Australian Government

MURRAY–DARLING BASIN AUTHORITY

Cost estimates report

Constraints Management Strategy Prefeasibility

December 2014

Executive Summary

As part of CMS prefeasibility, the MDBA undertook work to estimate the potential costs associated with mitigating negative impacts of higher flows. Summary cost estimate results are presented in Table 1.

The purpose of the prefeasibility cost estimates is to inform decisions by Basin governments about whether to proceed to the feasibility stage, not specific investment decisions.

The MDBA investigated in particular the costs associated with two types of activity:

- The possibility of negotiating easements with landholders, or other arrangements, which would provide for the passage of environmental flows over their land.
- The possibility of infrastructure works to mitigate the impacts of higher environmental flows.

These are not the only options that are possible. For example, another option would be flow advice so landholders know in advance when an environmental flow will happen. However, they are the options that are likely to be most material to the potential costs.

The MDBA engaged independent consultants to assist in developing cost estimates.

If the CMS were to progress to feasibility, further work could be undertaken at a local level, including with a sample of properties at a property-by-property level, to develop more detailed and robust cost estimates.

The cost estimates are subject to assumptions and limitations which are considered reasonable in light of the purpose of prefeasibility cost estimates, i.e. to inform decisions about whether to proceed to feasibility. In particular:

- They were generally based on a desktop analysis, drawing largely on GIS-based spatial data.
- Easement estimates assume that land values, agricultural gross margins, and impacts of higher flows can be generalised in a model. In reality they would vary from property to property.
- Infrastructure cost estimates make generic assumptions about the works required.
- Infrastructure estimates are based on a GIS analysis of what infrastructure would potentially be affected, and incomplete information on the depth of inundation. For the purposes of prefeasibility it was not possible to verify, on ground, the extent to which infrastructure items would actually be affected.
- Estimated costs of crossings and bridges assume that only 75 percent of the full estimated cost would be paid. This is intended to account for (i) a proportion of works on crossings would not be required, as interrupted access would also be addressed through easements; (ii) there would be scope for cost sharing as upgrades to bridges and crossings would also provide considerable benefits to stakeholders, above and beyond mitigating the impacts of a constraints-relaxed flow regime.

Table 1: Summary of CMS prefeasibility cost estimates

CMS region	Estimated costs ($m) Costs are for maximum flow rates in each region, and associated frequency, timing and duration of flows in each region, as per the MDBA's "BP2800RC" model except where indicated										
	Easements (GHD reports)	Roads (URS report)		Bridges/ crossings (URSs report)		Bridges/crossings (rationalised by 25%)		Other infrastructure		Total (bridges/crossings rationalised by 25%)	
		Moderate[1]	High	Moderate	High	Moderate	High	Moderate	High	Moderate	High
Hume-Yarrawonga (40 GL/day)	6	<1	<1	6	7	4	6	5	10	16	22
Yarrawonga-Wakool (35 GL/day)	7	11	18	88	109	66	82	Nil costed[2]		84	107
Yarrawonga-Wakool (50 GL/day)[3]	~8	11	17	114	142	85	106			~105	~131
Yarrawonga-Wakool (77 GL/day)[4]	~14	26	39	178	220	134	165			~174	~218
Goulburn[5] (40 GL/day)	6	6	10	1	1	<1	<1	18	30	31	47
Murrumbidgee (48.5 GL/day)	18	12	20	15	18	11	14	22	25	66	80
Lower Darling (17 GL/day)	<1	<1	<1	2	2	<2	<2	3	4	4	6
South Australia (80 GL/day)	2	<3	3	Nil	Nil	Nil	Nil	Nil	Nil	<5	5
Gwydir	Not estimated										

[1] "Moderate" and "High" estimates reflect outcomes of probabilistic analyses undertaken by URS, which take into account potential variation in infrastructure costs.
[2] There may be costs associated with levees but it was not possible to estimate these costs due to insufficient information.
[3] Modelled hydrological outputs were not available to inform estimates in the Yarrawonga-Wakool assuming relaxation of constraints to 50GL/day or 77GL/day. Infrastructure costs for these flow rates are based on untested hydrological assumptions (assume 2 extra flow events every 10 years) and should be treated as indicative and in the context of those assumptions. Easement costs are rough indicative estimates extrapolating from GHD estimates for 35GL/day and should be treated accordingly.
[4] As explained in note 3.
[5] Costs in Goulburn assume infrastructure works on levees, which would mitigate inundation impacts outside levees. Total costs would be lower if those works are not included.

Table 2: Details of estimated costs of "other infrastructure" as noted in Table 1

Region	Infrastructure item	Source	Prefeasibility cost estimates ($ million)
Lower Darling	Regulators on the Lower Darling	URS (2014) report to the MDBA	2.5 to 4
Murrumbidgee	Upgrade to Mundarlo Bridge	SKM (2013) estimated $8.7 million. This has been rounded up to an indicative $10 million.	10
	Stormwater system at Wagga	URS (2014) report to the MDBA	5.5 to 8
	Stormwater system at Narrandera	Advice by Narrandera Council (2014)	1
	Regulator on Yanco Creek	URS (2014) report to the MDBA	8 to 10
Goulburn	Levee outlet structures	URS (2014) report to the MDBA	4 to 8
	Levees minimum level of protection	Water Technology (2013) report to the Goulburn-Broken CMA – initial estimates	6
	Address levees critical points of weakness	Water Technology (2013) report to the Goulburn-Broken CMA – initial estimates	2
	Strategic levee realignment	Water Technology (2014) memo to the MDBA	6 to 14

Some potential costs were not estimated for the prefeasibility phase. This is because there is not yet enough information to estimate these costs on a consistent or robust basis. Costs not estimated include:

- Cost estimates in the Gwydir.
- Costs of mitigating impacts on specialist businesses, e.g. caravan parks and golf courses.
- Potential works on levees in the Yarrawonga-Wakool.
- Upgrades to stream gauging networks.
- Upgrades of drainage or stormwater management systems, additional to those already considered.
- Costs of mitigating impacts outside the seven key focus areas identified in the *Constraints Management Strategy 2013 to 2024.*

Preliminary estimates of cost indicate that addressing constraints in all seven key focus areas may exceed the $200 million set aside for constraints measures in the Water for the Environment Special Account. However, these estimates are preliminary only and will be refined with further investigation.

If the CMS progresses to the feasibility phase, it is recommended that further costing work be undertaken. This would include:

- Refining the work undertaken during 2014 by taking into account more local-level information.
- Developing estimates of costs associated with mitigation activities which were not considered for the prefeasibility cost estimates.

Introduction

As part of the CMS pre-feasibility phase, the MDBA undertook work to inform Basin governments of the potential costs associated with mitigating negative impacts that might be associated with higher managed environmental flows.

The purpose of the prefeasibility cost estimates is to inform decisions about whether to proceed to the feasibility stage, not specific investment decisions.

The MDBA investigated in particular the costs associated with two types of activity that could be undertaken to mitigate the impacts of higher flows:

- The possibility of negotiating easements with landholders, or other arrangements, which would provide for the passage of environmental flows over their land.
- The possibility of undertaking infrastructure works to mitigate the impacts of higher environmental flows—for example, works on roads or river crossings.

