Attachment 7 – Design Development Summary

Planning and design of the project has considered a range of alternatives to achieve the specific ecological objectives listed in Section 4.2 of this referral. The current design is the result of detailed assessments drawing on extensive investigations at the site and overseen by ecological, hydrological, and engineering expert review panels.

The preferred option was the result of three detailed options assessments in 2006, 2007 and 2012 as summarised in Part A below, and fundamentally underpinned the 2014 business case for this project. The project business case was approved within the Basin Plan process as part of a package of 36 SDL projects, which collectively achieve targeted environmental outcomes for the Murray-Darling Basin.

Key measures adopted in the current design to avoid and minimise impacts to native vegetation, including listed threatened species and communities, are summarised in Part B below.

Assessments carried out to inform this referral have identified a need for some further refinements to the project design and draft operating scenarios. A summary of key areas of potential refinements is provided in Part C below.

PART A – Summary of water management options development process

Key investigations that informed design development are summarised below.

Floodplain Options Investigation: Lindsay, Mulcra and Wallpolla Islands. Water Management Options, Ecological Associates 2006

In 2006, Ecological Associates was engaged to develop a set of ecological objectives for three Murray River Island Systems - Lindsay, Mulcra and Wallpolla Island. The report described the water regimes required to meet the ecological objectives and listed potential water management options available. Four water management options were investigated which looked at the Lindsay, Mulcra and Wallpolla Islands as one system. Each of the options is summarised in **Table 1** below.

Table 1: Summary of options investigated by Ecological Associates (2006)

Option	Description	Evaluation
1	Weir manipulations	• Raise Weir Pool at Lock 7, 8 or 9 • Lower Weir Pool at Lock 9 • Lower Weir Pool at Lock 7 and 8 – does not inundate significant areas of floodplain or wetlands. Option was not considered further.
2	Anabranch flow	• Lock 9 bypass – induce flow in the Wallpolla Creek system by allowing water to flow past Lock 9 in a regulated bypass channel • Re-location of Cullulleraine Pumps – induce flow in the Wallpolla Creek system by drawing water from the Cullulleraine diverters from within Wallpolla Creek • Improve flow and regulate flow at Stoney Crossing – the existing structure would be modified to allow greater flows to pass, to provide fish passage and to regulate flow • Improve flow in Upper Potterwalkagee Creek – increase flow and provide more control over flow around Lock 8 via the upper Potterwalkagee Creek

		• Improve flow around Lock 7 – increase flow through creeks around Lock 7 by removing blockages and providing more control over flow by regulating flow • Lower sill of the Lindsay River Extension – increase flow through Lindsay River Extension by lowering the bed level of the creek.
3	Regulate Anabranch Levels and Flow	• Regulate lower Potterwalkagee Creek – inundate the floodplain in the lower part of Mulcra Island • Regulate Lower Lindsay River – inundate the floodplain in the lower part of Lindsay Island.
4	Lower sills and regulate individual wetlands	• Increase inundation in wetlands by reducing the level at which they receive flow and constructing regulators to both detain and exclude water from wetlands.

The floodplain options assessment was a high-level scoping exercise which did not make recommendations about the preferred watering option. Instead, the report identified resource or knowledge gaps that would need to be filled in order to investigate the options further and identify a preferred option.

Floodplain Options Investigation: Lindsay, Mulcra and Wallpolla Islands, Ecological Associates 2007

In 2007, Ecological Associates conducted further investigations into floodplain water management options with the aim of refining the options identified in 2006. The report reviewed floodplain hydraulics, current and modified hydrology and hydrogeology, ecological values and associated environmental water requirements, and based on this information, identified priorities for water management and options to address water management priorities.

The highest priority for water management was identified to be Red Gum Forest and Red Gum Woodland WRC, which makes a key contribution to a large number of objectives and is significantly threatened by water-related threats. Although they contribute to fewer objectives, anabranches were the next highest priority as they are very important to the few objectives to which they relate. Semi-permanent and Temporary Wetland WRCs have a similar priority for water management, while the lowest priorities for management were identified as Black Box Woodland and Lignum Shrubland, as these WRCs make relatively smaller contributions to the ecological objectives and their water requirements are not as threatened as the other classes.

Twelve water management options were described for the Lindsay Island system to address the water management priorities, including floodplain and anabranch components as summarised in **Table 1**.

