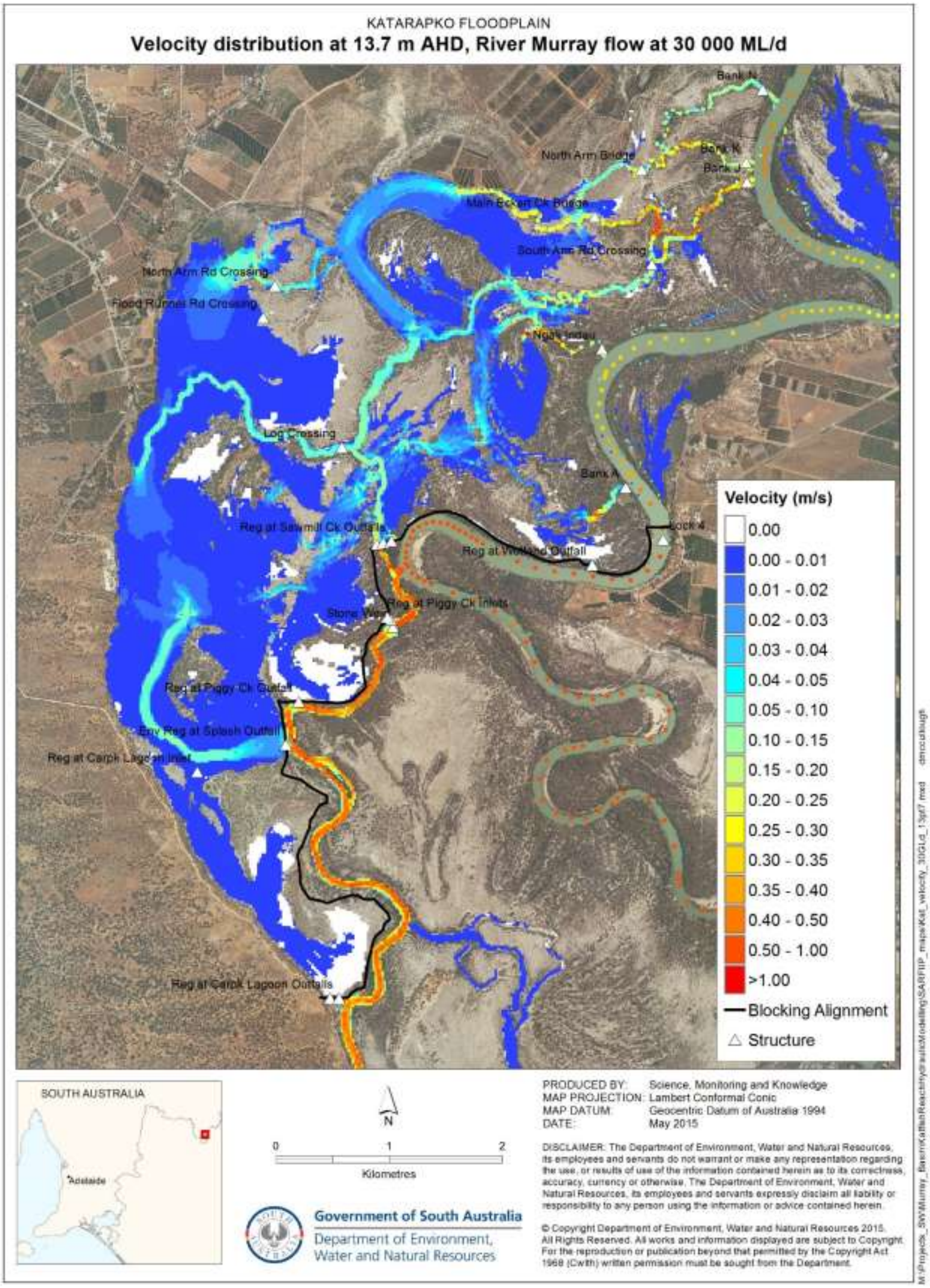

Figure A.5 Velocity distribution at 13.7 m AHD inundation height (Lock 4 weir pool 14.0 m AHD), River Murray flow at 30 000 ML/d

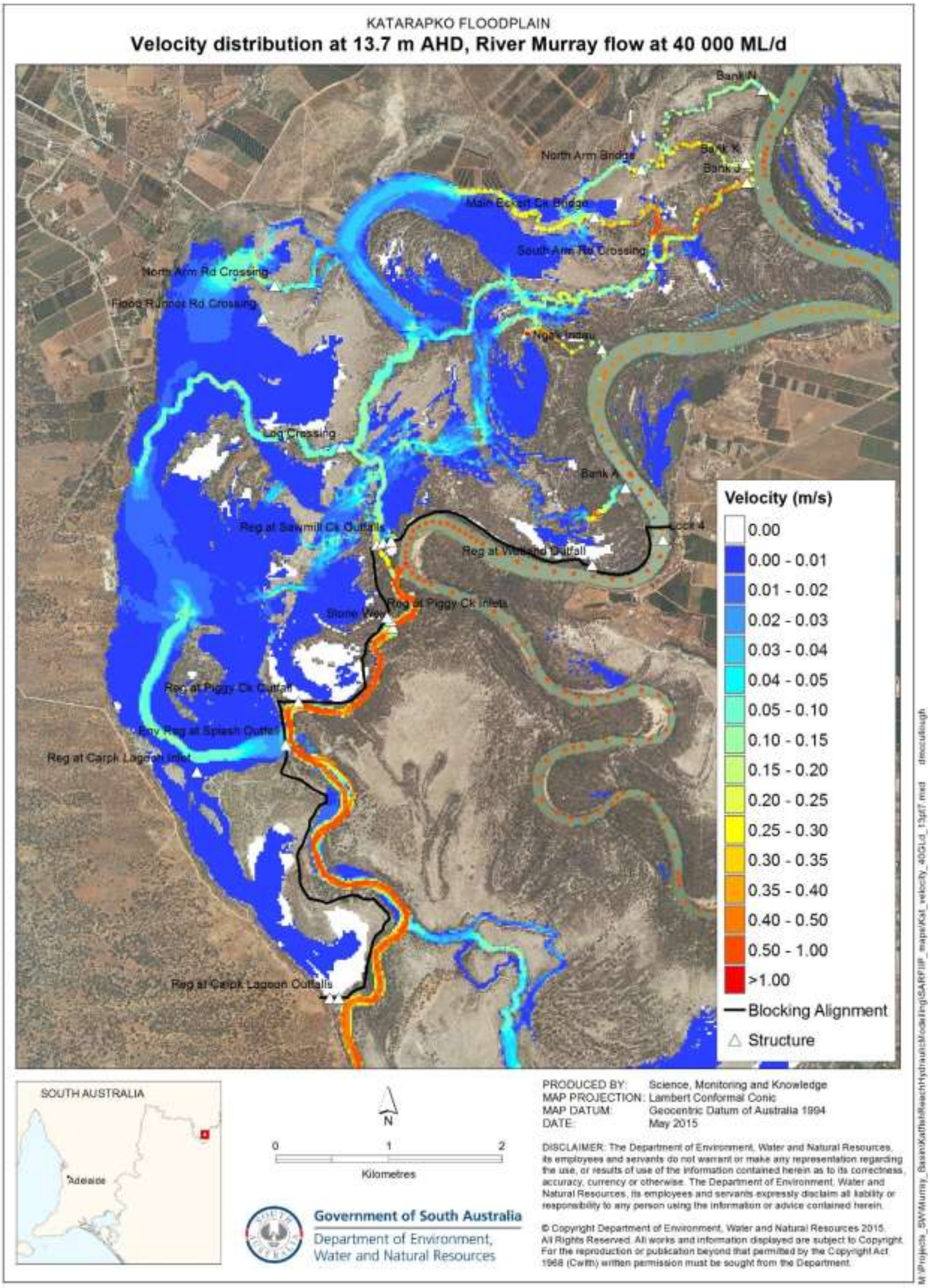

Figure A.6 Velocity distribution at 13.7 m AHD inundation height (Lock 4 weir pool 14.0 m AHD), River Murray flow at 40 000 ML/d