These are not the only options that are possible. For example, another option would be flow advice so landholders know in advance of a flow. However, they are the options that are likely to be most material to the potential costs that may be associated with mitigation.

The MDBA engaged independent consultants (GHD, URS and Water Technology) to assist in developing the cost estimates. The MDBA also took into account earlier work by SKM (2013) and Water Technology (2013) to estimate costs of potential upgrades to the Mundarlo Bridge and levee-related works in the Goulburn.

This report describes the approaches used, and how the technical work undertaken by consultants and others informed the cost estimates.

A separate report on flow inundation and mapping information (MDBA 2014) provides further details on the information prepared by MDBA and provided to the costing consultants.

Methods used to estimate costs

Estimates of the costs of easements or other arrangements

Approach in reaches other than South Australia

In five CMS reaches (Goulburn, Hume-Yarrawonga, Yarrawonga-Wakool, Lower Darling, and Murrumbidgee) costs were estimated using a model developed by GHD. This model estimated the costs of hypothetical easements with landholders, by considering how changes in the flow regime could affect the worth of the affected land, taking into account in particular the impacts of different flow scenarios on agricultural activities.

It was assumed for the purposes of prefeasibility cost estimates that easements would be the preferred mitigation option. In practice, alternative mitigation options may be viable on the proviso that they focus on lasting solutions to provide certainty and protection to stakeholders over time. However, even if alternative mitigation options are pursued, the associated costs would be of a similar magnitude, as they would need to reflect the same impacts that would be experienced as a result of flow regime changes. Consequently, the costs associated with easements are considered a reasonable approximation for the prefeasibility assessment.

A similar assessment was not undertaken in the Gwydir as insufficient information was available to inform a robust estimate. A similar approach could be applied if and when relevant information becomes available.

Key inputs to the model included (further details are at Appendix E):

- Information on impacts of changes in flows, as identified through analysis of inundation maps corresponding to specified flow rates.
- Spatial data on land use (particularly agricultural land use).
- Hydrological data relating to “baseline” and “CMS” flow regimes.
- Data on land worth and gross margins.
- Understanding of how different flow regimes affect agricultural activities (e.g. crop or pasture production).
- Assumptions regarding the extent of “interrupted access” (refer to Appendix C).

In estimating the costs of easements, it was assumed that the changes in flows being considered through the CMS would primarily affect the productive (agricultural) value of the land, rather than its amenity value. In some regions (e.g. the upper Murray) the amenity value can be considerably higher than the productive value. If the impacts of a post-CMS flow regime are primarily on productive (rather than amenity) value, easements are likely to be a far more cost effective option for securing an ongoing right to release higher managed flows, than alternatives such as purchasing land outright. It should be noted however that there may be some individual landholders for which outright sale is a possible solution.

The estimates of easement costs are indicative and subject to a range of caveats due to the assumptions that have been made. If it is decided that easements should be pursued as a

mitigation option, more detailed work would need to be undertaken, including with a sample of properties at a property-by-property level, to determine the costs associated with specific easement arrangements.

Further details are in the costing methods report by GHD (2014) listed at Appendix A.

Approach in South Australia

In South Australia, the main impacts of higher regulated flows would be on “shacks” (i.e. private houses, used largely for recreation, on the banks of the River Murray) rather than on agricultural land. Given the different nature of the impacts, rather than easements with landholders, it is anticipated that a different type of land management arrangement would be negotiated.

The costs that would be associated with such arrangements were estimated by GHD, using a similar conceptual approach to the method used for estimating the costs of easements in other reaches, but taking into account the different nature of the impacts.

Key inputs to the estimates included (further details are at Appendix E):

- Data on numbers of shacks and allotments inundated at different flow rates.
- Land and capital values for the relevant allotments and shacks.
- Assumptions regarding various activities that might have to be undertaken to mitigate impacts of higher flows (e.g. costs of cleanup).

Further details are in the South Australia costs report by GHD (2014) listed at Appendix A.

Estimates of the costs of infrastructure works

Approach to costing roads, bridges, and crossings

The costs of most infrastructure works were estimated using a model developed by URS Australia. This model assumed that “unit rates” can be used to estimate the costs of infrastructure work on most structures—e.g. roads, bridges, crossings.

Desktop-based GIS analysis was used to identify what infrastructure would potentially be affected, through assessment of the intersections between GIS-based infrastructure datasets, and modelled inundation maps at different flow rates. Fit-for-purpose inundation depth data were not available. With this approach, it was not possible to verify, on-ground, the extent to which infrastructure items would actually be affected at a particular flow rate. It is likely that this has resulted in cost estimates which are conservative, as infrastructure that may in fact not be affected has been included in the costings.

For the purposes of pre-feasibility cost estimates, URS made broad informed assumptions regarding the types of actions that would be appropriate to deal with specific impacts—for example what types of bridge or road works would be required. During the feasibility phase, further work would be required to determine more precisely what infrastructure would be affected and to what extent, and what infrastructure measures would be needed.

Key inputs to the model included (further details are at Appendix E):

- Information on impacts of changes in flows, as identified through analysis of inundation maps and assessments of what would be potentially affected by inundation.
- Spatial data on the location and specifications of infrastructure (e.g. roads, bridges, crossings).
- Hydrological data relating to "baseline" and "CMS" flow regimes.
- Information on "unit rates" associated with different infrastructure works, drawing on accepted industry references (e.g. Rawlinson's Australia Construction Handbook).

Further details are in the costing methods report by URS (2014) listed at Appendix A.

Approach to other specific infrastructure items

Recognising that "unit rates" cannot be used to estimate the costs of some more specific works that may be required (e.g. upgrades to regulators), estimates of the costs of other specific infrastructure items took into account work by URS (2014) and other independent consultants (SKM 2013 and Water Technology 2013, 2014). These items are summarised in Table 3 and relevant reports are listed at Appendix A.

Table 3: Specific infrastructure items

Region	Infrastructure item	Rationale	Source for pre-feasibility cost estimates
Lower Darling	Regulators on the Lower Darling	Low commence-to-flow thresholds into the Great Darling Anabranch currently prevent the delivery of regulated flows above 9,000 ML/day.	URS (2014) report to the MDBA
Murrumbidgee	Upgrade to Mundarlo Bridge	Mundarlo Bridge is currently a constraint to flows of greater than approximately 30,000 ML/day at Gundagai.	SKM (2013) report to NSW OEH
	Stormwater system at Wagga	Upgrades would help stormwater system to better cope with higher flows.	URS (2014) report to the MDBA
	Stormwater system at Narrandera	Upgrades would help stormwater system to better cope with higher flows.	Advice by Narrandera Council (2014)
	Regulator on Yanco Creek	Regulator could control flows into the Yanco Creek system and direct Murrumbidgee flows to environmental assets.	URS (2014) report to the MDBA
Goulburn	Levee outlet structures	Upgrading of levee outlet structures would improve capacity of existing levees to manage flows, and help mitigate impacts.	URS (2014) report to the MDBA
	Levees minimum level of protection	Works could bring all levees up to a minimum standard level of protection for a 5-year ARI flood event.	Water Technology (2013) report to Goulburn-Broken CMA
	Address levees critical points of weakness	Works could focus on discrete locations along levees that do not offer the same level of protection as the levee more generally.	Water Technology (2013) report to Goulburn-Broken CMA
	Strategic levee realignment	Upgrades to levee system could help mitigate impacts by keeping higher flows within the levees.	Water Technology (2014) advice to the MDBA

Hydrological assumptions

Implementation of the CMS would result in changes to the frequency, timing and duration of environmental flows.

