Wilcannia Weir Replacement

Aquatic Ecology Assessment

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Executive summary

Water Infrastructure NSW proposes to replace the existing Wilcannia Weir on the Darling River (Baaka) with a new weir located about five river kilometres downstream of the existing weir (the proposal). This would provide a more reliable long-term town water supply for Wilcannia to meet community needs. The existing weir would also be partially removed and decommissioned as part of the proposal. The proposal is located in the Central Darling local government area.

The proposal is declared State significant infrastructure under section 2.13 and Schedule 3 of the State Environmental Planning Policy (Planning Systems) 2021. The proposal is subject to assessment in accordance with Part 5 Division 5.2 of the *Environmental Planning and Assessment Act 1979* and the environmental assessment requirements of the Secretary of the NSW Department of Planning and Environment (the SEARs) (SSI-10050), dated 28 August 2020.

This aquatic ecology assessment has been prepared on behalf of Water Infrastructure NSW to assess the potential impacts to aquatic ecology from constructing and operating the proposal in accordance with the SEARs and the *Aquatic Ecology in Environmental Impact Assessment – EIA Guideline* (Department of Planning, 2003). It includes a description of the existing environment with reference to threatened aquatic species and communities, provides a summary of the field survey conducted to inform the assessment, including significance assessments, assesses the impacts of constructing and operating the proposal on threatened aquatic species and communities and recommends measures to mitigate and manage the impacts identified. The assessment also includes an aquatic ecology biodiversity offset strategy prepared in accordance with the *NSW Biodiversity Offsets Policy for Major Projects* (Office of Environment and Heritage, 2014).

Description of the proposal

The proposed new weir would be located about two kilometres south of the Wilcannia township. The key features of the new weir include:

- Storage capacity of about 7,832 megalitres of water when the weir gates and fishway gates are closed
- A fixed crest portion of the weir about five metres high and 21.5 metres wide
- A fishway about 120 metres long and 10.5 metres wide to provide fish passage past the weir
- Remotely operated weir gates (with a manual function) to manage the storage, release and quality of water within the weir pool
- An upgraded unsealed access track about three kilometres long, between the Barrier Highway and the left (southern) side of the new weir
- A new unsealed access track about 270 metres long, between Union Bend Road and the right (northern) side of the new weir
- A permanent maintenance access track about 120 metres long, from the top of the right riverbank extending along the length of the fishway
- An electricity easement from the existing overhead powerlines on Union Bend Road to a new substation on the right side of the new weir.

Other elements of the proposal include:

- Partial removal and decommissioning of the existing weir, which is located in the Wilcannia township
- A small recreation area, known as a community river place, at Union Bend
- Conversion of an existing flow gauging station, located between the new and existing weirs, into a weir pool height gauging station.

The new weir would have dual modes of operation comprising a normal operation mode when it would operate at the same full supply level as the existing weir, and a drought security operation mode when it would operate at a new full supply level one meter above the existing full supply level.

When the new weir is at the existing full supply level it would result in a weir pool of about 66.71 river kilometres comprising the existing 61.79 river kilometres of weir pool upstream of the existing weir plus a new section of weir pool of about 4.92 river kilometres between the new and existing weirs, which is referred to as the 'new town pool'.

When the new weir is at the new full supply level it would result in the 66.71 river kilometres of weir pool that occurs at the existing full supply level being one metre deeper and an additional 18.81 river kilometres of weir pool upstream of the existing weir pool that is less than one metre deep, to create a weir pool that is about 85.52 river kilometres long.

The existing weir pool and proposed new town pool (new weir in normal operation mode) and extended weir pool (new weir in drought security operation mode) are shown in **Figure ES-1**.

Existing environment

The semi-arid, lowland region of the Darling River (Baaka) is characterised as meandering, slow-flowing and turbid, often surrounded by extensive floodplains containing billabongs, swamps and River Red Gum (*Eucalyptus camaldulensis*) riparian zone and forests (Lintermans, 2007). The freshwater environment of the main Darling River (Baaka) channel comprises an extensive range of physical aquatic environments including deep pools, shallow runs/riffles, benches and sand/gravel beds (Department of Primary Industries (DPI), 2015). Other aquatic habitat features within the channel include aquatic and riparian vegetation, overhanging banks, fallen trees, snags and woody debris which have fallen instream and now form important niche habitats that provide protection from predatory birds and other fish, feeding and breeding locations, as well as shade and refuge from flows (Lintermans, 2007).

There are 15 weirs along the main channel of the Barwon-Darling River (Baaka) upstream of Menindee Lakes, including Wilcannia Weir. These weirs create weir pools that submerge aquatic habitat features (woody debris and aquatic vegetation), reduce flows and increase the occurrence of cease-to-flow events downstream of each weir. The non-flowing (lentic) water pooled behind weirs can cause reduced water quality, potential increased occurrence of algal blooms, as well as impacts to breeding and spawning conditions of several native species that require flowing conditions. Existing weirs also present barriers to fish movement along the river, particularly during low flow periods (weirs are drowned at higher/flood flows). Conversely, weir pools may provide refuge habitat for a range of biota during extended cease-to-flow periods.

The Darling River (Baaka) is 'Type 1 – Highly Sensitive Key Fish Habitat' (Department of Planning, Industry and Environment, 2021). It supports a diverse assemblage of native and introduced aquatic species. Nineteen fish species are known to inhabit the system, including 15 native species and four alien species (DPI, 2015). Three native species that are listed as threatened under both the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and NSW *Fisheries Management Act 1994* (FM Act) are predicted to occur at Wilcannia: Murray Cod (*Maccullochella peelii*), Silver Perch (*Bidyanus bidyanus*) and the western population of the Olive Perchlet (*Ambassis agassizii*). The Darling River Snail (*Notopala sublineata*), which is listed as a critically endangered aquatic species under the FM Act, is also predicted within the system (although no live specimens have been recently recorded in the Darling River (Baaka)), as is the River Mussel (Mallen-Cooper and Zampatti, 2020). Turtle species that have been recorded upstream and downstream of Wilcannia include the Eastern Long-necked Turtle (*Chelodina longicollis*), Broad-shelled Turtle (*Chelodina expansa*) and Murray River turtle (*Emydura macquarii*). Collectively, all of the native fish and aquatic invertebrates within the natural creeks, rivers, streams and associated lagoon, billabongs, lakes, anabranches, flow diversion to anabranches and floodplains of the Darling River are included in the Darling River Endangered Ecological Community, listed under the FM Act.