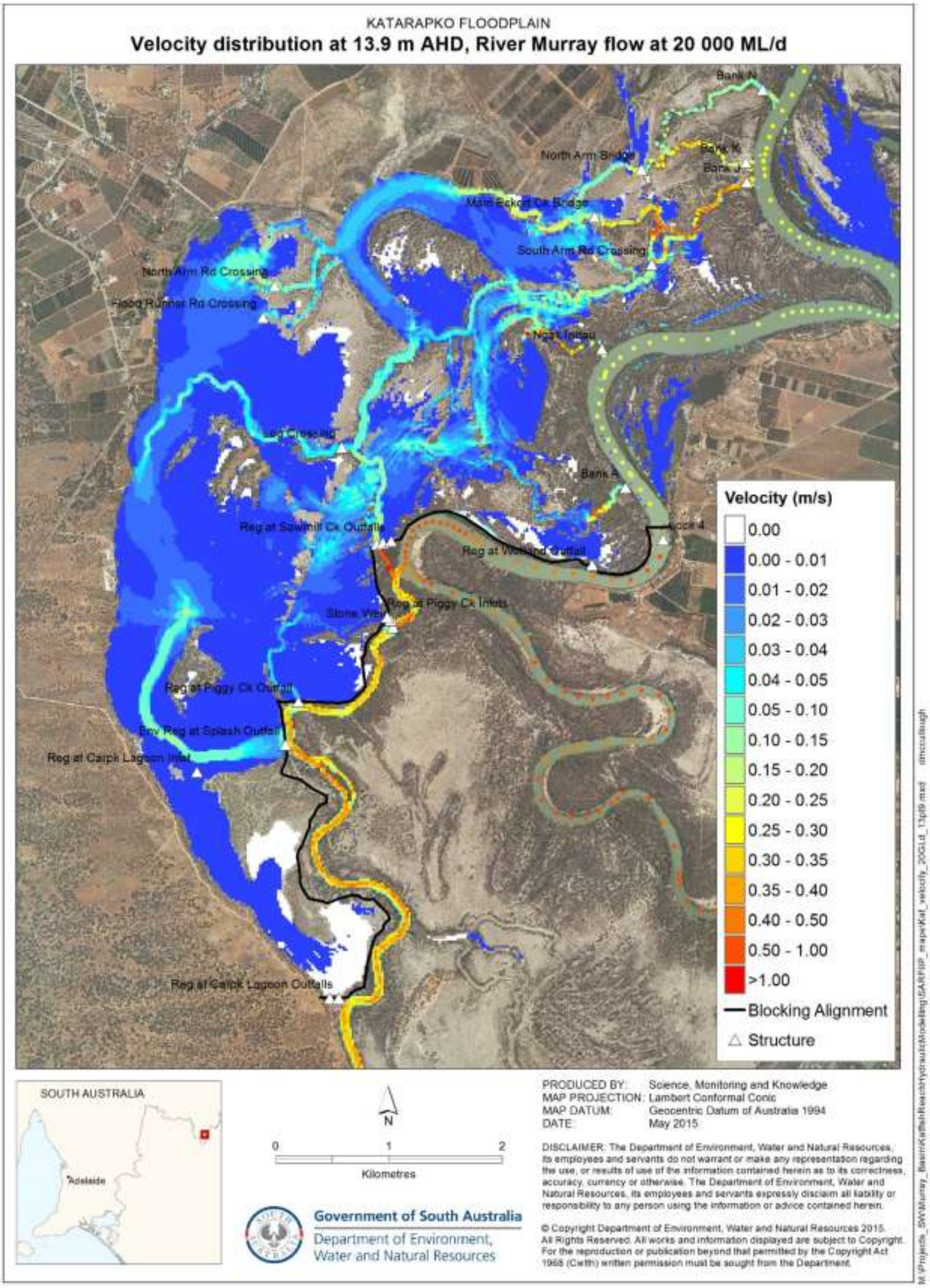

Figure A.7 Velocity distribution at 13.9 m AHD inundation height (Lock 4 weir pool 14.2 m AHD), River Murray flow at 20 000 ML/d

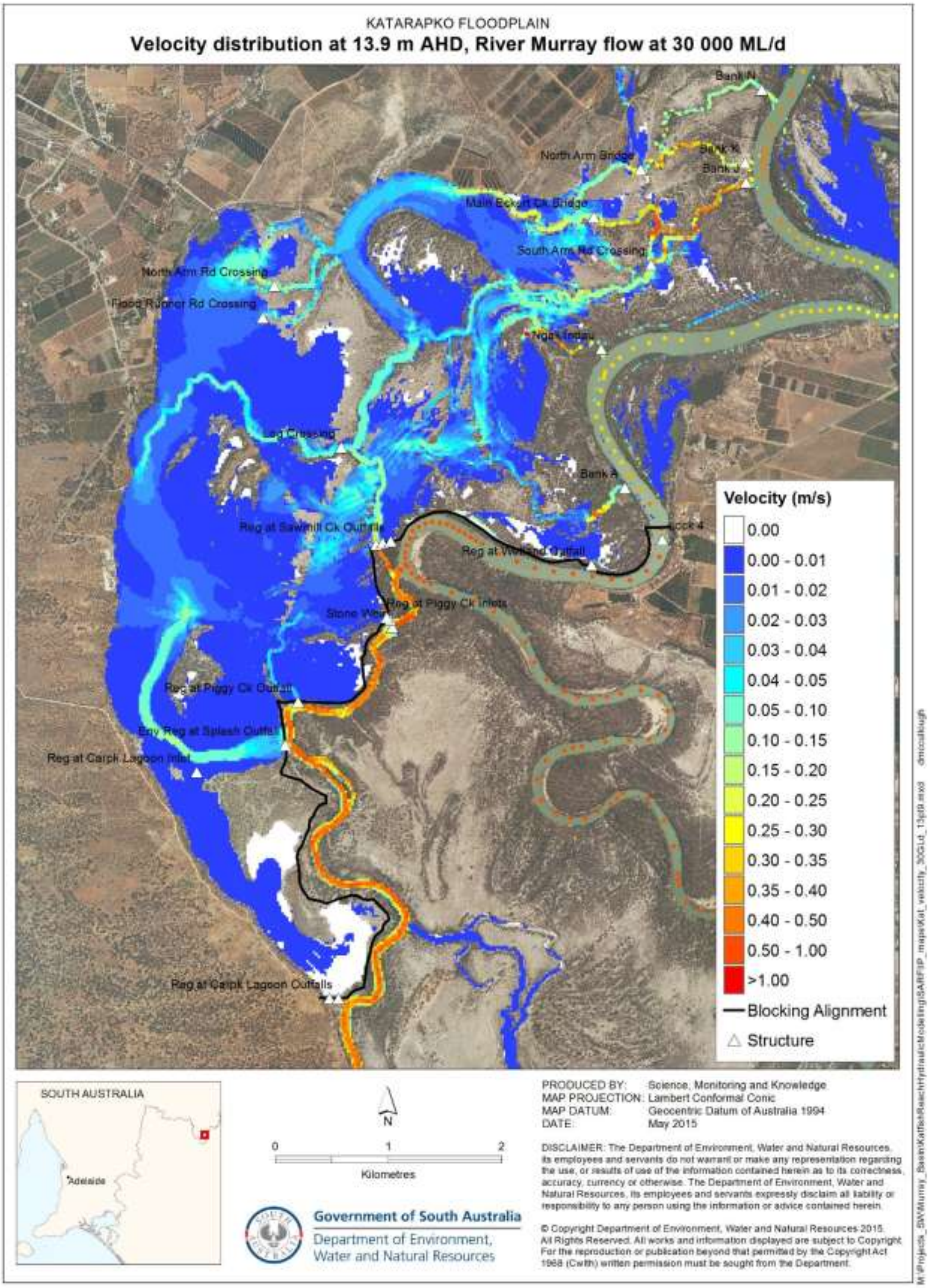

Figure A.8 Velocity distribution at 13.9 m AHD inundation height (Lock 4 weir pool 14.2 m AHD), River Murray flow at 30 000 ML/d