The nature of these flows will depend on future environmental watering decisions. However, it is not possible at this time to predict what those flow regimes will be.

For the purposes of prefeasibility cost estimates, it was assumed that flow regimes would change as per a comparison between the MDBA's "baseline diversion limit" (BDL) and "BP2800RC" model runs. Further details are at Appendix B to this report.

It is important to recognise that this comparison of flow regimes does not allow for estimates of costs that were not envisaged in the BP2800RC package, i.e. on a reach-by-reach basis or for all of the flow rates considered for the CMS prefeasibility stage.

In particular, the BP2800RC model run assumed managed flows of up to 40 GL/day downstream of Yarrawonga Weir. It was therefore not possible using the BP2800RC modelled flow data to estimate costs associated with higher managed flows, e.g. of up to 50 GL/day or 77 GL/day.

Therefore, as a "range finding" exercise, and in the absence of modelled hydrological data to inform detailed costings on a reach-by-reach basis or for a wider range of flow rates, costs were also estimated (for infrastructure only) in the context of two alternative assumptions regarding changes in flows. It is important to recognise that these assumptions do not represent what would necessarily be feasible hydrologically.

- Assume an average of 2 extra events per decade, across all reaches.
- Assume an average of 4 extra events per decade, across all reaches.

The first of these alternative assumptions was used to estimate infrastructure costs associated with flows of up to 50 GL/day and 77 GL/day. Cost estimates for the flow scenarios of up to 50 GL/day and 77 GL/day should therefore be considered as indicative and in the context of the hydrological assumptions they are based on.

The cost estimates also include rough indicative estimates of easement costs that might be associated with flows of up to 50 GL/day and 77 GL/day, extrapolated from GHD's estimate for flows of up to 35 GL/day. These are preliminary "back of the envelope" estimates only, and further analysis (based on appropriate hydrological data) would be required to develop robust estimates.

If further hydrological data become available, further cost estimates could be developed to reflect additional scenarios, which may be more appropriate than the ones for which cost estimates have been developed to date.

Rationalisation of crossings costs

URS estimated the full cost of undertaking mitigation works on bridges and crossings. However, in practice it is unlikely that the full cost of this work would be required, as:

- A proportion of the works on bridges and crossings infrastructure would be to mitigate the effects of "interrupted access"—i.e. access to agricultural land that is not itself inundated

but to which access is cut off. A proportion of the estimated cost of easements is also aimed at mitigating interrupted access.

- Rather than implement two mitigation options to mitigate the same impact, a proportion of the works on crossings (which are generally more expensive than easements) would not be implemented.

Upgrades to bridges and crossings could potentially provide considerable benefit to stakeholders, above and beyond mitigating the impacts of a post-CMS flow regime. There would be scope for cost-sharing. This would be consistent with previous infrastructure works by the (then MDBC) in the Hume-Yarrawonga reach, whereby cost sharing arrangements were negotiated for the upgrades of bridges and crossings.For the purposes of prefeasibility it was not possible to determine a precise extent to which the costs of crossings would fall below the full cost. Therefore it was assumed that there would be a “rationalisation” of funding for crossings by 25 percent (in other words, only 75 percent of the full cost would be paid). This is broadly consistent with the contributions which the (former) Murray–Darling Basin Commission made to the costs of structures under the Hume-Yarrawonga Access Works Program.[6]

If CMS were to progress to the feasibility stage, it would be necessary to investigate a sample of properties on an individual basis to assess in more detail the extent to which funds would best be spent on easements or infrastructure, and appropriate cost-sharing arrangements.

[6] MDBC contributions averaged about 70 percent, in nominal terms. Further details are at Appendix D.

Results

Overall estimates

Overall cost estimates for relaxation of constraints in specific regions, and for possible "packages" of regions are presented in Table 4 and Table 5. The estimates suggest that:

- Preliminary estimates of cost indicate that addressing constraints in all seven key focus areas may exceed the $200 million set aside for constraints measures in the Water for the Environment Special Account. However, these estimates are preliminary only and could be refined with further investigation.
- For a "BP2800RC" flow regime, which assumes constraints in the Yarrawonga-Wakool are relaxed to 40 GL/day downstream of Yarrawonga Weir, total estimated costs (moderate estimate) are on the order of $200 million. Total costs increase to around $290 million if it is assumed that constraints in the Yarrawonga-Wakool are relaxed to 77 GL/day downstream of Yarrawonga Weir.
- The largest costs would be in the Yarrawonga-Wakool, followed by the Murrumbidgee and then the Goulburn.
- The smallest costs would be in the Lower Darling and South Australia.
- More investigations are needed in the Gwydir to prove feasibility before cost estimates could reasonably be provided.

Table 4: Overall summary of cost estimates

CMS region	Estimated costs ($m) Costs are for maximum flow rates in each region, and associated frequency, timing and duration of flows, as per the MDBA's BP2800RC model except where indicated										
	Easements (GHD reports)	Roads (URS report)		Bridges/crossings (URS report)		Bridges/crossings (costs rationalised by 25%)		Other infrastructure[7]		Total (bridges/crossings rationalised by 25%)	
		Moderate[8]	High	Moderate	High	Moderate	High	Moderate	High	Moderate	High
Hume-Yarrawonga (40 GL/day)	6.44	0.02	0.03	5.90	7.40	4.43	5.55	5.00	10.00	15.88	22.01
Yarrawonga-Wakool (35 GL/day)[9]	6.78	11.30	18.10	88.40	109.12	66.30	81.84	-	-	84.38	106.72
Yarrawonga-Wakool (50 GL/day)[10]	8.00	11.40	17.00	113.76	141.59	85.32	106.19	-	-	104.72	131.19
Yarrawonga-Wakool (77 GL/day)[11]	14.00	26.10	39.30	178.35	220.19	133.76	165.14	-	-	173.86	218.44
Goulburn (40 GL/day) (without levee upgrades)	7.28	7.20	10.95	0.97	1.05	0.73	0.79	4.00	8.00	19.20	27.01
Goulburn (40 GL/day) (with levee upgrades)	6.40	6.32	9.64	0.89	0.96	0.66	0.72	18.00	30.00	31.39	46.76
Murrumbidgee (48.5 GL/day)	17.59	12.42	19.81	14.81	18.34	11.11	13.76	24.50	29.00	65.62	80.16
Lower Darling (17 GL/day)	0.30	0.03	0.04	2.00	2.40	1.50	1.80	2.50	4.00	4.33	6.15
South Australia (80 GL/day)	1.95	2.60	3.30	-	-	-	-	-	-	4.55	5.25
Gwydir	Not estimated										

[7] "Other infrastructure" includes items as listed in Table 3, plus potential costs associated with infrastructure already covered by the Hume-Yarrawonga Access Works Program (refer to Appendix D). Note there could also be costs associated with mitigation options not considered for prefeasibility, e.g. levees in the Yarrawonga-Wakool.