Four alien species are known to occur in the Darling River (Baaka) and include Common Carp (*Cyrinus carpio*), Eastern Gambusia (*Gambusia holbrooki*), Redfin Perch (*Perca fluviatilis*) and Goldfish (*Carassius auratus*). Carp is the most common alien fish in the catchment and there are several mapped 'carp hot spots' immediately upstream and downstream of Wilcannia (DPI, 2015).

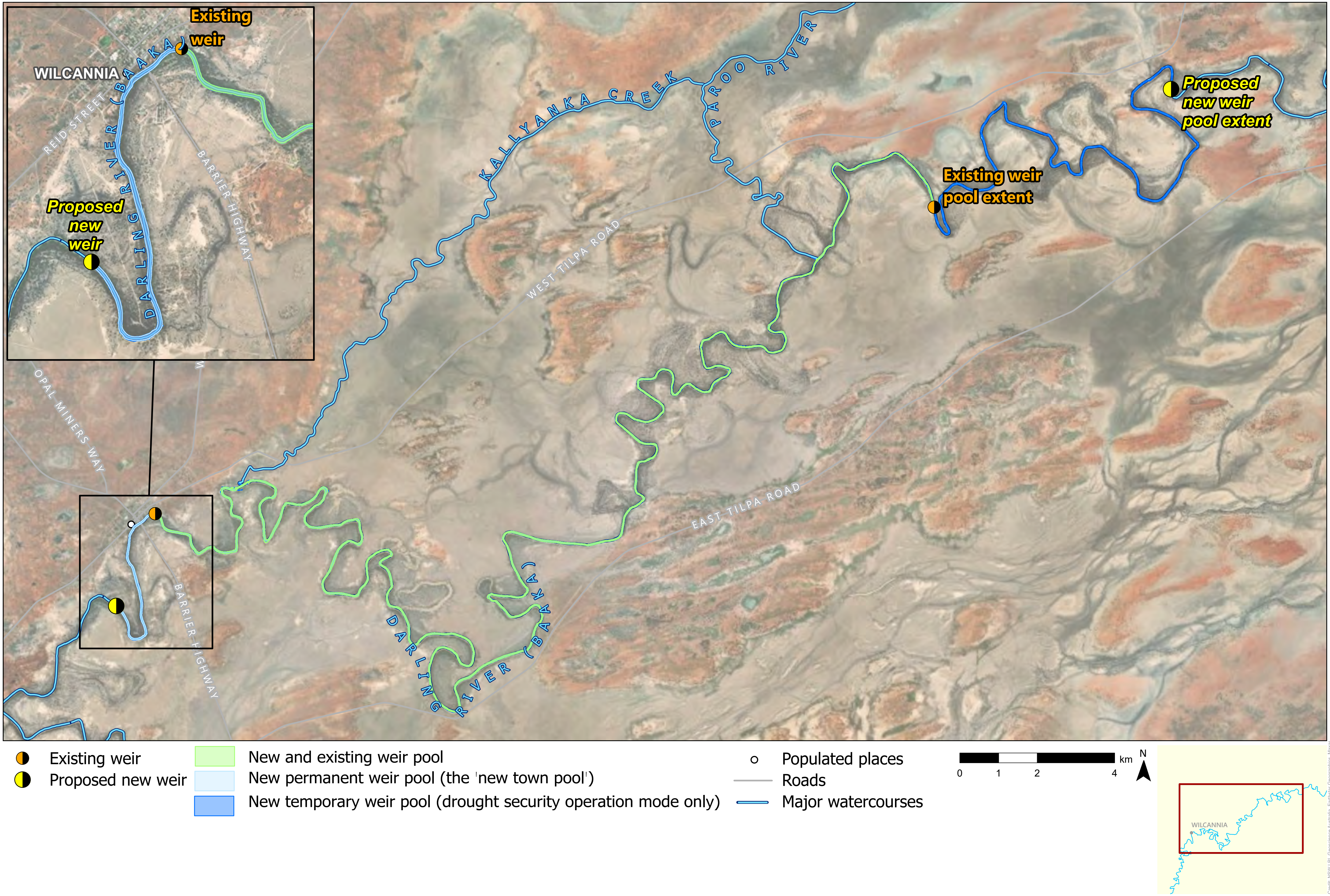


Figure ES-1 The proposed weir pool in normal and drought security operation modes

An assessment of fish community status of the Barwon-Darling valley by Fisheries NSW in 2015 suggested that the fish community between Tilpa and Menindee Lakes was in moderate health and fish condition status is mapped as fair to good in the main channel and good in anabranches and inflowing unregulated creek and rivers, with minimal reaches below poor condition and some parts in good to very good condition (DPI, 2015).

The proposal lies wholly within the Darling River endangered ecological community (EEC).