Table 1: Summary of water management options for the Lindsay Island system (Ecological Associates 2007)

Option	Description	Evaluation
1	Raise Lock 7	The objective of this option was to increase the extent of flowing watercourses / anabranches and to introduce water to wetlands by raising Lock 7 approximately 1.12 m above normal operating level (up to 23.32 mAHD) and was considered in conjunction with other works to regulate watercourses from downstream that would enable inundation of the floodplain. This option proposed an initial weir raising of 0.5 m to assess the effect of the change before considering larger manipulations.

		Raising Lock 7 without any other works was deemed to provide minimal environmental benefit as flows would remain within the banks of the watercourses which already flow (Upper Mullaroo Creek and Lindsay River), although it would slightly extend the distance that these creeks flow. Weir raising would not increase inflows to Lake Wallawalla.
2	Raise Lock 6	This option considered raising Lock 6 weir pool to inundate floodplain areas upstream and reviewed floodplain inundation levels of 19.25 m, 19.87 m, 20.0 m, 20.5 m, 21.0 m, 21.5 m and 22.0 m AHD. A level of 19.87 mAHD achieved no real change in wetland connectivity or floodplain inundation area, with wetland connectivity not increasing until water levels exceed 20.5 m to 21.0 m AHD. A level of 21.0 mAHD is required to begin inundation of floodplain areas in the lower Lindsay River system. This option was not considered further as a viable option for increasing floodplain inundation at Lindsay Island as raising the weir to greater than 21.0 mAHD was considered beyond the reasonable range for Lock 6 due to structural and Murray River depth reasons; and raising to lower levels achieved no floodplain inundation benefits.
3	Lower Lock 6	This option considered lowering water levels at Lock 6 to increase the head difference between Lock 7 and Lock 6, which generates flows through Mullaroo Creek and the Lindsay River, with the aim of extending the length of stream along which flow occurs. This option was not considered further as the length of extended stream flows achieved (1.6 km) compared to the recession of the weir pool (0.52 km) associated with lowering Lock 6 levels, was not sufficiently beneficial.
4	Lower Lindsay River weir and fish ladder	The objective of this option was to inundate the lower Lindsay Island floodplain by installing a weir structure on the Lindsay River downstream of “the Crankhandle” to hold water at an elevation close to the Lock 7 weir pool, which would facilitate upstream floodplain inundation, and introduce water to wetlands, including Lake Wallawalla during moderate flow events. The weir proposed to raise the minimum level of the lower Lindsay River from 19.25 m to 20.5 m AHD to increase flooding within the banks of the Lower Lindsay River and more readily allow inflow to the Crankhandle wetland. This would reduce the extent of the flowing habitat in the upper Lindsay River and Upper Mullaroo Creek to a minor degree. The weir would allow water levels to be raised up to 22 m AHD on a seasonal basis using a Murray River fresh (short pulse (about 2 weeks duration) of freshwater) but without extensive floodplain works, would not allow water to be retained longer than the duration of the fresh. This option was considered as a stand-alone option, or it could be designed as a component of the larger scale option to inundate the Lindsay River floodplain by diverting water from Lock 8.
5	Upper Mullaroo Creek weir and fish ladder	This option considered a weir on Mullaroo Creek approximately 5 km downstream of Mullaroo Bridge with the aim of promoting inundation of the surrounding floodplain and wetlands. This option was tested for weir levels between 19.25 m AHD (Lock 6) and 22.21 m AHD (Lock