[8] "Moderate" and "High" estimates reflect outcomes of probabilistic analyses undertaken by URS, which take into account potential variation in infrastructure costs.

[9] Based on BP2800RC modelled hydrology, which assumed relaxation of constraints to 40 GL/day. The discrepancy between 35 GL/day and 40 GL/day was not considered material for the purposes of prefeasibility cost estimates.

[10] Numbers for YW @ 50 GL/day are based on untested hydrological assumptions (infrastructure) plus extrapolation from work by GHD (2014) for easements

[11] Numbers for YW @ 77 GL/day are based on untested hydrological assumptions (infrastructure) plus extrapolation from work by GHD (2014) for easements

Table 5: Possible "packages" of constraints relaxation scenarios

Possible "package"	What it would include	Estimated cost, moderate estimate (as per Table 4)
"BP2800RC" package	Constraints relaxed as per "BP2800RC" modelled scenario, i.e. - 40 GL/day in Hume-Yarrawonga (Doctor's Point) - 40 GL/day in Yarrawonga-Wakool (downstream of Yarrawonga Weir) *[note that for the purposes of prefeasibility, cost estimates for Yarrawonga-Wakool are for 35 GL/day inundation]* - 40 GL/day in Lower Goulburn (McCoy's Bridge) - 50 GL/day in Murrumbidgee (Wagga) - 18 GL/day in Lower Darling (Weir 32) - 80 GL/day at South Australian border	$206m
"BP2800RC" package - with Yarrawonga-Wakool constraint relaxed to 77 GL/day	Constraints relaxed as per "BP2800RC" modelled scenario, but with Yarrawonga-Wakool relaxed to 77 GL/day instead of 40 GL/day.	$296m
"BP2800RC" package - without Murrumbidgee	Constraints relaxed as per "BP2800RC" modelled scenario, without the Murrumbidgee.	$141m
"BP2800RC" package - without Goulburn	Constraints relaxed as per "BP2800RC" modelled scenario, without the Goulburn.	$175m
"BP2800RC" Murray stem only	- 40 GL/day in Hume-Yarrawonga (Doctor's Point - 40 GL/day in Yarrawonga-Wakool (downstream of Yarrawonga Weir) *[note that for the purposes of prefeasibility, cost estimates for Yarrawonga-Wakool are for 35 GL/day inundation]* - 80 GL/day at South Australian border	$105m

Estimates by CMS region

Hume-Yarrawonga (Upper regulated Murray)

Assuming a hypothetical flow regime as per the "BP2800RC" model run, which would allow managed flows of up to 40 GL/day at Doctor's Point, costs in the Hume-Yarrawonga reach were estimated to fall in the range $16 million (moderate estimate) to $22 million (high estimate). The main components of this estimate are:

- Easements: approximately $6 million
- Roads: less than $1 million
- Bridges and crossings: range from $9 million to $16 million.

The estimated costs for bridges and crossings take into account (i) work on crossings that would potentially be affected by higher managed flows of between 25 GL/day and 40 GL/day, and (ii) potential further upgrades to crossings on which works were undertaken under the Hume-Yarrawonga Access Works Program to allow managed flows of up to 25 GL/day. These two cost components have been estimated using different methods:

- The costs for bridges and crossings that would be affected by higher managed flows of between 25 GL/day and 40 GL/day have been estimated by URS (2014) using the same method as has been applied in other reaches to estimate the potential costs of bridges and crossings. The estimated range of costs is from $5 million to $6 million.
- The costs of potential further upgrades to crossings previously identified as affected by managed flows of up to 25 GL/day have been estimated as described in Appendix D. The range is estimated to be from approximately $5 million to $10 million.

As per the methodology outlined on page 9 of this report, it was assumed for prefeasibility costing purposes that the cost of bridges and crossings would be rationalised by 25 percent.

The estimated costs do not include the potential costs associated with mitigating impacts on specialist businesses. This issue is discussed further on page 21.

Downstream of Yarrawonga Weir to Wakool Junction (Mid-Murray)

Assuming a hypothetical flow regime as per the "BP2800RC" model run, which would allow managed flows of up to 40 GL/day downstream of Yarrawonga Weir, the costs of mitigating impacts for flows just below this rate (up to 35 GL/day at Tocumwal)[12] were estimated to fall in the range $84 million (moderate estimate) to $107 million (high estimate). The main components of this estimate are:

[12] CMS prefeasibility work in the Yarrawonga-Wakool drew on information which was generated with reference to both the Tocumwal gauge and downstream of Yarrawonga Weir. Inundation maps (i.e. the areas modelled as inundated at specified flow rates, which informed the assessment of effects and/or impacts of higher flows) were generated with reference to the Tocumwal gauge, while hydrological data (i.e. frequency, timing and duration of flows) were generated with reference to downstream of Yarrawonga Weir. Flow rates at the two sites are similar, but not identical—in general, a given flow rate at Yarrawonga Weir equates to a slightly lower flow rate at Tocumwal. For practical purposes the discrepancy is not material to the prefeasibility cost estimates described in this report.

- Easements: approximately $7 million
- Roads: range from $11 million (moderate estimate) to $18 million (high estimate)
- Bridges and crossings: range from $66 million (moderate estimate) to $82 million (high estimate).

Modelled flow data were not available to inform an estimate of the costs associated with managed flows of up to 50 GL/day or 77 GL/day at Tocumwal.

The costs of easements that might be required for flows of 50 GL/day or 77 GL/day could reasonably be expected to be greater than the estimated cost for flows of up to 35 GL/day (i.e. $7 million). Taking into account preliminary analysis by GHD (2014), indicative working estimates of $8 million (for 50 GL/day) and $14 million (for 77 GL/day) have been extrapolated.

Infrastructure costs for these flow rates were estimated using two alternative assumptions regarding changes in flows:

- Assume an average of 2 extra events per decade, across all reaches.
- Assume an average of 4 extra events per decade, across all reaches.

These frequencies do not indicate the likelihood or feasibility of this type of flow regime, but help to provide an indication of costs.

Taking into account the above assumptions:

- If there are 2 additional events per decade the costs have been estimated at $105 to $131 million (for flows of up to 50 GL/day) or $174 to $218 million (for flows of up to 77 GL/day).
- If there are 4 additional events per decade the costs have been estimated at $114 to $147 million (for flows of up to 50 GL/day) or $195 to $254 million (for flows of up to 77 GL/day).

It is important to note that the above cost estimates do not include potential works on levees in the Yarrawonga-Wakool. Infrastructure works on levees could change patterns of inundation, and hence reduce the costs that might be associated with easements over land. There was insufficient data on which to undertake an analysis of this for prefeasibility.

Notwithstanding the current lack of sufficient information on which to assess costs associated with levees, it should be recognised that levees may be a significant factor in the delivery of flows beyond 20 GL/day for most of the region.

Even without levee costs, the estimated costs in the Yarrawonga-Wakool are higher than in any other reach. The estimated cost of works on crossings, in particular, is significant. This reflects the large number of individual crossings in the reach (more than 200 crossings and 40 bridges potentially affected at flows of 77 GL/day) and the nature of the landscape and hydrology.