Methodology for the impact assessment

The methodology for assessing the potential aquatic ecology impacts of the proposal included:

- Desktop assessment — The desktop assessment involved a review of public database searches, literature and previous reports relevant to the proposal, as well as the proposal design. The database search included the Protected Matters Search Tool (Department of Agriculture, Water and the Environment, 2021), Bionet – The Atlas of NSW Wildlife Threatened Species Profile Database (Environment, Energy and Science Group, 2021), the Atlas of Living Australia (ALA, 2021) and key fish habitat mapping and threatened species distribution maps (Department of Planning, Industry and Environment, 2021).
- Field survey — A visual aquatic habitat assessment of the Darling River (Baaka) upstream and downstream of Wilcannia was undertaken in November 2020. The purpose of the field assessment was primarily to characterise the aquatic environment of the Darling River (Baaka) in the reach that would be impacted by the proposal. This involved a visual aquatic habitat assessment at 25 accessible sites along the length of this reach.
- Storage behaviour modelling — Public Works Advisory, on behalf of Water Infrastructure NSW, has carried out storage behaviour modelling of the operation of the proposal. This modelling simulated flows in the Darling River (Baaka) upstream and downstream of the proposed new weir for a 119-year period from 1900 to 2019. The modelling is based on preliminary operating rules for the new weir including a translucency rule when it is in drought security operation mode. A spells analysis of the simulated flows downstream of the new weir provided details of predicted flow conditions downstream of the new weir. An analysis of upstream conditions in the weir pool also provided information on the extent, duration and frequency of inundation.
- Hydrodynamic modelling – Public Works Advisory, on behalf of Water Infrastructure NSW, also carried out hydrodynamic modelling of water velocities in the weir pool for both the existing weir and the new weir when it is normal operation mode. The hydrodynamic modelling provided water velocities for nine flow scenarios ranging from less than or equal to one megalitre per day up to 5,000 megalitres per day. The difference in water velocities between the new and existing weirs were analysed for each flow scenario. The analysis considered about 100 kilometres of the Darling River (Baaka) upstream of the new weir, which includes the 'new town pool' created between the new and existing weirs, the existing weir pool, and about 30 kilometres of the river upstream of the existing weir pool. A focus for the analysis was the impact of the proposal on water velocities during the native fish breeding season at the upstream end of the existing weir pool and the reach of the river upstream of the existing weir pool, which are characterised by higher quality fish habitat than the other areas modelled.
- Risk assessment — A risk assessment approach based on the likelihood of an impact occurring and the consequence of that impact was used to determine the magnitude of risks to aquatic values. Likelihood and consequence criteria were adapted from the *Threatened Species Status Assessment Manual* (Threatened Species Scientific Community, 2015) as a way for establishing whether the proposal could have an adverse effect on the population, habitat or life history needs of a threatened species.

Construction impacts

The construction of the proposal presents a number of risks to aquatic ecology:

- Instream works — Instream works are required for the construction of the new weir and partial removal of the existing weir. Without implementation of appropriate management and mitigation measures, instream construction activities may directly harm aquatic species if they come into contact with equipment or machinery, or by smothering aquatic vegetation and species (i.e. clogging fish gills) from the disturbance and mobilisation of riverbed sediment within the works area.

- Removal of instream vegetation — The construction of the new weir and partial removal of the existing weir would require clearing of instream vegetation and displacement of aquatic habitat features, particularly large woody debris and rocks, which may be within the construction footprint area or immediately adjacent to the instream footprint on the bank slopes. Removing aquatic habitat features has potential to directly impact aquatic species that depend on them for food supply, shelter, spawning and recruitment processes.
- Removal of riparian vegetation and riverbank excavation — Removal of riparian vegetation and significant bank excavation works are proposed on both sides of the Darling River (Baaka) at the new weir site. The partial removal and decommissioning of the existing weir would also require clearing of a small amount of riparian vegetation to allow construction plant and equipment to access the site. Clearing of riparian vegetation and riverbank excavation can indirectly impact aquatic species as it can affect water quality if runoff is able to mobilise exposed soils into the waterway or may reduce channel stability which could result in increased bank erosion and subsequent sediment deposition downstream of the works.
- Construction work sites near to the river — Construction work sites are proposed alongside the Darling River (Baaka) and these have the potential to impact water quality due to mobilisation of sediments and other contaminants via wind, stormwater runoff or construction discharges/dewatering. Mobilisation of sediments and poor water quality have the potential to directly harm native species that are unable to tolerate changes to water quality or can favour the proliferation of pest species that may be able to tolerate poorer water quality (ie Common Carp).
- Concrete works —Concrete works are proposed alongside the river and these could result in concrete dust, concrete slurries or washout water entering downstream waters. Concrete by-products are alkaline, with a pH of around 12, and therefore have the potential to alter the pH of downstream watercourses which can be harmful to aquatic life that are sensitive to changes in water quality. Additionally, concrete washout water contains high levels of chromium that can accumulate in the gills and intestines of fish.
- Temporary barrier to fish passage — The installation of temporary structures during construction has the potential to temporarily hinder or possibly prevent movement of fish within the Darling River (Baaka) main channel. Potential barriers to fish passage include silt curtains and cofferdams.

Operational impacts – fish passage

The existing Wilcannia Weir prevents upstream fish passage except during high flow events (about 2500 megalitres per day and above) when the weir is drowned out such that downstream water levels are close to upstream water levels. Downstream fish and larval passage is possible at lower flows as fish / larvae can pass over the weir crest. The new weir is designed to provide upstream and downstream fish passage when flow is greater than 60 megalitres per day. The inclusion of a fishway substantially increases the number of day that fish passage is possible from a mean 51 days per year at the existing weir to 162 days per year at the new weir. Not only is this a marked increase in fish passage overall, but importantly the number of days that upstream fish passage is available during the spawning season (October to April) would also increase significantly.

Increased fish passage would provide species with an improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which would in turn boost biodiversity, long-term population resilience and contribute to food webs.

Operational impacts – upstream inundation

During the operational phase of the proposal, potential risks to the aquatic community of the Darling River (Baaka) are associated with changes to the extent, depth, frequency and duration of upstream inundation due to the position of the new weir and its operating at times at levels above the full supply level (FSL) of the existing weir, as well as changes to flows downstream of the new weir.

Changes to upstream inundation would occur due to:

- The new weir being about 4.92 river kilometres downstream of the existing weir, resulting in this section of the river becoming permanently inundated, which is known as the 'new town pool'.
- The new weir having dual modes of operation; a normal operation mode when it would operate close to the same FSL as the existing weir (depending on flow rate required to optimise fishway operation), and a drought security operation mode when it would operate at a FSL one metre above the existing FSL, and would inundate additional areas upstream of the existing weir pool.