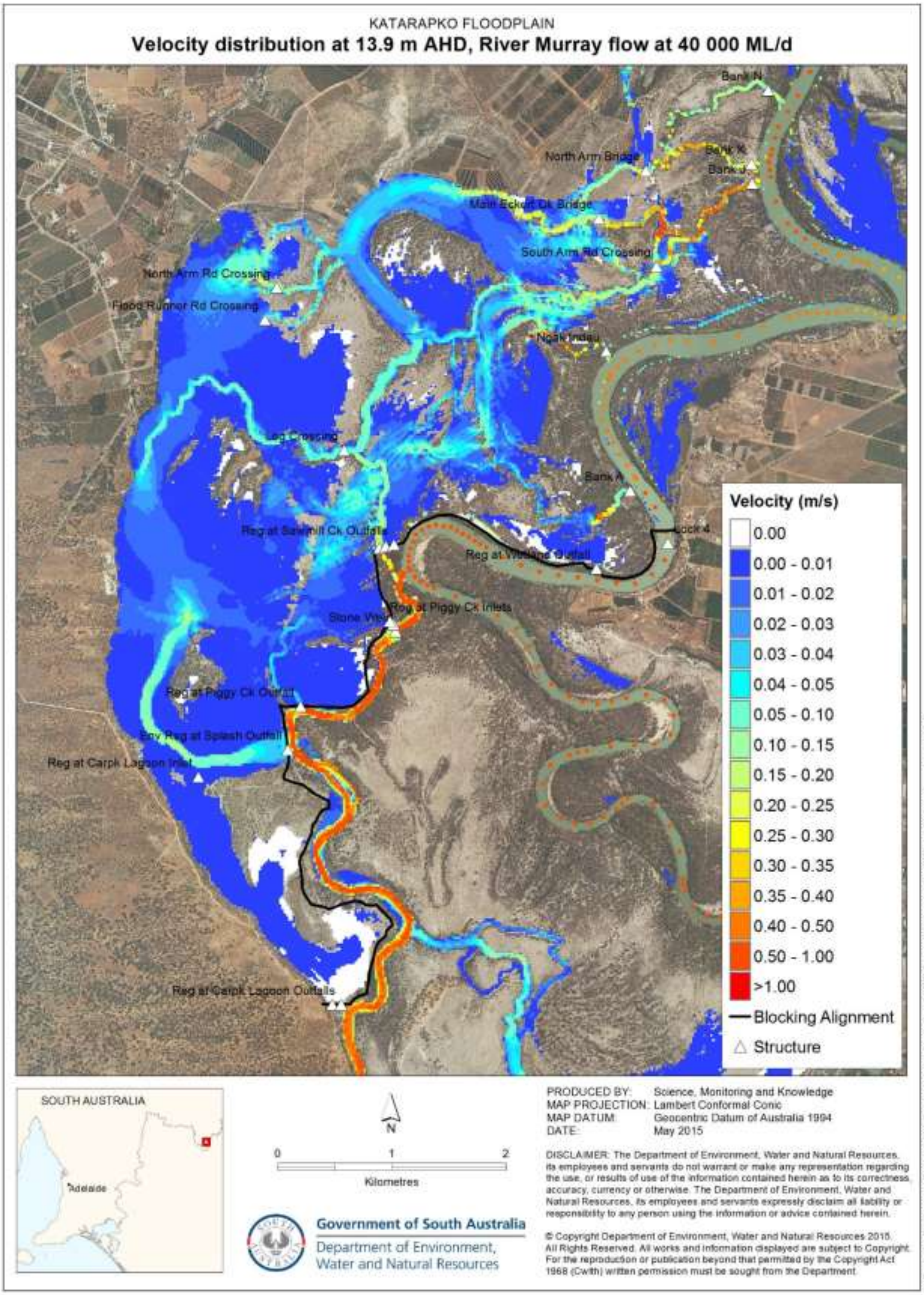

Figure A.9 Velocity distribution at 13.9 m AHD inundation height (Lock 4 weir pool 14.2 m AHD), River Murray flow at 40 000 ML/d

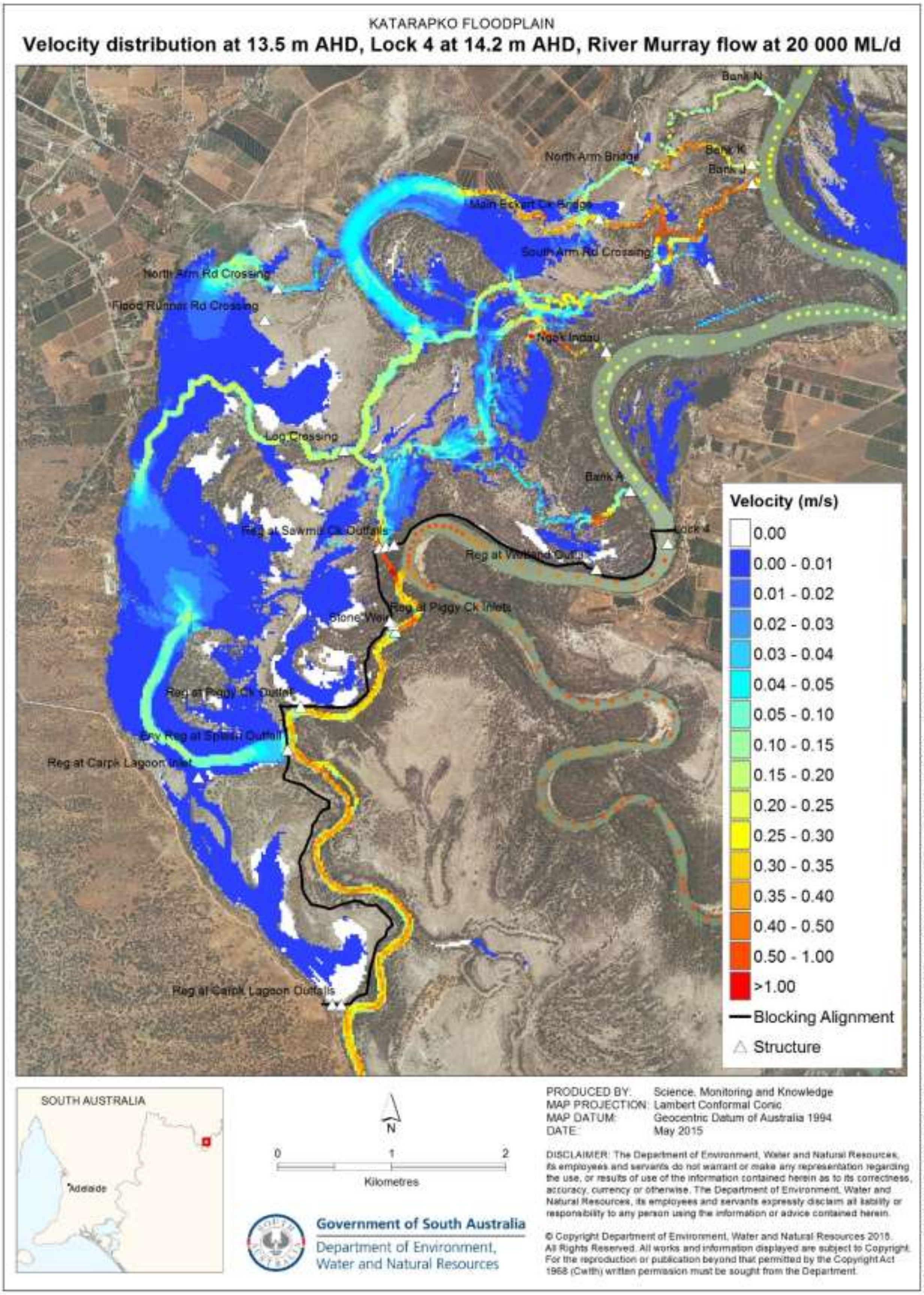

Figure A.10 Velocity distribution at 13.5 m AHD inundation height (Lock 4 weir pool 14.2 m AHD), River Murray flow at 20 000 ML/d