As per the methodology outlined on page 9 of this report, it was assumed for prefeasibility costing purposes that the cost of bridges and crossings would be rationalised by 25 percent.

The estimated costs do not include the potential costs associated with mitigating impacts on specialist businesses. This issue is discussed further on page 21.

Also not costed were potential costs to management of irrigation infrastructure, or other mitigation measures such as upgrades to the stream gauging network, drainage or stormwater systems.

Goulburn

Assuming a hypothetical flow regime as per the "BP2800RC" model run, which would allow managed flows of up to 40 GL/day downstream of Goulburn Weir, costs in the Goulburn were estimated to fall in the range:

- $19 million (moderate estimate) to $27 million (high estimate) if it is assumed that there is a need to mitigate inundation impacts both inside and outside the levee system; or alternatively
- $31 million (moderate estimate) to $47 million (high estimate) if it is assumed that there are significant works on levees that remove the need to mitigate inundation impacts outside the levees.

The main components of these estimates are:

- Easements: approximately $7 million (if inside and outside the levee system), falling to approximately $6 million (if only inside the levees).
- Roads: range from $7 million to $11 million (if inside and outside the levees), falling to $6 to $10 million (if only inside the levees).
- Bridges: approximately $1 million.
- Costs associated with works on levees, including regulating structures ($4 to $8 million), critical points of weakness ($2 million), minimum standard of protection ($6 million) and strategic levee realignment ($6 million to $14 million).

As per the methodology outlined on page 9 of this report, it was assumed for prefeasibility costing purposes that the cost of bridges and crossings would be rationalised by 25 percent.

The extent to which works on levees and regulators are undertaken will determine whether there is a need to mitigate inundation impacts outside the levee network, and hence costs associated with easements, roads and bridges. Assumptions are summarised in Table 6.

Modelled flow data were not available to inform an estimate of the costs that would be associated with increased managed flows in the mid-Goulburn (above Goulburn Weir). For the purposes of pre-feasibility cost estimates in the mid-Goulburn, the following hydrological assumptions were made:

- For infrastructure cost estimates: assume an average of 2 extra events per decade.
- For easement cost estimates: assume an average of 1 extra event per decade, of the flow events relevant to the estimation of easement costs (i.e. flows during the periods June-July, August-September, and October-November).

Both these assumptions are broadly similar to the modelled changes in flow frequencies assumed in the lower Goulburn.

Table 6: Assumed relationship between levee works and estimated costs

Assumed levee works	Estimated costs ($m)	Estimated other costs ($m)			Estimated total costs ($m)
		Easements	Roads	Bridges	
Option 1: Works on regulating structures: - Deep Creek outlet - Hancocks Creek outlet - Wakiti Creek outlet - Loch Garry regulator - Hagans Creek outlet	4 to 8	7	7 to 11	1	19 to 27
Option 2: More significant works - Works on regulating structures (as above) - Upgrade to minimum standard of protection - Address levees critical points of weakness - Strategic levee realignment	4 to 8 6 2 6 to 14	6	6 to 10	1	31 to 47

The estimated costs do not include the potential costs associated with mitigating impacts on specialist businesses. This issue is discussed further on page 21.

Also not costed were:

- The potential for works on designed points of weakness (i.e. places for the levee to intentionally fail).
- The potential costs of a gauging network in the Goulburn.
- The potential costs associated with upgrades to drainage or stormwater systems.

Murrumbidgee

Assuming a hypothetical flow regime as per the "BP2800RC" model run, which would allow managed flows of up to 50 GL/day at Wagga Wagga, costs in the Murrumbidgee associated with managed flows of up to 48.5 GL/day were estimated to fall in the range $66 million (moderate estimate) to $80 million (high estimate). The main components of this estimate are:

- Easements: approximately $18 million
- Roads: range from $12 million to $20 million
- Bridges: approximately $10 million, mostly associated with potential works on the Mundarlo Bridge near Gundagai
- Other crossings: range from $11 million to $14 million

- Specific works on a regulator at Yanco Creek: on the order of $8-10 million.
- Specific works on Wagga stormwater gates: on the order of $5-8 million.
- Specific works on Narrandera stormwater gates: on the order of $1 million.

As per the methodology outlined on page 9 of this report, it was assumed for prefeasibility costing purposes that the cost of bridges and crossings would be rationalised by 25 percent.

The total estimated costs in the Murrumbidgee are higher than in all other reaches, except the Yarrawonga-Wakool reach. This reflects: (i) the large area of land inundated in the Murrumbidgee under the flow scenario being examined, which is larger than the area inundated in any other reach under consideration; (ii) the relatively large number of roads and crossings affected, larger than in all reaches other than the Yarrawonga-Wakool; and (iii) the specific infrastructure items being considered.

The potential works on the Mundarlo Bridge would allow higher flows of up to 48,500 GL/day at Wagga Wagga. SKM (2013) estimated the cost of a concept bridge design at $8.7 million. For the purposes of CMS prefeasibility, this has been rounded up to an indicative $10 million.

A regulator at the Yanco Creek offtake would be able to regulate diversion flows entering the Yanco Creek system, and direct Murrumbidgee River flows to environmental assets downstream. Currently the absence of a regulator acts as a constraint on how much managed environmental water can be delivered in the Murrumbidgee, as some of this water is lost to the Yanco Creek system. URS (2014) has estimated the costs of this work.

Works on Wagga and Narrandera stormwater gates would improve the drainage capacity of the stormwater system in those towns, and mitigate the risk of inundation under higher environmental flows. URS (2014) has estimated the costs of the work on the Wagga gates. The estimated cost of the Narrandera work is based on advice from Narrandera Shire Council.

There are other programs and processes underway which may cover all or some of the costs for the Mundarlo Bridge and the Yanco Creek regulator. If these items were fully funded by other sources it would reduce the cost estimate by between $18 million and $20 million.

The estimated costs do not include the potential costs associated with mitigating impacts on specialist businesses. This issue is discussed further on page 21.

Lower Darling

Assuming a hypothetical flow regime as per the “BP2800RC” model run, which would allow managed flows of up to 18 GL/day at Weir 32, and assumes a regulator on the Lower Darling which would reduce flows into the Great Darling Anabranch, costs in the Lower Darling were estimated to fall in the range $4 million (moderate estimate) to $6 million (high estimate). The main components of this estimate are:

- Easements: less than $1 million
- Bridges and crossings: less than $2 million
- Works on regulators on the Great Darling Anabranch and Yartla Lake: range from $2 million to $4 million

As per the methodology outlined on page 9 of this report, it was assumed for prefeasibility costing purposes that the cost of bridges and crossings would be rationalised by 25 percent.

The low estimated costs of easements in the Lower Darling reflect in part the benefits that are expected to arise for pasture from increased flows. In practice, because of these benefits, it is likely that many landholders may not have much incentive to negotiate easements, and may simply allow the higher flows over their land. Further investigations are required during feasibility to confirm the extent to which this may be the case.

The purpose of the proposed works on regulators on the Great Darling Anabranch and Yartla Lake would be to confine flow to the Lower Darling main channel during a regulated environmental flow.

Potentially, some of the costs on regulators could be met from other programs or processes. Outside the Constraints Management Strategy, the ongoing Menindee Lakes Water Savings project has been set up to investigate how the system could be managed more effectively. This project includes a study of the potential to install a regulator on the Great Darling Anabranch.