The existing weir pool extends about 61.79 river kilometres along the Darling River (Baaka) upstream from the existing weir when at the existing FSL of 65.71 metres Australian Height Datum (AHD). The new town pool would extend the total weir pool to about 66.71 river kilometres when the new weir is at the existing FSL. The temporary increase in the FSL of one metre during drought security operation mode would result in a weir pool that is one metre deeper and extends about 18.81 river kilometres further upstream than the existing weir pool, to create a weir pool that is about 85.52 river kilometres long.

These changes to upstream inundation would result in the following key impacts to the aquatic ecosystems:

- The new town pool would permanently change from a flowing (lotic) to a still-water (lentic) environment representing a permanent change (loss) from Type 1 to Type 2 habitat.
- When the new weir is in drought security operation mode, the change in the environment at the upstream extent of the extended weir pool would depend on whether there are inflows to the weir pool:
  - When there are inflows to the weir pool, there would be a shift from flowing to non-flowing and deeper habitat up to the level of the drought mode FSL. This would occur during the initial filling stages of the weir pool when declining inflows trigger drought security operation mode but while inflows are still occurring
  - Where there are no inflows to the weir pool, there would be a shift from dry river bed and shallow refuge pools to deeper and longer pools; sections of channel bed that would have been dry would become inundated.

The permanent change in the hydraulic characteristics of the river at the new town pool from a flowing environment to a still water environment has the potential to impact the abundance and diversity of species reliant on flowing conditions as it can disrupt life-cycles of species and degrade habitat conditions (Sheldon, 2017). The native Freshwater Fish Community Status in this section of channel has been classified as fair. However, the reach may still support Murray Cod and other species that are part of the Darling River Endangered Ecological Community, such as River Mussels, which were observed during site inspections.

At the upstream end of the extended weir pool, while there would not be a permanent change from flowing to non-flowing hydraulic habitat, there would be a number of potential effects associated with inundation during drought security operation mode. The increase in the area of inundation may provide additional refuge habitat for fish and other aquatic organism during non-flowing periods. This could benefit some native species but may also benefit pest species (such as Carp). However, the relative effect compared to current conditions is likely to be small because even under current condition there is a large length of inundated river reach that provides similar habitat for aquatic biota.

River Mussels have been recorded in the reach of the Darling River (Baaka) upstream of the existing weir pool. River Mussels are sedentary, filter-feeders and are considered to be "oxyconformers", meaning they rely on flow for their food source and to maintain a stable environmental supply of oxygen (Sheldon and Walker, 1989; Jones, 2007; Ponder, et al, 2020). Hence, River Mussels tend to be recorded in permanent lotic (flowing) habitat rather than lentic (still) weir pools which may also be subject to low oxygen conditions. Recent surveys have also shown that long duration cease to flow conditions experienced in the Darling River (Baaka) in 2017-2020 resulted in mortality of River Mussels, especially in sections of the river that experienced dry channel bed, including areas upstream of the existing weir pool, and that while not ideal habitat, isolated pools may provide refuge habitat for some individuals during extended cease to flow periods (Sheldon et al. 2020). The analysis of the duration of upstream inundation during drought security operation mode predicts that the proportion of time this section of the river remains wet but not flowing would be comparable to the length of time that the channel would have otherwise been dry (i.e. there is no substantial shift in conditions from lotic (flowing) to lentic (non-flowing), the shift is from dry to wet but not flowing). The implications for River Mussels of this shift from lotic to lentic, or dry to lentic conditions is likely to vary and would depend on the frequency and duration of any change in hydraulic conditions as a result of proposed drought security operation mode. Although it is acknowledged that non-flowing habitat is not ideal habitat for River Mussels, Sheldon et al. (2020) suggest that River Mussels are more likely to survive cease to flows where refuge pools are present. It is considered possible that River Mussels would be able to survive submerged within the expanded weir pool during drought security operation mode for a period of time equivalent to the existing duration of dry conditions. Upon resumption of inflows the weir would return to normal operation mode and flowing conditions would be restored to upstream reach similar to what currently occurs.

Operational impacts – flowing water habitat

Public Works Advisory modelling of storage behaviour predict the new weir would result in a reduction in water velocities upstream due to the operation of the weir gates. At high flows the new weir has a more substantial backwater effect than the existing weir, causing flows near the new weir to slow down and the water level to rise. The backwater effect increase as the flow rate increases, with the greatest increase in the water level of the weir pool occurring nearest to the weir.

The water velocity reductions are modelled to vary greatly across the length of the weir pool depending on channel characteristics. The new weir would have a significant impact on water velocities in the new town pool where the river would change from a flowing river reach to weir pool. Elsewhere the impact of the new weir on water velocities would be relatively minor, particularly at lower flow rates. Within the existing weir pool, the effect of the new weir on water velocities diminishes with distance upstream, with the difference in water velocities being less than 0.1 metres per second for all flow rates up to 5,000 megalitres per day (ML/day) except at two shallow bars where higher water levels for a give flow would result in lower velocities over those bars. The difference in water velocities between the new and existing weirs would be negligible upstream of the existing weir pool.

The predicted reduction in water velocities have the potential to effect flowing water habitats, which support biodiversity and ecosystem integrity in the Darling River (Baaka). The new weir would significantly reduce flowing water habitat conditions in the new town pool. This reach of the river currently provides some ‘good’ (water velocities greater than 0.3 metres per second (m/s)) flowing water habitat at flow rates of 1,400 ML/day and above. Under the proposal, the new town pool would only provide good flowing water habitat during flows of 5,000 ML/day and above, and only then in a very small number of locations.