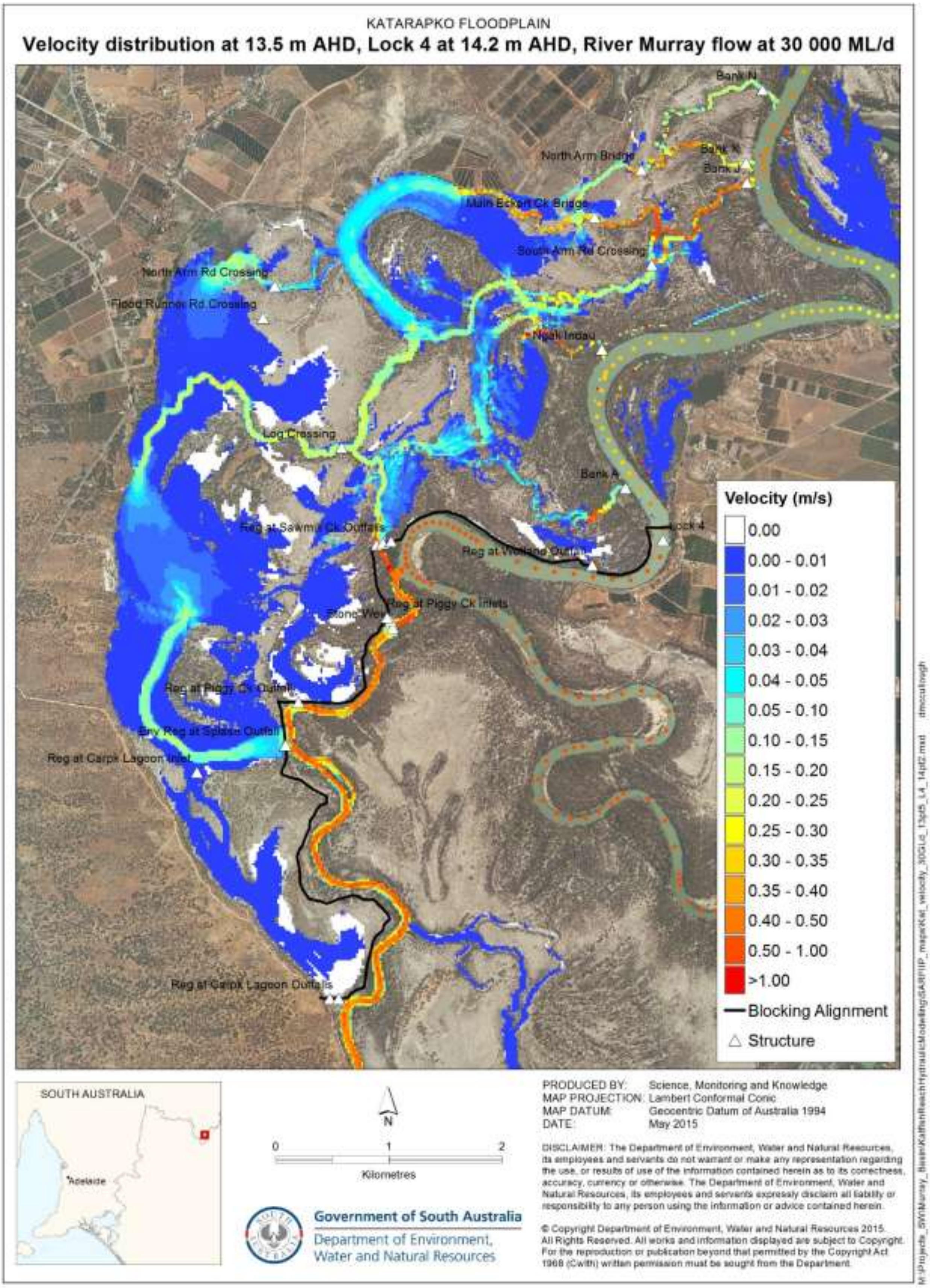

Figure A.11 Velocity distribution at 13.5 m AHD inundation height (Lock 4 weir pool 14.2 m AHD), River Murray flow at 30 000 ML/d

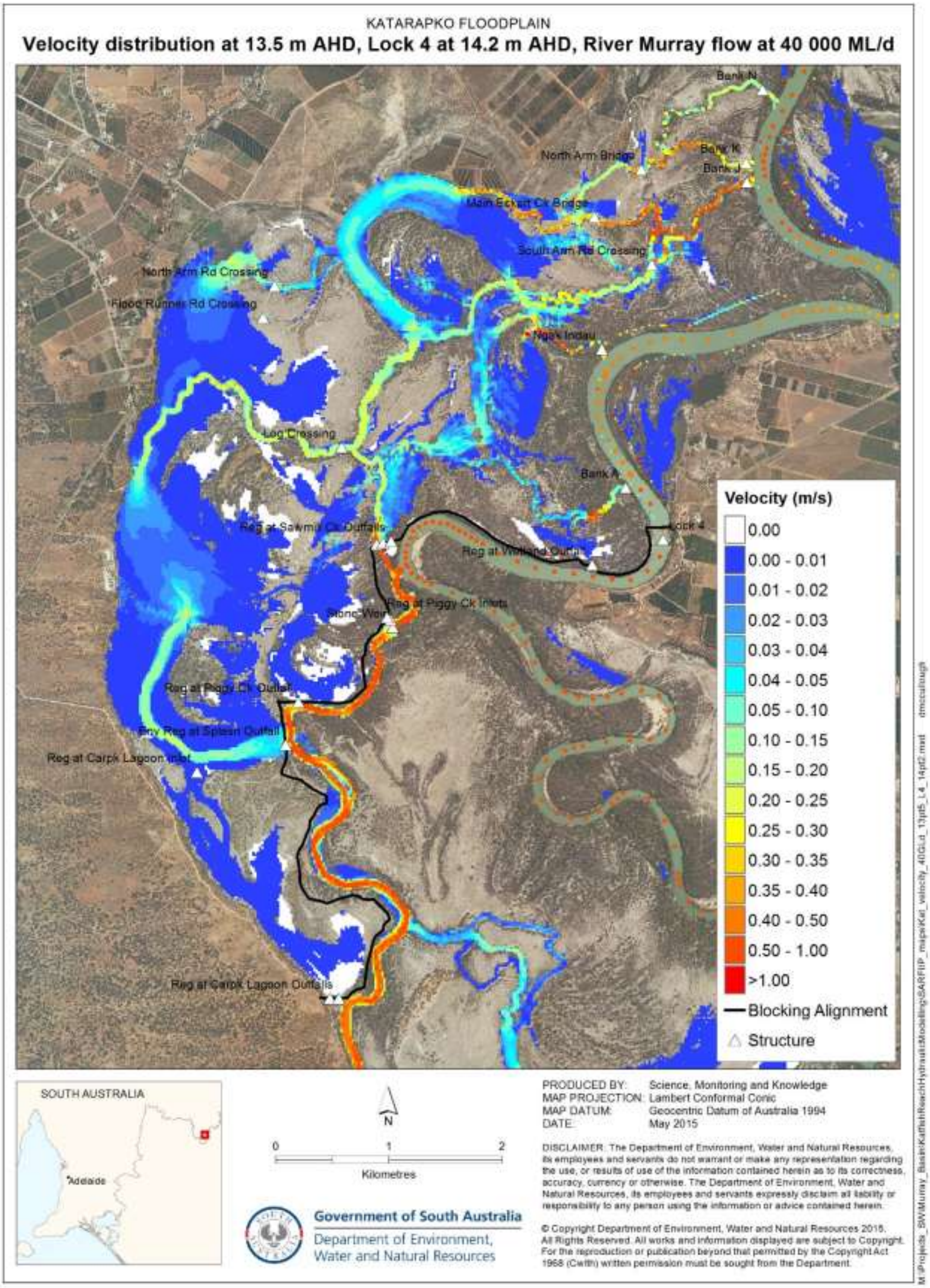

Figure A.12 Velocity distribution at 13.5 m AHD inundation height (Lock 4 weir pool 14.2 m AHD), River Murray flow at 40 000 ML/d

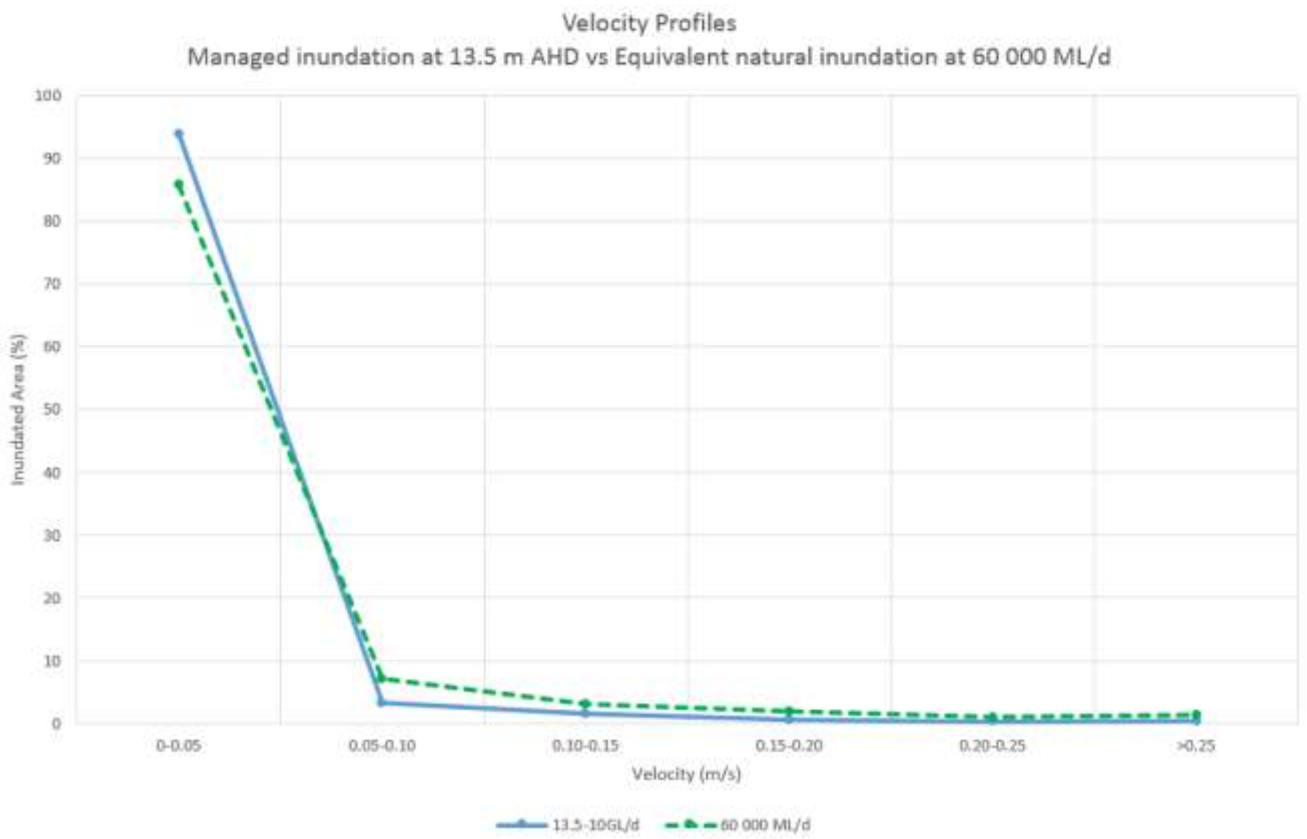

Figure A.13 Velocity profiles by percent total impounded area at 13.5 m AHD inundation option and equivalent natural flow based on inundated area at 60 000 ML/d