		7). At the maximum weir level of 22.21 m AHD (Lock 7) analysis of the LIDAR failed to show increased flooding outside the banks of the existing waterways. This option was not considered further as it would not be effective in increasing floodplain inundation and was likely to drown important Murray Cod habitat in Mullaroo Creek.
6	Lower Toupnein Creek regulator	This option considered a new regulator at a natural constriction on the channel of Toupnein Creek with the aim of promoting floodplain inundation during peaks in river flow. This option was not considered further as constructing a regulator on Toupnein Creek would stop the initial backwater flooding from the Murray River from extending up Toupnein Creek and reduce flooding overall, would not increase the flooding frequency for flows entering the upstream end of Toupnein Creek, and would form a barrier to fish passage.
7	Lower sills and regulate effluents in Upper Mullaroo Creek system	The objective of this option was to provide a regulated, continuously flowing stream habitat in the upper Mullaroo Creek system, providing fish passage between the Lock 6 and 7 weir pools and habitat for flow-dependent fauna, by constructing regulating structures on three effluents of the upper Mullaroo Creek and upper Lindsay River systems. Although a regulator would provide more flexibility in managing fish habitat and passage under a variety of future scenarios, this option was considered a lower priority given that fish were already able to pass between the creek and the river this location under current conditions (Engledow and Vilizzi 2006, in Ecological Associates, 2007).
8	Lower sills and regulate effluents in Upper Lindsay River system	The objective of this option was to provide a regulated, continuously flowing stream habitat in the upper Lindsay River system to provide fish passage between the Lock 6 and 7 weir pools and habitat for flow-dependent fauna by constructing regulating structures on three anabranches (Lindsay River North, Middle and South). Structures for Lindsay River Middle and South were not considered further due to the limited additional length of channel flow and habitat able to be created. Lindsay North had potential to increase flows to 280 ML/d at the normal weir level, while fish passage could be improved by replacing the current structure with a regulator capable of varying flow if Lock 7 were to be raised seasonally by 0.5 m.
9	Lower sills and regulate connection channels in the Upper Lindsay Wetland Complex	The objective of this option was to increase flood frequency and duration in upper Lindsay Wetland Complex by seasonal or periodic raising of Lock 7 weir pool by 0.5 m. However, at this level, the surrounding floodplain would not be inundated and pumping was considered to be less costly and a simpler alternative to achieve the objective.
10	Lower bed level of Lindsay River extension	The objective of this option was to maintain the health of riparian trees and to improve aquatic habitat by excavating to lower the bed level of the channel.

		The value of this option was considered questionable because lowering the bed would only benefit the watercourse itself, would not provide a flowing habitat, and the works were relatively high cost.
11	Lower and regulate sills to individual wetlands	This option considered modifying flow paths between watercourses and various wetlands with the aim of increasing opportunities to introduce water and control the wetland water regime, including works to lower or broaden flow paths, and install regulators. Sites that best met the effectiveness criteria for the works (based on hydrology of the source and physical characteristics of the flow path), were Wetland 33, Wetlands 24, 29, 32 and 34, the upper Mullaroo wetland complex, and the Crankhandle complex. Further consideration of this option was not ruled out by Ecological Associates (2007).
12	Inundate Lindsay Island floodplain	This option considered delivering water from the Lock 8 weir pool to the Lindsay Island floodplain by constructing a new 20 km channel along with up to 42 regulating structures with the aim of watering woodland areas on approximately 6,000 ha of the Lindsay Island floodplain. With a storage level of 24.6 mAHD and potential maximum operating water level of 25.69 mAHD (top of lock), Lock 8 could provide sufficient head to inundate woodland areas of Lindsay Island currently beyond the maximum possible operating level of Lock 7 of 23.32m AHD (top of lock). This option could interact with several other options described above.

The option with the greatest benefit for anabranches at Lindsay Island were associated with improving flows at Lindsay North (Option 8) where flow already occurs as works on Mullaroo Creek would improve shorter lengths of anabranch. The option with the greatest benefit for wetlands and floodplains at Lindsay Island was Option 12 as it potentially introduces water to a wide range of water regime classes in continuous areas of floodplain providing extensive, integrated habitat, followed by a weir on the lower Lindsay River (Option 4). Both of these options operate at low, regulated flows and can operate at any time, but Option 12 had a significantly higher capital cost and would require extensive works on private land (e.g. 20 km of channel through Trust for Nature's Neds Corner property). Only two significant options to improve flooding at individual wetland sites across Lindsay, Mulcra and Wallpolla Islands were identified in the study, neither of these being at Lindsay Island.

Lindsay Island Water Management Options Investigation – Part A Options Assessment (GHD 2012)

The aim of this study investigation was to identify and evaluate opportunities for large scale and integrated water management works and measures, prioritise these works and develop concept designs to inform project costs and other potential future project delivery requirements, recognising that previous options investigations were targeted at specific wetlands or areas of the floodplain.

Two groups of options were identified a part of this study: primary options and secondary options. Primary options comprise works which have a widespread impact in terms of the flooding extent achieved, generally requiring at least one main structure of larger size/higher cost. These options aimed to achieve large-scale inundation, maximising outcomes in terms of enhanced connectivity between floodplain elements, the floodplain and the Murray River. Hydraulic modelling was undertaken on key primary options to determine general system capabilities and characteristics, and to confirm the relationships of floodplain interconnections. Secondary options comprise a range of works, which would generally operate in conjunction with the primary options to target specific additional areas or enhance the transfer of flow around the system.

Primary options

Table 2 summarises the four primary options evaluated.