There would be a reduction in ‘high quality’ (greater than 0.3 metres per second) and ‘minimum’ (greater than 0.2 metres per second) (as defined by Mallen-Cooper and Zampati 2020) flowing water habitat conditions in the existing weir pool. ‘High quality’ and ‘minimum’ flowing water habitat conditions are those that have water velocities that are most supportive of native fish spawning. While flows of 5,000 ML/day currently create ‘high quality’ flowing water habitat conditions in several locations in the existing weir pool, the proposal would reduce this to a much smaller number of locations. A reduction in ‘high quality’ flowing water habitat conditions would mean there are fewer locations in the river channel where water velocities are supportive of native fish spawning. However, a flow rate of 5,000 ML/day would continue to provide a large number of ‘minimum’ flowing water habitat conditions. A similar impact would occur at lower flow rates; flows of 1,300 ML/day currently create some ‘minimum’ flowing water habitat conditions, but would generate negligible ‘minimum’ flowing water habitat conditions under the proposal

The new weir would not significantly reduce flowing water habitat conditions at the upstream end of the existing weir pool and especially upstream of the existing weir pool during normal operating mode . While there would be a small decrease in ‘high quality’ and ‘minimum’ flowing water habitat conditions at high flow rates, these habitat conditions would still exist at many locations in this reach of the river.

Operational impacts – downstream flows

Impacts to aquatic ecology downstream of the new weir were considered by analysing the outputs from the storage behaviour modelling for cease-to-flow, very-low-flow and other low flow events. The hydrology impact assessment of the proposal has identified that the new weir would result in an increase in short duration cease-to-flow events, and therefore an increase in the total number of cease-to-flow events, but that the mean duration of cease-to-flow events would reduce for events of both less than and more than 20 days duration.

The predicted increase in short duration cease-to-flow events has the potential to result in local scale impacts immediately downstream of the new weir. There is the potential for aquatic fauna to be stranded on channel margins if the new weir stops discharging suddenly when it transitions to drought security operation mode causing downstream water levels to drop rapidly. The downstream extent of any impact to aquatic ecology is likely to be short for the predicted increase in short duration cease-to-flow events given that discharge from the new weir would recommence relatively quickly (within days). Downstream flows would continue as pools drawdown and these pools would refill once discharge from the weir recommences. The short duration of the increased number of cease-to-flow events at the weir discharge point means that downstream pools are unlikely to draw down to levels that would result in downstream flows ceasing before refilling occurs.

The increase in cease-to-flow events predicted by the storage behaviour modelling is based on operating rules that trigger a transition of the new weir from normal to drought security operation mode when upstream flows fall below a trigger level without the benefit of climate and catchment context. It is probable that the predicted increase in the number of short duration cease-to-flow events could be largely avoided by adaptive management and decision making based on upstream flow conditions and climate and flow forecasts to ensure that decisions to enter drought security operation mode are based on a realistic assessment of the likelihood of drought conditions being experienced.

Operational impacts – water velocities

Analysis of the hydrodynamic modelling for the upper end of the existing weir pool and further upstream identified that the proposal would result in very little change in water velocity distribution at low flows and a small decrease at higher flows but no significant shift to a lower velocity category. Importantly, water velocities in this reach of the river are not predicted to fall below critical thresholds for native fish spawning and larval drift, with at least 90 per cent of the river cross sections analysed predicted to experience water velocities greater than 0.2 metres per second for about 50 per cent of the time during the spawning season under both current and proposed conditions.

The proposal would have a greater impact on water velocities at the lower end of the existing weir pool. The downstream end of the existing weir experiences some areas of high velocity flow, but these are predicted to reduce with the new weir due to the operation of the weir gates. At high flows the new weir has a more substantial backwater effect than the existing weir, causing flows near to the new weir to slow down and the water level to rise.

The proposal would result in a substantial reduction in water velocities in the reach of the river between the new and existing weirs as it would be fundamentally changed from a flowing water habitat to weir pool.

Management and mitigation measures

Management and mitigation measures are recommended for implementation during construction of the proposal to reduce the potential for construction activities to result in the mobilisation of poor-quality runoff and erosion/sedimentation.

The primary mitigation measure during operation is that decisions to enter drought mode are based on a review of climate and flow conditions and forecasts to avoid unnecessary drought mode operations. This would avoid many unnecessary small duration filling induced cease to flows. Nuanced operation of gate and fishway operation should also be implemented to balance fishway operational requirements with the need to maximise flowing water conditions upstream of the existing FSL and to avoid rapid downstream declines in flow.

Aquatic biodiversity offset strategy

The Darling River (Baaka) at Wilcannia is classified as 'Type 1- Highly Sensitive Key Fish Habitat' and the proposal would result in the loss of some of this habitat. Accordingly, Water Infrastructure NSW is negotiating with Fisheries NSW to develop an appropriate aquatic biodiversity offset strategy for the proposal in accordance with the *NSW Biodiversity Offsets Policy for Major Projects* (State of NSW and Office of Environment and Heritage, 2014).

Glossary of terms and abbreviations

Acronym/term	Definition
AHD	Australian Height Datum
ALA	Atlas of Living Australia
ANZG	Australian and New Zealand Governments
CEMP	Construction environmental management plan
CSWMP	Construction soil and water management plan
CtF	Cease-to-flow
Darling River EEC	Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
DPE	Department of Planning and Environment
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment (former)
EEC	Endangered ecological community
EESG	Environment, Energy and Science Group
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FM Act	*Fisheries Management Act 1994*
FSL	Full supply level
Jacobs	Jacobs Group (Australia) Pty Ltd
KFH	Key fish habitat
KTP	Key threatening process
Left and right	Reference to left and right (of the river) is with respect to the view in the downstream direction, in accordance with industry practice
MDBA	Murray-Darling Basin Authority
ML/d	Megalitres per day
MNES	Matters of National Environmental Significance
m/s	Metres per second
NSW	New South Wales
The proposal	The Wilcannia Weir Replacement project
River kilometre	Distance along the centreline of a river (i.e. not in a straight line), measured in kilometres
SEARs	Secretary’s environmental assessment requirements

1. Introduction

Water Infrastructure NSW proposes to replace the existing Wilcannia Weir on the Darling River (Baaka) with a new weir located about five kilometres downstream of the existing weir (the proposal) (refer to **Figure 1-1**). The existing weir would also be decommissioned and partially removed as part of the proposal. The proposal is located in the Central Darling Shire local government area and would provide a more reliable long-term town water supply for Wilcannia to meet community needs. The proposal is funded by a $30 million commitment from both the NSW and Commonwealth governments.