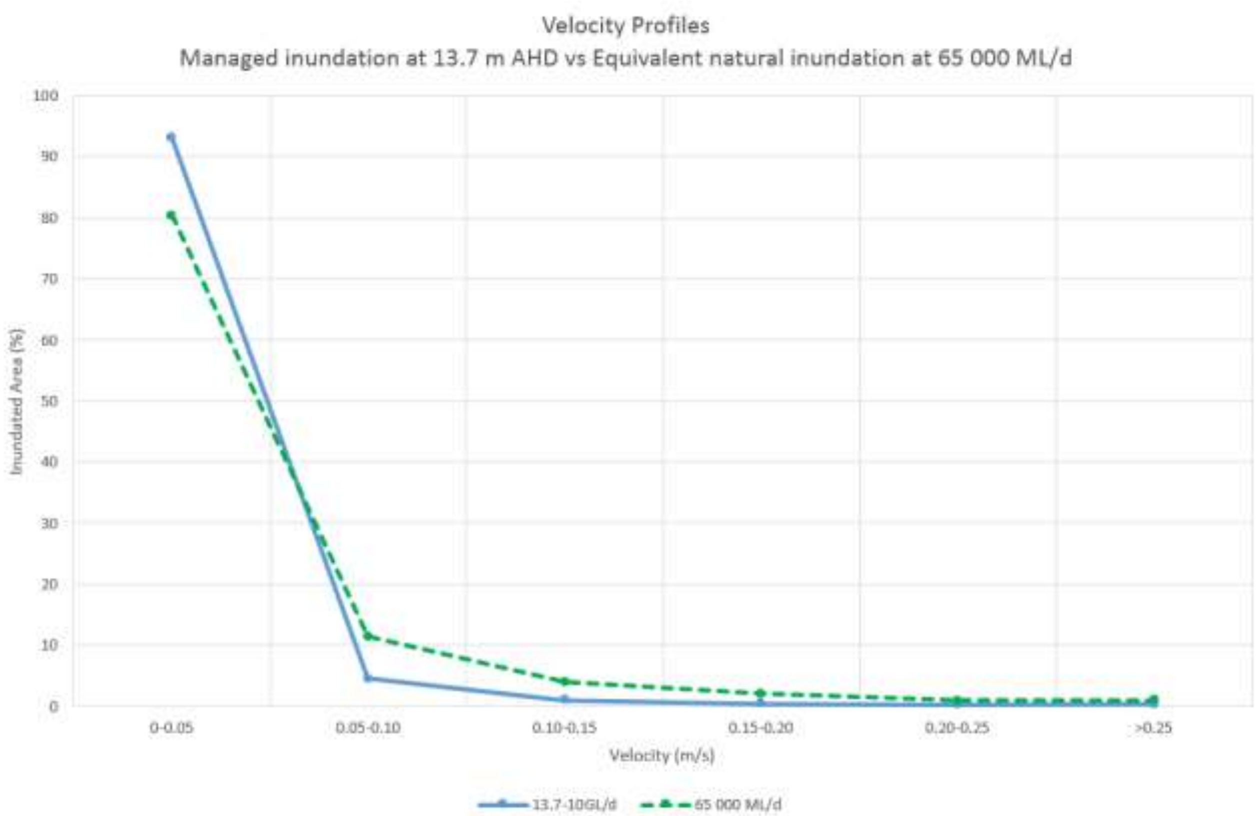

Figure A.14 Velocity profiles by percent total impounded area at 13.7 m AHD inundation option and equivalent natural flow based on inundated area at 65 000 ML/d

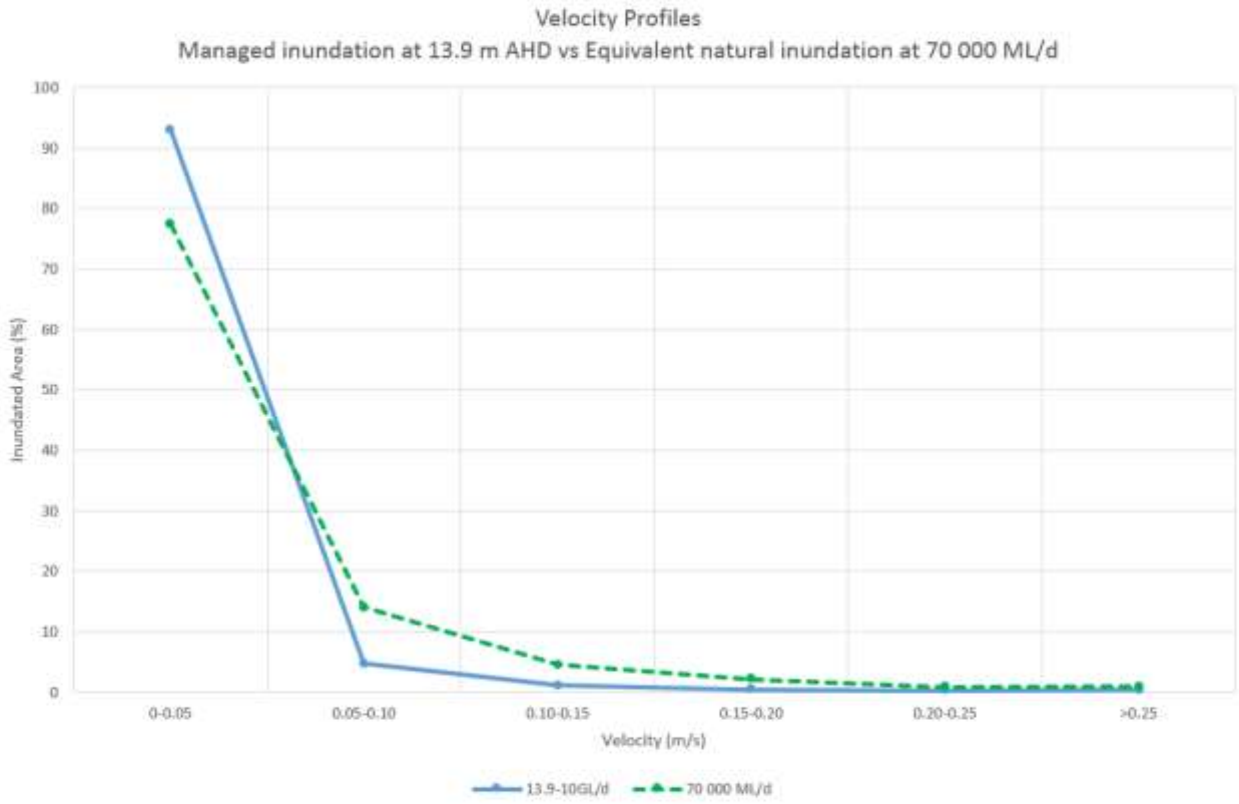

Figure A.15 Velocity profiles by percent total impounded area at 13.9 m AHD inundation option and equivalent natural flow based on inundated area at 70 000 ML/d