South Australia

Assuming a hypothetical flow regime as per the "BP2800RC" model run, under which managed flows of up to around 80 GL/day would occur at the South Australian border, costs in South Australia were estimated to be up to around $5 million. The main components of this estimate are:

- Land management arrangements: approximately $2 million.
- Roads: up to approximately $3 million.

As noted on page 7, in South Australia GHD estimated the costs of "land management arrangements", rather than easements as in the other reaches. This reflects the fact that in South Australia, the main impacts of higher flows would be on "shacks" (i.e. private houses, used largely for recreation, on the banks of the River Murray) rather than on agricultural land.

GHD's estimates were based on information supplied by the South Australian Department of Environment, Water and Natural Resources (DEWNR) on shacks and allotments that would be affected at flows of 60 GL/day and 80 GL/day at the South Australian border.

The costs of works on roads in South Australia were estimated by URS (2014) using the same method as in other reaches. The costs are associated with a relatively small distance of sealed and unsealed roads which have been assessed by the DEWNR as affected under flows of 80 GL/day at the South Australian border.

It was assumed for prefeasibility costings purposes that cost estimates in South Australia should consider only impacts on shacks and on access to those shacks (i.e. affected roads). Impacts on other land (e.g. agricultural land and other types of land use) could not be accurately assessed from desktop methods alone without on-ground verification, and hence costs (if any) would be considered during the feasibility stage.

Gwydir

Cost estimates were not developed in the Gwydir due to lack of sufficient information to inform robust estimates. If and when relevant information becomes available, it is anticipated that estimates could be developed drawing on the methods applied by GHD and URS in other reaches.

Discussion

The cost estimates are subject to assumptions and limitations which are considered reasonable in light of their purpose, i.e. to inform decisions about whether to proceed to feasibility.

Costs not estimated

Some potential costs were not estimated for the purposes of prefeasibility. This is because there was insufficient information on which to estimate these costs on a consistent basis.

As noted in the results section of this document, costs not estimated include those associated with levee works in the Yarrawonga-Wakool; gauging networks; stormwater management (other than the works specifically considered in Wagga Wagga and Narrandera); pumps; impacts on other forms of land use in South Australia; and potentially other activities.

Also not estimated were the potential costs associated with mitigating impacts on specialist businesses. Table 7 presents an indicative assessment of the nature of specialist businesses that might be affected. The information in this table is preliminary and is not intended to be an exhaustive or definitive list.

Mitigation costs associated with specialist businesses are likely to be relatively small (particularly compared to infrastructure) and therefore not material for this pre-feasibility level assessment. If the CMS were to progress to the feasibility phase, further work would need to be undertaken to explore in more detail how higher flows would affect these activities.

Table 7: Potential impacts on specialist businesses

Region	Business type	Name/location	Potential impacts of higher flows
Hume to Yarrawonga	Caravan parks	Ball Park Caravan Park, Albury; Corowa Caravan Park, Corowa; potentially others	Impacts likely to occur with flows of around 40 GL/day. Could require relocation of caravans, evacuation and/or access issues.
	Canoe club	Mitta Mitta Canoe Club, South Albury	May be impacted at 40 GL/day. May face development restrictions in areas adjacent to the river due to higher flows which would affect tourism in the area.
	Recreational area	Norieul Park	May be impacted at 40 GL/day. As above (the site also has a café and other tourist facilities that may be privately owned).
Yarrawonga to Wakool	Caravan parks	Tocumwal, Deniliquin, Mathoura, Moama and downstream of Echuca	Closure of Tocumwal beaches and boat ramp for flows of 20 GL/day (at Tocumwal). At flows between 50 GL/day and 77 GL/day (at Tocumwal), McLean's Beach caravan park at Deniliquin is evacuated. Just above 77 GL/day, causeway on Picnic Point Rd may be overtopped making access difficult to Mathoura. At flows of 77 GL/day (at Tocumwal) two caravan parks in Moama and one downstream park may be required to close low-lying areas to camping.
	Golf courses	Yarrawonga, Deniliquin	Yarrawonga and Border Golf Club would be affected by inundation at 68 GL/day (at Yarrawonga). Deniliquin Golf Club would also be affected by higher flows.

Region	Business type	Name/location	Potential impacts of higher flows
Goulburn	Trout farm	Eildon	Higher flows may cause drainage issues for the trout farm.
	Quarries	Various locations	May be inundation and drainage issues following high flow events.
	Caravan parks	Boulevard, Eildon; Blue Gums, Eildon; Thornton Breakaway Twin Rivers; Acheron Goulburn River; Seymour Victoria Lake; Shepparton Aspen Lodge; Shepparton River Bend; Kanayapella	Minor inundation in some locations at 20 GL/day, with more serious inundation from 30 GL/day. These parks are often on river flats so caravan location and recreational amenity are the issues here and won't be quite so easy to mitigate. Victoria did a review of caravan park susceptibility to flooding which has some generic statements and mitigation recommendations.
Murrumbidgee	Caravan parks	Wagga Wagga Beach Caravan Park; Darlington Point Riverside Caravan Park; potentially others	Though not inundated at the levels being investigated in this study they would need to be watched closely. Wagga Wagga City Council has indicated that they would consider evacuating the Beach Caravan Park as a precautionary measure for the highest flow band (7.15 metres at Wagga) as it is approaching the normal evacuation level of 7.3 metres. Evacuation would require the relocation of caravans, and having utilities disconnected.
	Recreational and tourist areas	Wilks Park; Wiradjuri Reserve, access to other reserves and state forests	These areas provide boat ramp access and camping grounds for tourists. Some may be closed off due to restricted access and closure of roads which affects tourism and local businesses in the area.
South Australia	Caravan parks	Loxton, Renmark	Requires relocation of caravans during flood events, which affects local tourism.
	Recreational and tourist areas	Various locations	These areas provide boat ramp access, picnic facilities and camping grounds for tourists. Some may be closed off due to restricted access and closure of roads which could affect tourism if alternative locations are not available.

It should also be noted that costs were not estimated in areas other the seven key focus areas identified in 2013 for further analysis in the *Constraints Management Strategy 2013 to 2024* (MDBA 2013). Those seven key focus areas were identified as regions which included the most important physical constraints, and which were most worthy of further investigation. It is possible that there may also be costs associated with mitigating impacts in areas outside the seven key focus areas—for example, in the Murray between Wakool Junction and the South Australian border. However, it is considered that these costs would be relatively small, and not material for the purposes of the prefeasibility phase.

Limitations of the methods used to develop cost estimates

The prefeasibility cost estimates were based on a desktop analysis, drawing largely on GIS-based spatial data, as well as other data as outlined in Appendix E.

The cost estimates need to be considered in light of the inherent limitations of these data, including in terms of currency and resolution at the local level. If the CMS were to progress to the

feasibility stage, more detailed on-ground analysis, including at a property-by-property level, would inform more robust cost estimates.