Table 2: Summary of primary options (GHD, 2012)

Option	Name	Description	Target inundation level	Inundation area
1	Lindsay River Environmental Regulator, Lower	Major regulating structure on Lindsay River adjacent to Berribee Homestead with vertical slot fishway. Minor works to manage breakouts such as: • Four regulator and crossing combination structures • One regulator structure • One levee, mostly shallow (0.55 m deep), 2.3 km long	23.2 mAHD	3,520 ha
2	Lindsay River Environmental Regulator, Middle	Major regulating structure on Lindsay River north of the Channel Track with vertical slot fishway. Minor works to manage breakouts such as: • Two regulator and crossing combination structures • One regulator structure • One levee, 1.1 to 0.5 m deep, 1 km long • One levee, mostly shallow (0.55 m deep), 2.3 km long	23.2 mAHD	3,360 ha
3	Lindsay River Environmental Regulator, Upper	Major regulating structures on Lindsay River near the main Island Crossing (mid-island) and another structure on the Mullaroo Creek, both with vertical slot fishways. Minor works to manage breakouts such as: • Two regulator and crossing combination structures • One regulator structure • One levee, average 0.3 m deep, 2.3 km long	23.2 mAHD	1,960 ha
4	Upper Lindsay and Mullaroo Flood Complex	Major regulating structures on Lindsay River (upstream of the Mullaroo Effluent confluence in Upper Lindsay Island, adjacent to local high point) and another structure on the Mullaroo Creek (1 km downstream of the confluence of Mullaroo and Little Mullaroo Creeks), both with vertical slot fishways. Minor works to manage breakouts such as:	24.0 mAHD	1,480 ha

		• Two regulator and crossing combination structures • Thirteen regulator structure • Eight levee, minor only		

The assessment recommended the adoption of Primary Option 1, due mainly to having the largest inundation area and associated potential for environmental benefits. Primary Option 2 achieved a similar inundation area but was not preferred as the main regulator location was within an area of particular cultural heritage significance. Options 3 and 4 were not preferred due mainly to high cost compared to area benefitted by inundation. All options were considered to have similar levels of risk in relation to salinity and ecological impacts (hollow-bearing trees, threatened species habitat, hydrodynamics of Mullaroo Creek and upper Lindsay River).

Secondary options

Preliminary assessments evaluated works across 23 wetland areas based on cost-effectiveness and ecological impact (area inundated, current condition, impacts on fish ecology). The assessment identified the following as the high priority wetlands: Crankhandle Wetland Complex, Crankhandle West (Lower Area), Lake Wallawalla, combined Toupnein Creek and Webster's Lagoon, Lake Wallawalla East, Lindsay South Effluent (Southern Wetland), Lake Wallawalla West, Upper Mullaroo Wetland Complex (Extended). Crankhandle West (Upper Area) and Crankhandle West (Middle Area) were identified as medium priority wetlands.

Further engineering and ecological investigations were recommended to further assess risks and benefits associated with the preferred primary and secondary options.

Lindsay Island Water Management Options Investigation – Part B Concept Development and Design (GHD 2013a)

This report presents conceptual designs for the priority works, as identified in the Part A – Options Assessment Report (GHD 2012). Concept designs were developed for Primary Option 1 (Berribee Regulator), including the secondary options enabled by inundation from the Primary Option (Lake Wallawalla, Upper Mullaroo Wetland Complex, Upper Lindsay Wetland Complex, Upper Lindsay East Wetland Complex, Lower Lindsay River - Southern Pocket East) along with other priority wetlands identified by the Mallee CMA (Crankhandle Wetland Complex, Crankhandle West (Upper Area), Wallawalla West, Wallawalla East, Lindsay South Effluent (Southern Wetland), North West Area of Lindsay Island).

Refinements made during concept design to address environmental and heritage risks identified for the options described in the Part A report included:

- Wallawalla West outlet regulator relocated further west to avoid potential archaeological sites
- Reduced top water level for Wallawalla East and Lindsay South to 25.3 mAHD to minimise the potential for inundation of Old Mail Road
- Reduced inundation level within northern Crankhandle West to reduce extent of levee bank works required along the Lindsay River.

An alternative mode of filling the Crankhandle West area is via pumping from either the Lindsay River or the Crankhandle Wetland Complex was also recommended to eliminate the need for the channel excavation and associated regulator works, although this pumping option has not been adopted at this stage.