1.1 Approval and assessment requirements

The proposal involves the construction and operation of a new weir and the partial removal of the existing weir at Wilcannia and is declared State significant infrastructure under Schedule 3 of the State Environmental Planning Policy (State and Regional Development) 2011. The proposal is subject to assessment in accordance with Part 5 Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the environmental assessment requirements of the Secretary of the NSW Department of Planning and Environment (DPE) (the SEARs) (SSI-10050), dated 28 August 2020.

The Minister for Planning approves State significant infrastructure projects in accordance with section 5.14 of the EP&A Act.

The proposal is also determined to be a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and requires approval from the Australian Minister for the Environment.

This report has been prepared by Jacobs Group (Australia) Pty Ltd (Jacobs) as part of the environmental impact statement for the proposal. The environmental impact statement has been prepared to support the application for approval of the proposal and address the SEARs. This aquatic ecology assessment report addresses those parts of SEAR number 4 that pertain to aquatic ecology (refer to **Table 1-1**).

1.2 Proposal description

The proposed new weir would be located about two kilometres south of the Wilcannia township, and about five river kilometres downstream of the existing weir. The key design features of the proposal are shown in **Figure 1-3** and include:

- A new weir with storage capacity of about 7,832 megalitres of water when the weir gates and fishway gates are closed
- A fixed crest portion of the weir about five metres high and 21.5 metres wide, next to the left bank (southern side) of the river
- A fishway about 120 metres long and 10.5 metres wide, next to the right bank (northern side) of the river to provide fish passage past the weir that enables the upstream and downstream passage of native fish (and turtles) past the new weir. Overshot type regulator gates and a plunge pool are proposed to enable safe downstream fish and larvae passage
- Remotely operated weir gates (with a manual function) to manage the storage, release and quality of water within the weir pool
- A small recreation area, known as a community river place, at Union Bend
- An upgraded unsealed access track about three kilometres long, between the Barrier Highway and the left side of the new weir (southern side)
- A new unsealed access track about 270 metres long, between Union Bend and the right side of the new weir (northern side)

- A permanent maintenance access track about 120 metres long, from the top of the right riverbank extending along the length of the fishway
- An electricity easement about 360 metres long and 20 metres wide, from the existing overhead powerlines on Union Bend Road to a new substation on the right side of the new weir. The substation would connect to a main switchboard within a prefabricated concrete switch room at the top of the right riverbank near the weir gates
- Conversion of an existing flow gauging station, located between the new and existing weirs, into a weir pool height gauging station
- Decommissioning and partial removal of the existing weir on the Darling River (Baaka) in the Wilcannia township, situated between Victory Park Caravan Park (left riverbank) and Field Street (right riverbank) (refer to **Figure 1-4**).

The existing weir pool extends about 61.79 river kilometres along the Darling River (Baaka) upstream from the existing weir when at the existing full supply level (FSL) of 65.71 metres Australian Height Datum (AHD). Construction of the new weir would create a new section of weir pool of about 4.92 river kilometres between the new and existing weirs, which is referred to as the 'new town pool'. The new town pool would extend the total weir pool to about 66.71 river kilometres when the new weir is at the existing FSL.

The new weir would have dual modes of operation: a normal operation mode when the weir would operate as close to the existing FSL (65.71 metres AHD) as possible depending on gate operation to maintain fishway operation, and a drought security operation mode when it would operate at a new FSL of 66.71 metres AHD. These full supply levels are referred to from this point on as the normal full supply level and drought full supply level respectively. This temporary increase in the FSL of one metre would result in the weir pool being one metre deeper and extending about 18.81 river kilometres further upstream than the existing weir pool, to create a weir pool that is about 85.52 river kilometres long (refer to **Figure 1-1**).

In addition to the proposal features described above, the following temporary construction features would be required:

- Construction compound and materials laydown areas on both sides of the river near the new weir
- A staging area on the left side of the river near the existing weir
- Access tracks down to the bed of the river from both sides of the river at the new weir
- An access track down to the bed of the river from the southern side of the river at the existing weir site (within the Victory Park Caravan Park)
- Cofferdams to create dry work areas within the river channel.

The key construction features proposed at the new weir and existing weir are shown in **Figure 1-3** and **Figure 1-4** respectively.

Construction would start once all necessary approvals are obtained, and the detailed design is complete. It is anticipated that construction would start in early 2023 and take about 12 to 18 months to complete. Partial removal and decommissioning of the existing weir would take about 10 weeks and would occur after construction of the new weir is completed.