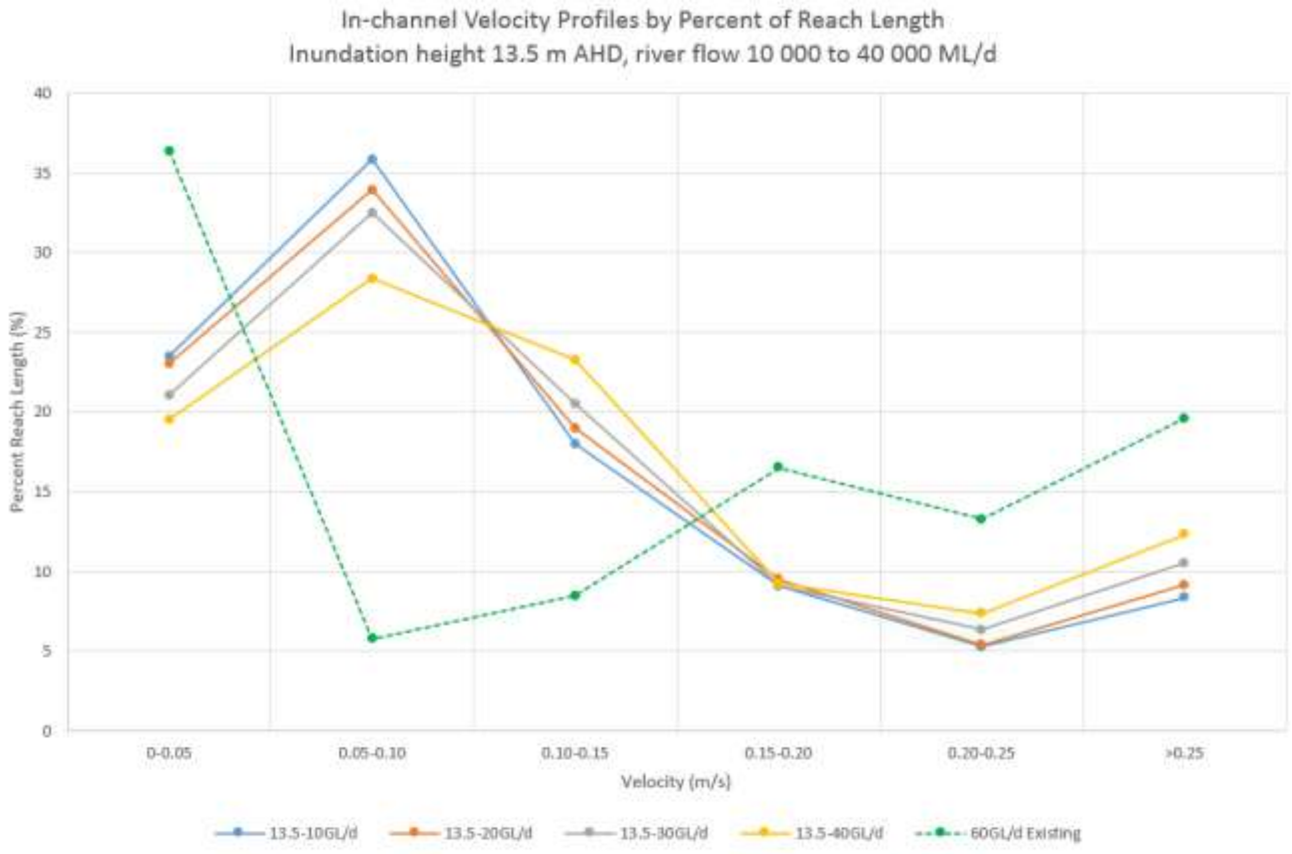

Figure A.16 Velocity profiles by percent reach length at 13.5 m AHD inundation option and equivalent natural flow based on inundated area at 60 000 ML/d

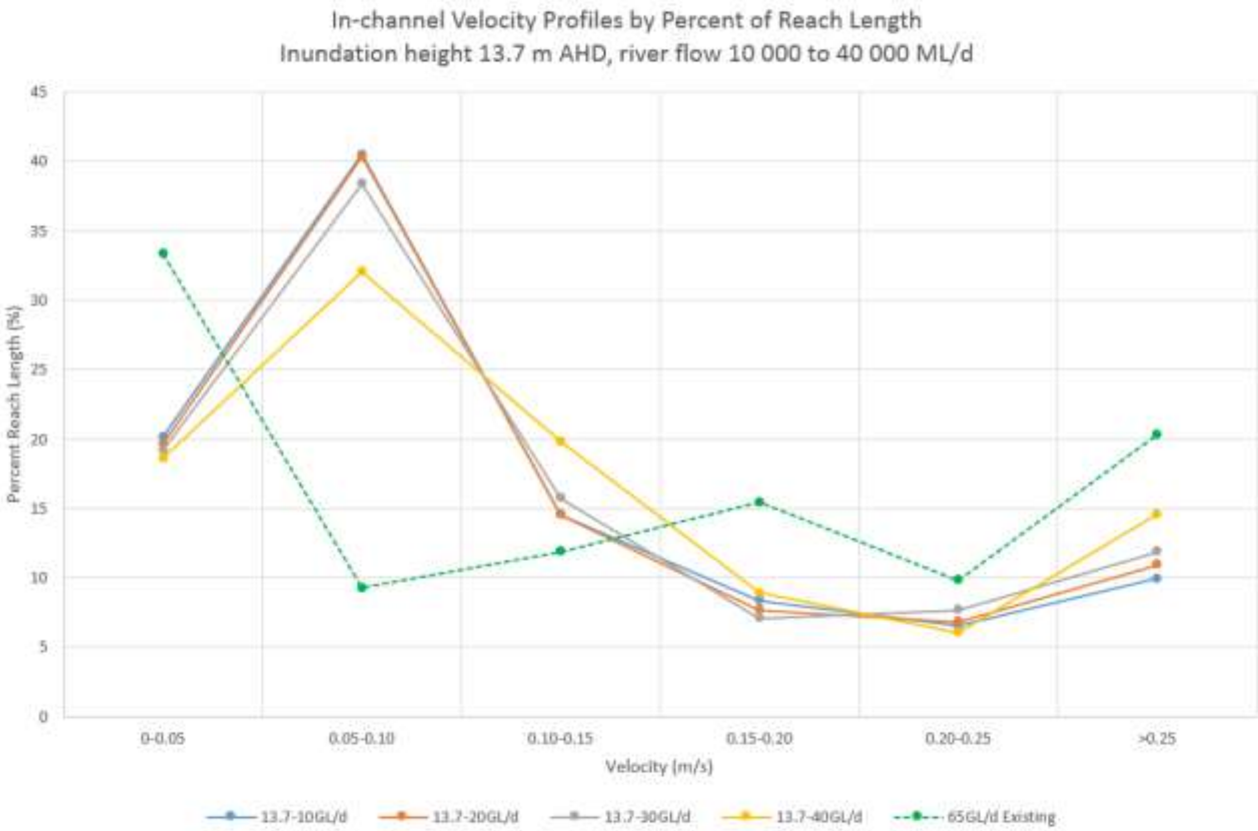

Figure A.17 Velocity profiles by percent reach length at 13.7 m AHD inundation option and equivalent natural flow based on inundated area at 65 000 ML/d

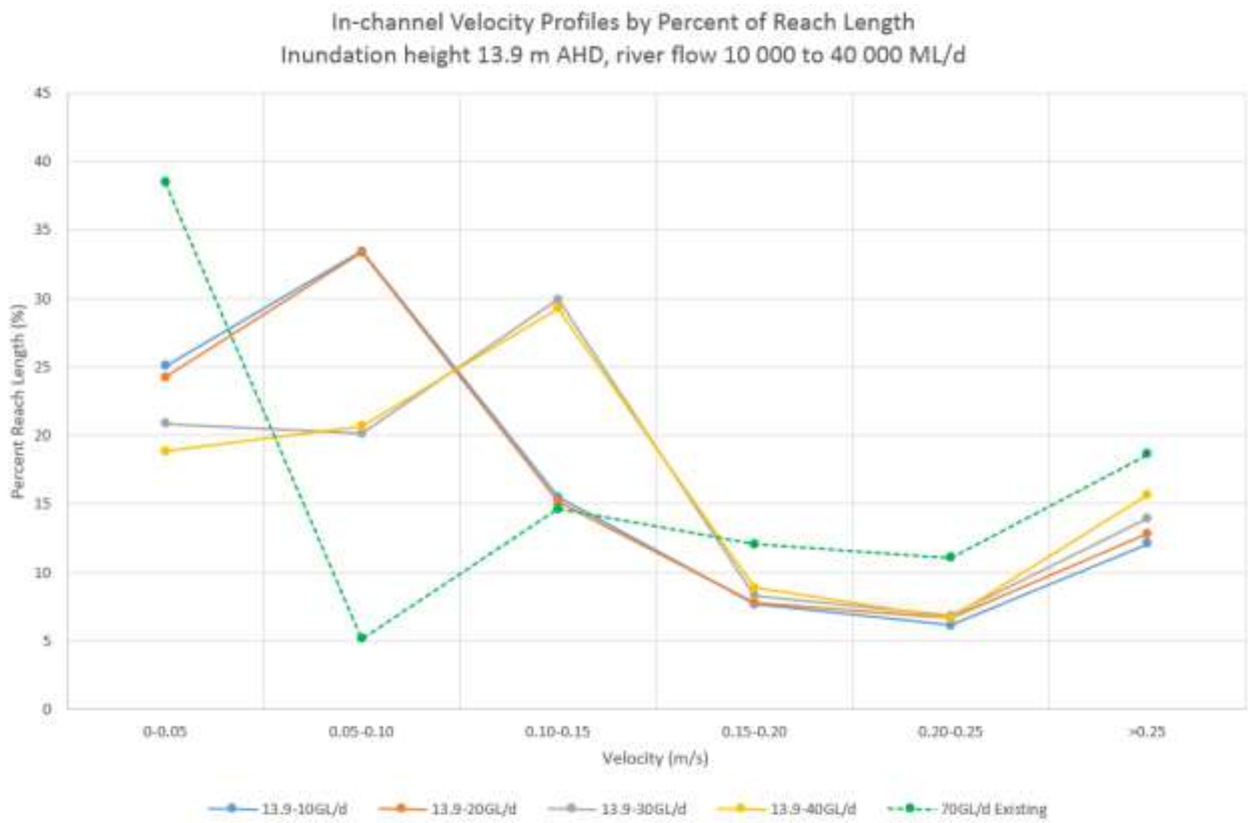

Figure A.18 Velocity profiles by percent reach length at 13.9 m AHD inundation option and equivalent natural flow based on inundated area at 70 000 ML/d