The concept design noted that further refinement of the design would require detailed flora, fauna and cultural heritage assessment, to inform siting of works, with flora and fauna assessments to also include consideration of net gains. In relation to operations, GHD (2014) recommended that additional consultation and additional hydraulic modelling be undertaken to improve the current level of understanding of the potential changes to flow regimes and other hydrodynamic attributes as a result of operating the scheme, with the aim to:

- Confirm the flood inundation levels that can be achieved across the floodplain under a range of Murray River flow conditions;
- Confirm the potential changes to flow rates and velocities along Mullaroo Creek and Upper Lindsay River, and evaluate in context of the potential impacts on fish;
- Evaluate to what extent the structures at the offtake to Mullaroo Creek and the Upper Lindsay River can be used to manage flow regimes in theses streams; and
- Improve the current understanding of the impacts of raising the Lock 7 weir pool level on floodplain inundation along the Murray River, particularly in New South Wales.

Lindsay Island Sustainable Division Limit Adjustment Supply Measures - Advanced Concept Design Report (GHD, 2017a)

In 2017, SA Water engaged GHD to progress the advanced concept design for the SDL measures at Lindsay Island, building on the 2014 advanced concepts through incorporation of additional geotechnical investigations, development of fish passage criteria (Hames et al, 2014), computational fluid dynamics modelling of the fishway at Berribee Regulator, hydraulic and hydrology assessments (Water Technology, 2016), flora and fauna assessments (GHD, 2014a, GHD, 2016a), outcomes of sheet pile trials and seepage control options assessment, and constructability reviews.

Key revisions to the advanced concept design include:

- The geometrical layout of the fishway and fishway entrance arrangements were confirmed through computational fluid dynamics modelling resulting in a slightly larger structure and an additional gate in structure
- Refinement of structure arrangements and sizing based on hydraulic analysis
- A drilled sheet piled wall was determined the preferred cofferdam solution for Berribee Regulator (change from Bulka Bag option) based on further geotechnical investigations and temporary works workshop
- The depth of the permanent sheet pile cut-off was reduced, and upstream/downstream erosion cut-offs removed based on geotechnical investigations.
- Several sections of access tracks were modified based on ground-truthing by Mallee CMA to avoid or minimise impacts to large trees and / or known cultural heritage values.

PART B – Summary of key design criteria to avoid and minimise impacts in current design

- The current design has located structures (e.g. containment banks and regulators) mostly on existing vehicle tracks and other previously disturbed areas. The containment banks would continue to be used as vehicle access tracks. Some containment banks deviate from existing vehicle tracks where necessary to avoid significant Aboriginal cultural heritage values or large trees located along existing tracks. These structures were sited to minimise impacts to large trees and other known environmental and heritage values.
- The current design has minimised the footprint of containment banks by:
  - Adopting the minimum bank height (freeboard) necessary to maintain safety and functionality, after considering wear and wave impacts
  - Adopting the minimum bank crest width necessary for road safety based on track design speed
  - Adopting the steepest batter slope that still meets embankment stability and road safety requirements (3H:1V)
- The current design has selected passing bay locations to avoid large trees where feasible to still meet safe sight distance requirements.

PART C – Key design and operational aspects for further investigation

The design report (R8, 2020a) identifies the following infrastructure as requiring further design investigations / realignment to avoid identified cultural heritage values: WE_A containment bank and regulator, CR_G channel, BERR_F regulator and containment bank, WW_A containment bank, CR_D containment bank, CR_E containment bank, CW_C containment bank, CR_G channel, Parts of CW_D channel high points, section of Bridge Track, and a section of new access track between CR_A to CW_B1.

Other further design investigations, include:

- Possible requirement for drop structure at WE_A regulator
- WW_B permanent pipeline construction methods
- Possible relocation of drop structure CR_D to CR_A
- Possible upgrade requirement for Wallawalla Causeway
- Possible realignment of CW_A containment bank to avoid a number of large trees
- Realignment of LS_A1 containment bank to contain fully within national park (some sections currently extend into private land at Neds Corner)
- Possible automation of the inlet regulator on Mullaroo Creek to manage hydrodynamic habitat attributes.

In addition to the above, further assessment and refinement of the draft operating scenarios is proposed to identify opportunities to avoid or minimise potential impacts on native fish, particularly Murray Cod and Silver Perch, associated with changes to hydrodynamic habitat attributes in Mullaroo Creek and the upper Lindsay River, while maximising environmental benefits to floodplain communities. This review would consider opportunities to maintain flowing habitat, as well as options to mitigate impacts such as amendments to the extent, frequency, duration and timing of watering events.