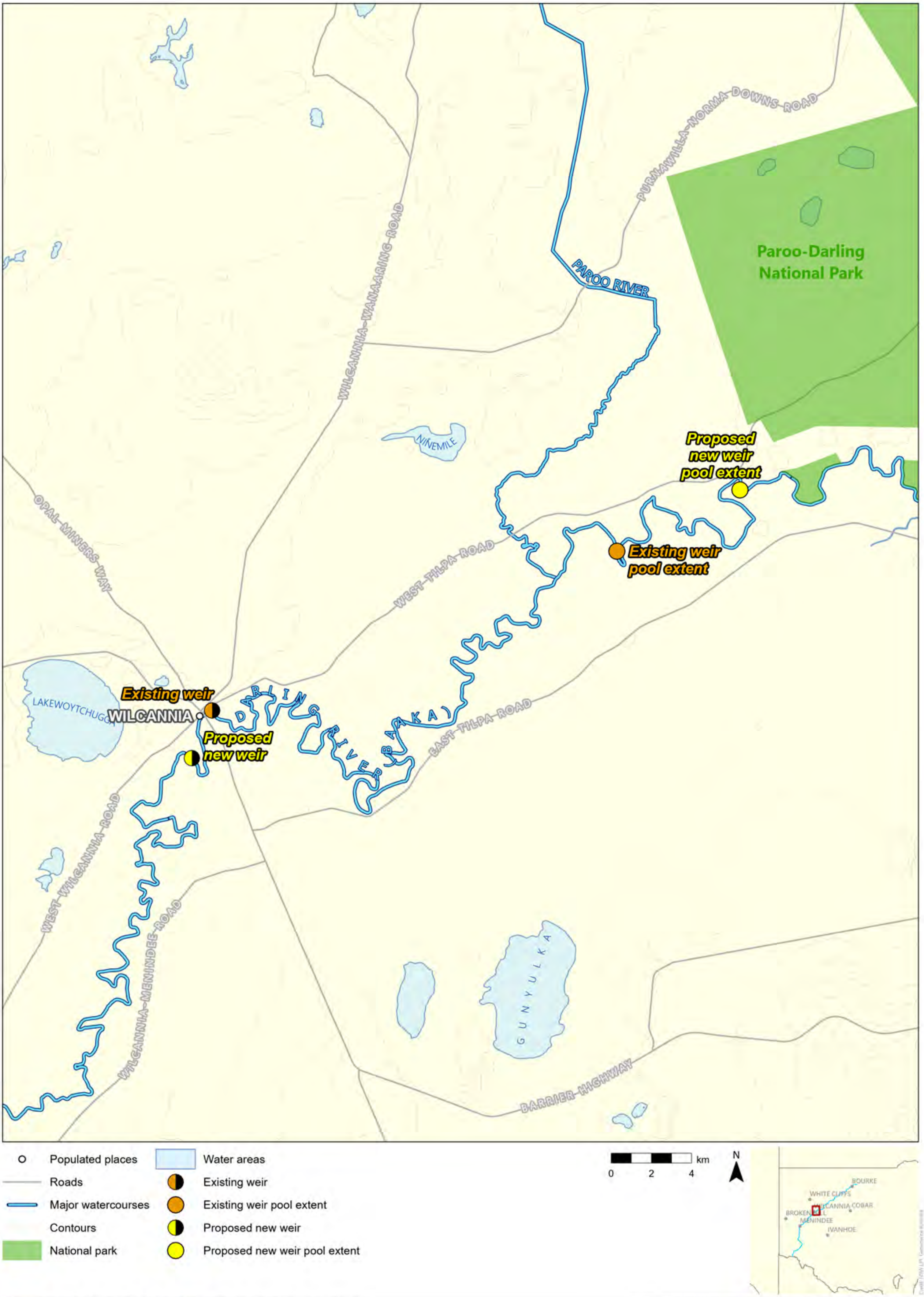


Figure 1-1: Proposal location and regional context

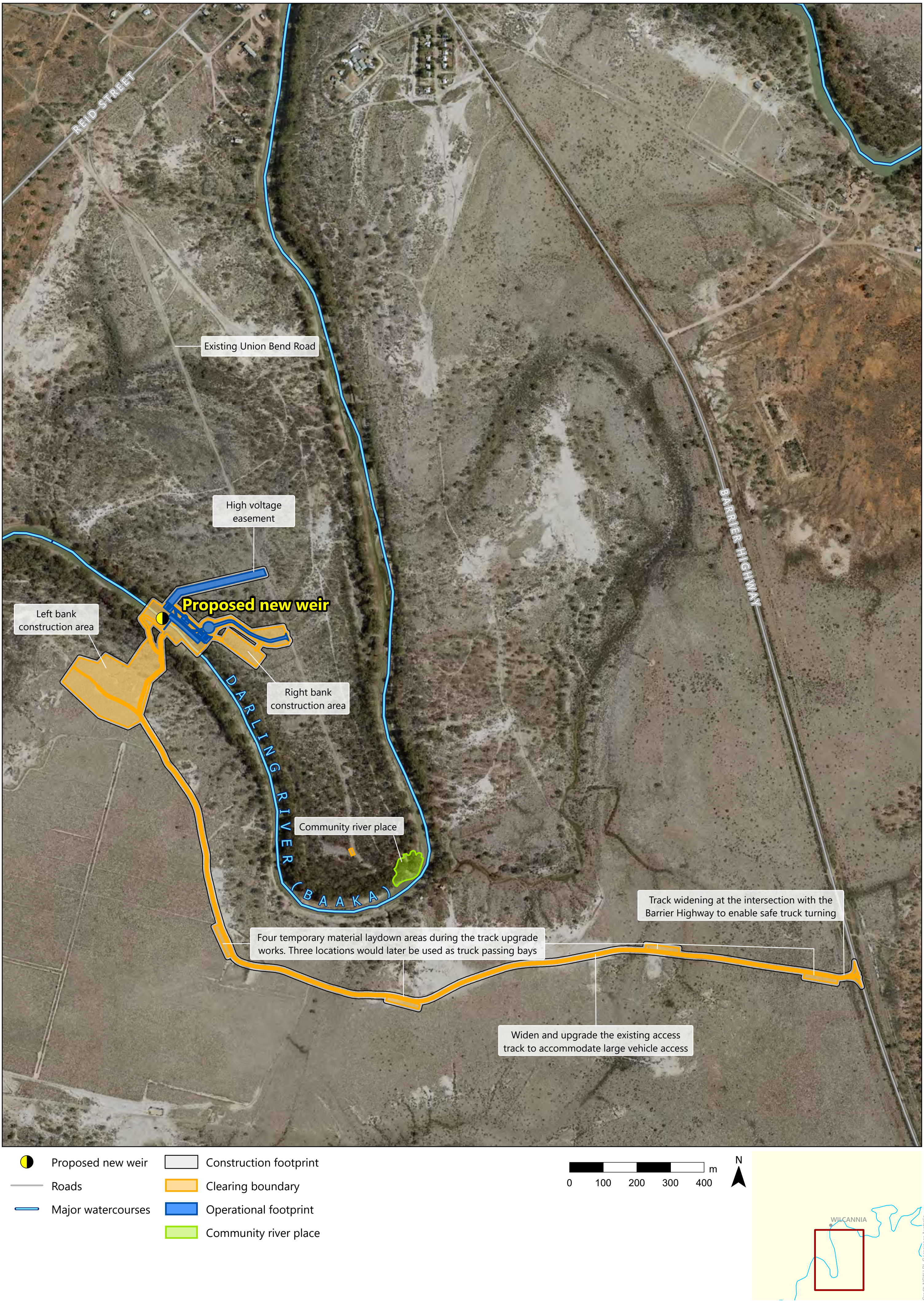


Figure 1-2: Key design features of the proposal – new weir site (overview)

Figure 1-3: Key construction features – new weir site (detail)

Figure 1-4: Key construction features - existing weir site

1.3 Purpose and scope of this report

The purpose of this report is to assess the potential impacts to aquatic ecology from constructing and operating the proposal. The report:

- Addresses SEAR number 4 as it pertains to aquatic ecology as shown in **Table 1-1**
- Describes the existing environment with respect to aquatic ecology
- Assesses the potential impacts of constructing and operating the proposal on aquatic ecology
- Recommends measures to mitigate and manage the impacts identified.