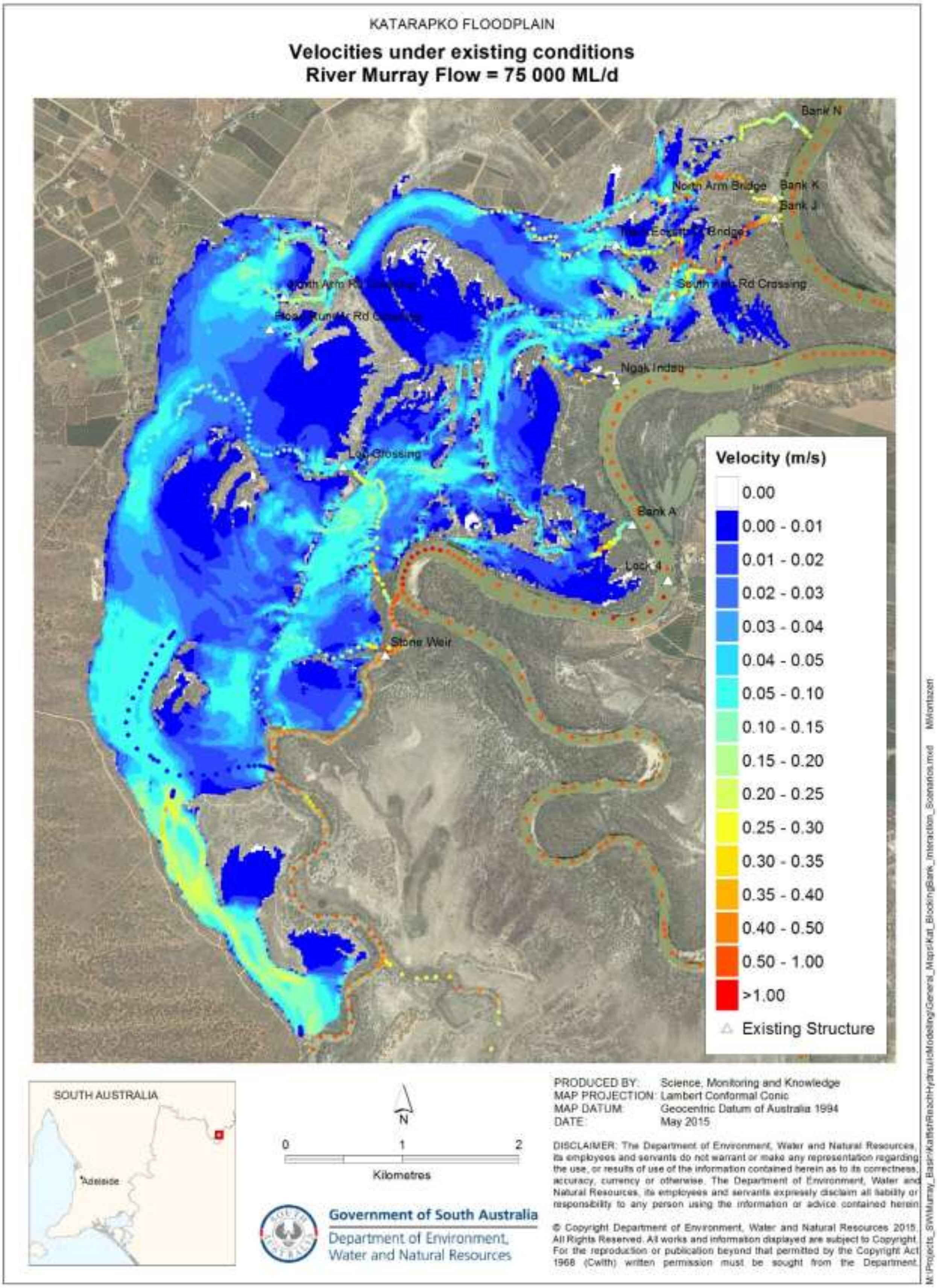

Figure A.19 Velocity distribution at 75 000 ML/d flow upstream of Lock 4 under existing floodplain conditions

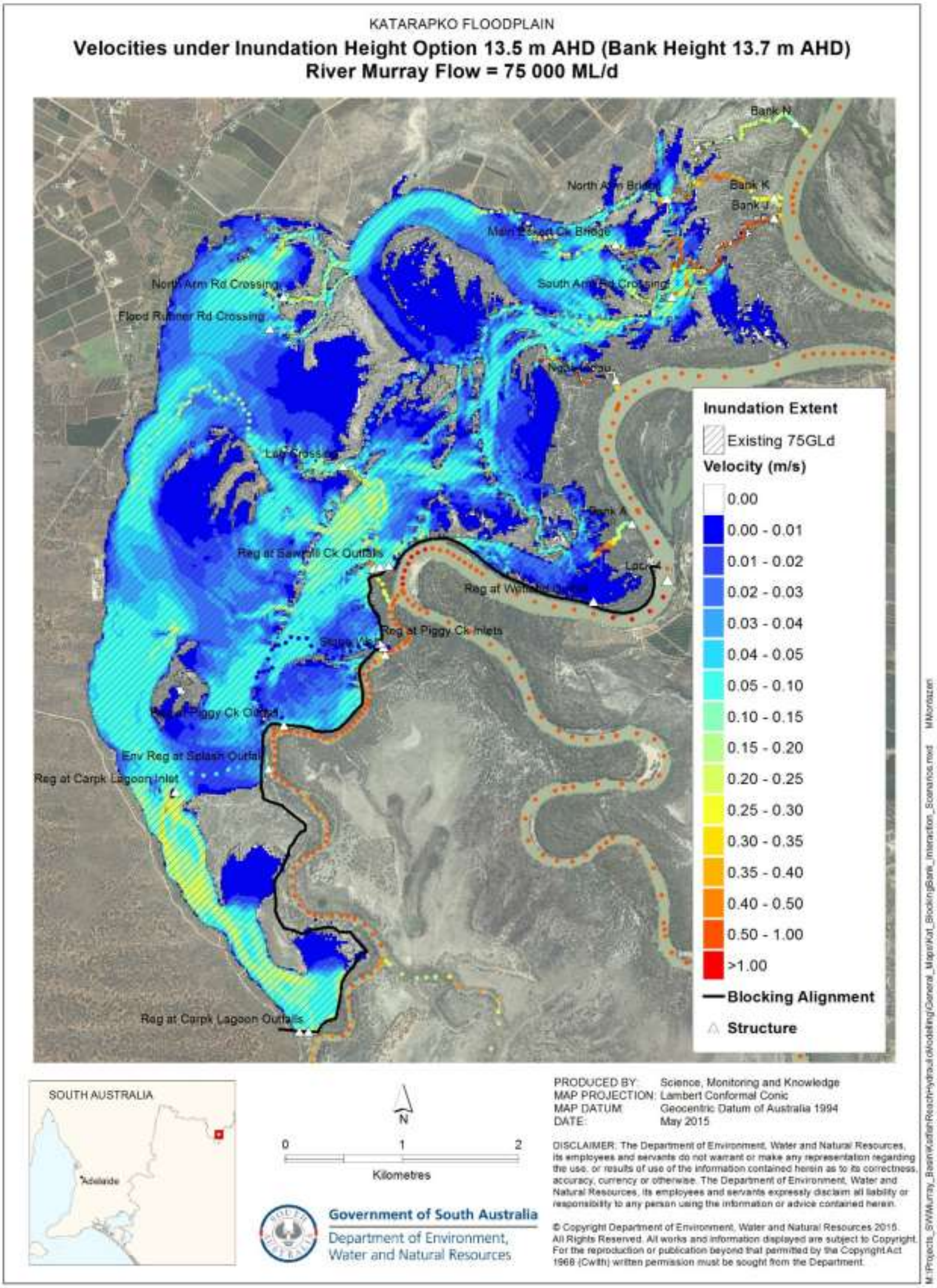

Figure A.20 Velocity distribution at 75 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.5 m AHD inundation option (bank height at 13.7 m AHD)