The methods for deriving the estimates made a number of simplifying assumptions. These assumptions included, for the estimates of costs of easements:

- Assumptions about how datasets on agricultural land use, and the impacts of inundation on that land use, should be interpreted.
- Assumptions about the nature of agricultural land values and gross margins, which were based on analysis of publicly available datasets and some consultation with regional experts, but which would benefit from more detailed ground truthing at the local level.
- Application of generalised gross margins, land values, impacts and costs, across sub-reaches. In reality, impacts and costs would vary on a property-by-property basis.
- Assumptions regarding the costs of administering and implementing easements (or other land management agreements) and the numbers of landholders with which such arrangements would need to be made.

These assumptions included, for the estimates of costs of infrastructure:

- Assumptions about the specific types of impacts on different road classes, and the type of road works that would be required.
- Assumptions about the specifications of bridges and crossings, and the types of works that would be required.
- Assumptions about what proportion of costs would actually need to be paid, to pay for works on crossings and bridges.
- Assumptions about the details of works on other infrastructure, including regulators and stormwater gates.
- A desktop-based GIS approach was used to identify potentially affected infrastructure. It was not possible using this approach to verify the extent to which a particular road, bridge or crossing would actually be affected at a particular flow rate, and if affected, the extent of impact (e.g. depth of inundation).

Further discussion of the assumptions and limitations of the cost estimates is included in the reports by GHD (2014) and URS (2014) listed in Appendix A.

Hydrological assumptions

The prefeasibility cost estimates were based on a very specific set of hydrological assumptions as outlined on page 9 and in Appendix B.

Changes to the hydrological assumptions could materially change the cost estimates. The prefeasibility cost estimates should therefore be considered in the context of the specific hydrological assumptions on which they were based.

Next steps

The prefeasibility cost estimates described in this report were developed for the specific purpose of informing Basin Governments' decisions as to whether to progress the CMS to the feasibility phase.

If the CMS progresses to the feasibility phase, further costing work would need to be undertaken to support the development of more detailed business cases in one or more of the CMS regions. This costing work should build on the work already undertaken to inform the prefeasibility cost estimates. The work would need to include:

- Refining the work undertaken during 2014 to estimate the costs of easements, particularly by taking into account improved local-level information on land use, agricultural enterprises, and impacts of changes in flow regimes.
- Refining the work undertaken during 2014 to estimate the costs of infrastructure works on roads, crossings and bridges, particularly by refining details of the nature of work required at a local level. This would also include validating if specific infrastructure features are actually impacted or not, and the extent of the impact.
- Developing estimates of costs associated with mitigation activities which were not considered for the prefeasibility cost estimates, such as mitigating impacts on specialist businesses, upgrades to gauging networks, levees in the Yarrawonga-Wakool, and potentially other mitigation options.
- Taking into account improved and updated hydrological assumptions, regarding "post CMS" flow regimes.

Appendix A—Key reports

GHD (2014) reports to the Murray–Darling Basin Authority:

- Goulburn – Estimated costs of establishing easements
- Hume-Yarrawonga – Estimated costs of establishing easements
- Yarrawonga-Wakool – Estimated costs of establishing easements
- Lower Darling – Estimated costs of establishing easements
- Murrumbidgee – Estimated costs of establishing easements
- South Australia – Estimated costs of land management arrangements
- Constraints Management Strategy Prefeasibility – Easement Costing Methodology

URS (2014) reports to the Murray–Darling Basin Authority:

- Regional Infrastructure Costing – overall report [includes reports below as appendices]
- Methodology and assumptions for regional infrastructure cost estimates
- Goulburn Region Leveed Floodplain Options
- Great Darling Anabranch and Yartla Lake Regulator
- Wagga Wagga Stormwater Flood Mitigation: Pumping Option
- Yanco Creek Offtake Regulator

Water Technology (2013) report to the Goulburn-Broken Catchment Management Authority for the Strategic Levee Audit

SKM (2013) report to the NSW Office of Environment and Heritage on the estimated costs of works on the Mundarlo Bridge

Water Technology (2014) advice to the MDBA on estimated levee realignment costs

Narrandera Council (2014) advice to the MDBA on estimated costs for stormwater works

Appendix B—Assumed flow regime changes

To develop prefeasibility cost estimates, it was necessary to define a "baseline" flow regime, and a "post-CMS" flow regime, as inputs to the costing methods.

- The "baseline" flow regime was assumed to be represented by modelling outputs from the MDBA's "baseline diversion limit" (BDL) model run.[13]
- The "post-CMS" flow regime was assumed to be represented by modelling outputs from the MDBA's "BP2800RC" model run.[14]

The "BP2800RC" model run represented, as of August 2014, the best available information on a post-CMS flow regime.

The "BDL" flow regime represented the most appropriate baseline for cost estimates, noting that:

1. The Basin Plan is expected to result in a different flow regime (e.g. the modelled "BP2800" flow regime)[15] to the "BDL" flow regime. The change to a "post-CMS" flow regime could, in theory, be represented by the difference between the "BP2800" flow regime and the "post-CMS" flow regime.
2. However, the Basin Plan has not yet been fully implemented. At the present time the "BP2800" flow regime is a purely hypothetical flow regime that has not yet been realised.
3. The costs that will be incurred in implementing mitigation options (e.g. easements or infrastructure works) would reflect the outcomes of negotiations with stakeholders, who will need to agree to those options, and associated funding, before they can be implemented.
4. Therefore, if mitigation options (e.g. easements and/or infrastructure works) were to be pursued, negotiations over costs would necessarily be with reference to a "baseline" which is defined by recent lived experiences.
5. Because of point (2) above, recent lived experiences do not correspond to the "BP2800" flow regime. Rather, the "BDL" flow regime is an appropriate modelled representation of this baseline. It is therefore considered a more meaningful baseline for the estimation of the actual costs that would be occurred.

The above assumptions were considered appropriate for CMS prefeasibility purposes. If the CMS were to progress to feasibility or beyond, it will likely be appropriate to use different hydrological assumptions as a basis for negotiating costs.

[13] The "BDL" flow regime is a modelled representation of flows in the Basin, taking into account a 114-year climate sequence from 1895 to 2009, and assuming a level of development as per 2009. Refer to MDBA (February 2012) *Hydrologic modelling to inform the proposed Basin Plan: methods and results*, section 3.3.
[14] Refer to MDBA (October 2012) *Hydrologic modelling of the relaxation of operational constraints in the southern connected system: methods and results.*
[15] Refer to MDBA (February 2012) *Hydrologic modelling to inform the proposed Basin Plan: methods and results*, section 3.4.

Appendix C—Interrupted access

Higher flows can result in "interrupted access"—i.e. land is not itself inundated, but access is cut off by inundation of adjacent land and/or access routes (e.g. roads or crossings). Interrupted access is of concern to landholders as it can affect their cropping and livestock activities.

In estimating the costs of easements, GHD's model took into account interrupted access by assuming that it could be expressed as a ratio of the area of land interrupted. The following assumptions were made:

Reach	Flow rate(s) investigated (ML/day)	Ratio assumed*
Goulburn	All	0.3
Lower Darling	All	0
Murrumbidgee	All	0.3
Yarrawonga-Wakool	20,000	0.15
	35,000	0.35
	50,000	0.5
	77,000	0.8
Hume-Yarrawonga	All	0.3
South Australia	n/a	n/a
Gwydir	n/a	n/a

*The ratio reflects the assumed area of land suffering interrupted access, as a proportion of the area of land inundated. In other words, a ratio of 0.3 would mean that for every 1,000 ha of land inundated, 300 ha of land is assumed to suffer interrupted access.