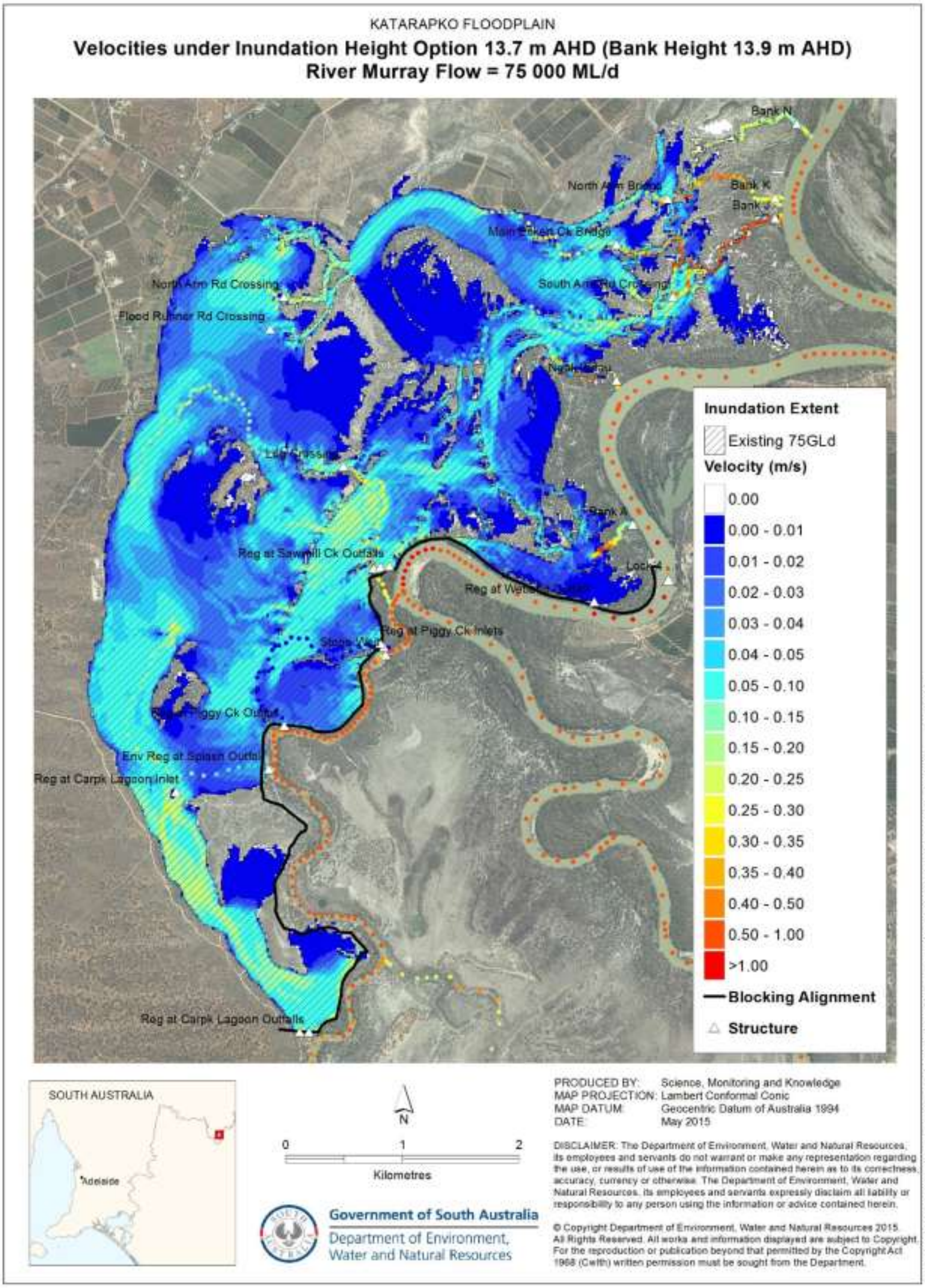

Figure A.21 Velocity distribution at 75 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.7 m AHD inundation option (bank height at 13.9 m AHD)

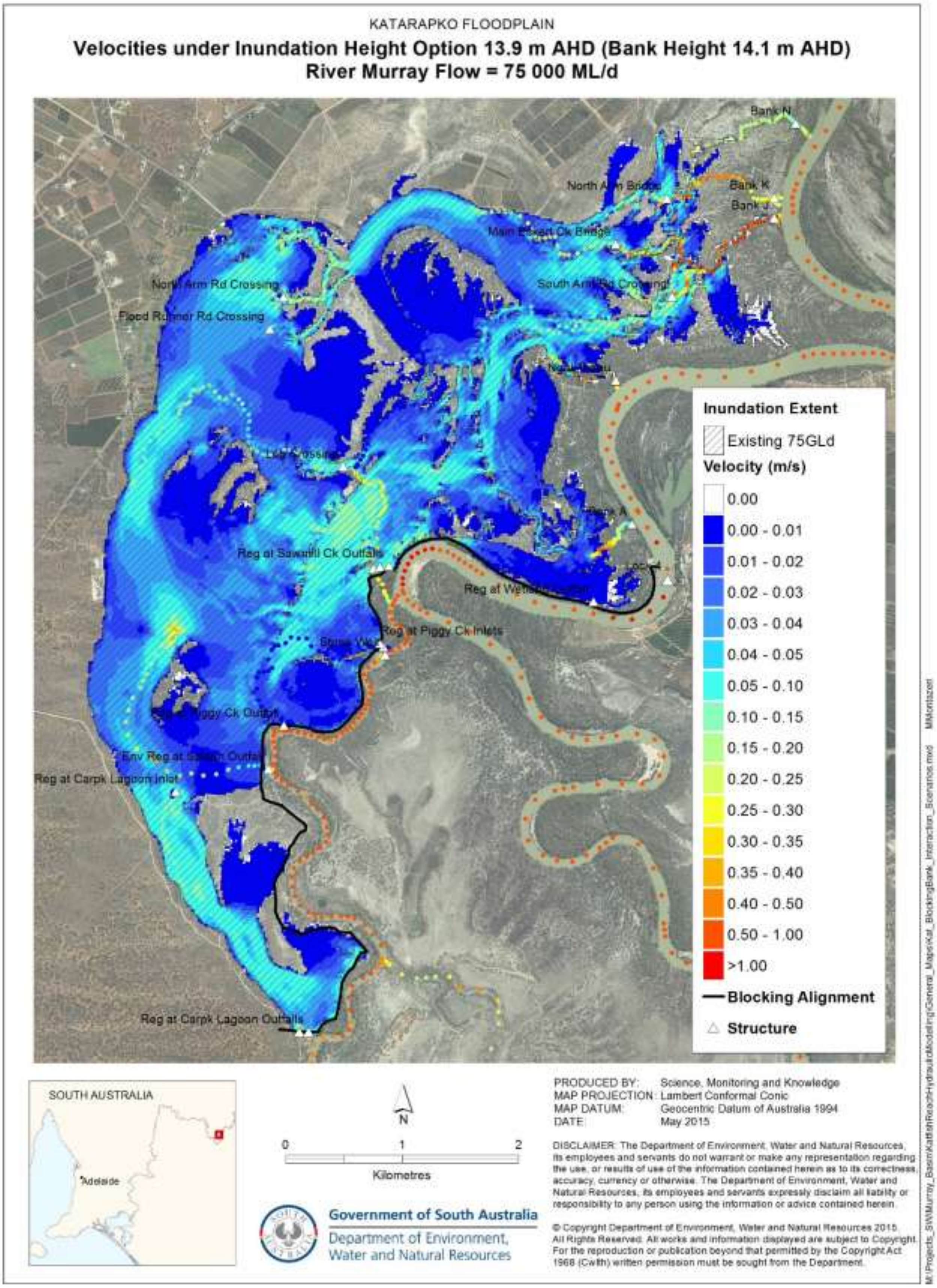

Figure A.22 Velocity distribution at 75 000 ML/d flow upstream of Lock 4 under upgraded floodplain conditions including blocking bank for 13.9 m AHD inundation option (bank height at 14.1 m AHD)

Government of South Australia

Department of Environment,
Water and Natural Resources