The ratios used in the Yarrawonga-Wakool reach reflected the findings of an analysis undertaken by the MDBA, using GIS, to assess, across a sample of 32 properties in the Yarrawonga-Wakool under different flow rate assumptions:

- The total area of land in each property.
- The area of land in each property which would suffer from inundation.
- The area of land which would suffer from interrupted access.
- The land uses which would be most affected by interrupted access.

This analysis produced the following results:

Flow rate (GL/day)	Total area (ha)		Ratio interrupted: inundated	% of interrupted land, by land use		
	interrupted	inundated		Modified pastures	Annual croppin g	Conservation
20	92.50	557.47	0.17	21%	0%	56%
35	463.30	1303.70	0.36	58%	0%	36%
50	940.64	1817.96	0.52	58%	0%	36%
77	3631.82	4428.02	0.82	49%	18%	30%

The ratios assumed in other reaches reflected the findings of the above analysis, plus an element of judgement taking into account GHD's past experience in the Hume-Yarrawonga reach.

Recognising that the ratios are just assumptions, GHD also undertook sensitivity analysis of how cost estimates would change if the ratios were decreased or increased.

Appendix D—Hume-Yarrawonga Access Works Program

Under the Hume-Yarrawonga Access Works program, the (former) Murray–Darling Basin Commission contributed towards the costs of upgrading bridges and crossings that would be affected by regulated flows of up to 25 GL/day at Doctor's Point.

MDBC contributions to individual structures ranged from 15 to 100 percent, depending on the relative extent to which additional regulated flows of up to 25 GL/day created additional impacts on those structures, compared to what would have occurred anyway.

As shown in Table 8 below, the MDBC's total contribution was approximately $2 million in nominal terms, over the period 1978 to 2010. This contribution was made towards a total of 90 structures, including 6 block banks, 55 bridges, 21 culverts and 8 causeways. In real terms (adjusted to 2014 dollars) the total contribution was on the order of $4.5 million.

Table 8: Costs associated with the Hume to Yarrawonga Access Works Program

Type of structure	Number	Total costs		MDBC contributions	
		Nominal	Real* ($2014, indicative)	Nominal	Real* ($2014, indicative)
Blockbanks	6	$ 39,390	$ 81,237	$ 38,409	$ 79,708
Bridges	55	$ 2,421,537	$ 6,070,392	$ 1,711,190	$ 4,050,670
Culverts	21	$ 162,318	$ 328,672	$ 127,102	$ 267,184
Causeways	8	$ 80,368	$ 195,821	$ 72,252	$ 176,058
Total	**90**	**$ 2,703,613**	**$ 6,676,123**	**$ 1,948,953**	**$ 4,573,619**

*Note: Nominal costs have been converted to 2014 dollars taking into account the year in which works were undertaken, and historical CPI data from the Australian Bureau of Statistics. It is important to note that the CPI reflects the price of a specified "basket" of goods and services and does not necessarily reflect changes in costs of infrastructure works. Therefore, all "real" costs in the table should be treated as indicative only.

For CMS prefeasibility, it was not possible to estimate with any certainty the potential costs of further work that may need to be undertaken on these crossings, to allow managed flows of up to 40 GL/day at Doctor's Point. To develop a robust estimate, detailed information would be required on the nature of the existing infrastructure, and how that infrastructure would be affected at different flow rates.

However, it was considered unlikely that the total additional costs would be in excess of the (real) cost of the works already undertaken, and that on the order of $5 million might be a reasonable "moderate" starting estimate for the costs that might be incurred. An indicative figure of $10 million was adopted as a "high" estimate.

It should be noted that for many of the crossings (particularly bridges) the focus of work may need to be on the access to the crossings rather than the crossings themselves.

Appendix E—Key datasets used

GHD estimates of easement costs

MDBA supplied GHD with data including:

- GIS layers showing inundation extents, developed from the following flow models:
    - RIM-FIM was used to develop inundation extents for the Lower Darling, Murrumbidgee (downstream of Hay), and Yarrawonga to Wakool reaches. The River Murray Floodplain Inundation Model (RIM-FIM) has been developed by the CSIRO as a research decision support tool for environmental flow management in the River Murray.
    - The MIKE hydraulic modelling suite was used in the development of inundation extents for the Goulburn, Murrumbidgee (upstream of Hay), and Hume to Yarrawonga reaches. Various consultants to the MDBA associated with these reaches used the MIKE modelling, mainly MIKE 11, developed by the Danish Hydraulic Institute (DHI) to generate the extents.
- Land use and management information as classified by the Australian Land Use and Management Classification (ALUM) version 7, and maintained by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) on behalf of the Australian Collaborative Land Use and Management Program (ACLUMP)
- Public land data drawn from NSW Cadastral data layers, and Victoria's Vicmap
- Analysis by Water Technology (2010 and 2014) of impacts of higher flows in the Goulburn
- Hydrological data relating to "baseline" and "CMS" flow regimes.

GHD independently obtained data including:

- Data on enterprise gross margins from the Victorian and NSW Departments of Primary Industries and the Grains Research and Development Corporation
- Data on agricultural land worth from the Victorian Valuer-General, NSW Land and Property Information Services report, and GHD contacts and professional experience
- Data to inform estimates of damages and cleanup costs from the Victorian and NSW Departments of Primary Industries and the Rapid Appraisal Method for Floodplain Management (Victorian Government, 2000)

GHD estimates of costs of land management arrangements in South Australia

GHD was provided with information supplied by the South Australian Department of Environment, Water and Natural Resources (DEWNR) on shacks and allotments that would be affected at flows of 60,000 ML/day and 80,000 ML/day in the South Australian River Murray.

URS estimates of infrastructure costs

MDBA supplied URS with a series of GIS layers drawn from the following sources:

- The NSW Digital Topographic Database
- Victoria's Vicmap data
- Analysis by Water Technology (2010 and 2014) of impacts of higher flows in the Goulburn
- GIS layers showing inundation extents, developed from the following flow models:
    - RIM-FIM was used to develop inundation extents for the Lower Darling, Murrumbidgee (downstream of Hay), and Yarrawonga to Wakool reaches. The River Murray Floodplain Inundation Model (RIM-FIM) has been developed by the CSIRO as a research decision support tool for environmental flow management in the River Murray.
    - The MIKE hydraulic modelling suite was used in the development of inundation extents for the Goulburn, Murrumbidgee (upstream of Hay), and Hume to Yarrawonga reaches. Various consultants to the MDBA associated with these reaches used the MIKE modelling, mainly MIKE 11, developed by the Danish Hydraulic Institute (DHI) to generate the extents.
- Hydrological data relating to "baseline" and "CMS" flow regimes.

URS independently obtained data including:

- Unit rates for infrastructure works from Rawlinson's Australian Construction handbook
- Unit rates for infrastructure works drawing on URS's previous professional experience

For estimates in South Australia, URS was provided with information supplied by the South Australian Department of Environment, Water and Natural Resources (DEWNR) on roads that would be affected at flows of 60,000 ML/day and 80,000 ML/day in the South Australian River Murray.