Table 1-1 How this assessment addresses SEAR number 4 as it pertains to aquatic ecology

Requirements	Where addressed in this report
4: Biodiversity assessment	
Include an aquatic ecological assessment from above and below Wilcannia Weir replacement that addresses all direct, indirect, and prescribed impacts of the new weir on Key Fish Habitat and associated flora and fauna including threatened species, populations, and communities during construction and operation for the life of the storage.	To complement the BDAR, an impact assessment on aquatic biodiversity and aquatic habitat values is provided in this report. **Section 4** describes the existing environment, including the aquatic environment upstream and downstream, flow regime, as well as predicted threatened aquatic species, populations and communities. In accordance with relevant Fisheries Policy and Guidelines, an assessment of impacts from the proposal during construction and operation are provided in **Sections 5** and **6**, respectively.
Include an assessment of the ecological impact of the Wilcannia Weir replacement upon the safe upstream and downstream passage of fish over the full range of weir operating conditions, including assessment of how the proposed operating rules of the weir may impact upon the safe fish passage as a result of the rules. The assessment must be performed in consultation with, and having regard to the requirements of DPI Fisheries.	In accordance with relevant Fisheries Policy and Guidelines, an assessment of impacts from the proposal during operation is provided in **Section 6**.
Include an Aquatic Biodiversity Offsets Strategy that is consistent with relevant policy and guidelines and is adequately funded to mitigate and manage impacts of the Wilcannia Weir replacement during construction and subsequent operation, focusing on protecting and improving the biodiversity and conservation values of the Darling River, its biota, and associated riparian zones in the medium to long term.	Water Infrastructure NSW is negotiating with Fisheries NSW to develop an appropriate aquatic biodiversity offset for the proposal as discussed in **Section 9**.

1.4 Report structure

The structure of the report is outlined below.

- **Section 1** provides an introduction to the report

- **Section 2** provides an overview legislation, policies and guidelines application to this assessment describes the methodology and approach for the assessment
- **Section 3** describes the methodology and approach for the assessment
- **Section 4** describes the existing environment
- **Section 5** describes potential impacts and a risk assessment for construction activities
- **Section 6** describes potential impact and a risk assessment for the proposal operation regime
- **Section 7** provides an impact assessment on sensitive receivers in accordance with Commonwealth and State legislation
- **Section 8** provides an evaluation of the fishway design
- **Section 9** outlines the proposed aquatic biodiversity offset strategy that Water Infrastructure NSW is currently negotiating with Fisheries NSW
- **Section 10** provides recommended mitigation and management measures
- **Section 11** concludes the key findings and recommendations from the investigation.

2. Legislative and policy context

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act protects Matters of National Environmental Significance (MNES). Under the EPBC Act, an action requires approval from the Minister for the Environment if the action has, will have, or is likely to have, a significant impact on MNES. MNES are defined in the EPBC Act and include the following biodiversity-related matters:

- Commonwealth marine areas
- Great Barrier Reef Marine Park
- Listed migratory species
- Listed threatened species and ecological communities
- Ramsar-listed Wetlands.

Where a proposal is likely to have a significant impact on a Protected Matter, the proposal is referred to the Minister for the Environment. The referral process involves a decision on whether or not the proposal is a 'controlled action'. When a proposal is declared a controlled action, approval from the Minister is required.

The proposal was declared a controlled action on 11 August 2020 (EPBC reference 2020/8713) for the reason that the proposed action is likely to have a significant impact on listed threatened species and communities protected by the EPBC Act.

Of relevance to this assessment, the following threatened species are expected to occur in the area and may be impacted:

- Silver Perch (*Bidyanus bidyanus)* – listed as Critically Endangered
- Murray Cod (*Maccullochella peelii*) – listed as Vulnerable.

The EPBC Offset Policy (Australian Government, 2012) states that "for assessments under the EPBC Act, offsets are only required if residual impacts are significant" and that "offsets are not required where the impacts of a proposed action are not thought to be significant or could reasonably be avoided or mitigated". The significance of impacts is determined in accordance with the S*ignificant Impact Guidelines 1.1 – Matters of National Environmental Significance* (Department of the Environment, 2013). As such, assessments of significance were prepared for the Silver Perch and Murray Cod and these are detailed in **Appendix B**.

The outcomes of the assessment of significance tests for the Silver Perch and Murray Cod indicate that no significant impacts are likely to occur to either EPBC listed species due to the proposed action therefore no offsets have been proposed.

2.2 State legislation

2.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act and the Environmental Planning and Assessment Regulation 2000 provide the framework for development assessment in NSW. The act and the regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process prior to proceeding to construction.

The proposal is declared State significant infrastructure and an environmental impact statement has been prepared under Division 5.2 of the EP&A Act. The SEARs have been issued and this report considers those requirements as relevant to aquatic species, communities and their habitat. An impact assessment has been carried out for threatened species, endangered populations and ecological communities listed under the *Fisheries Management Act 1994* (FM Act) and EPBC Act.

Under section 5.23 of the EP&A Act, the requirement for specified authorisations and specified provisions of legislation that may prohibit a State significant infrastructure project, do not apply. Of relevance to this report is that the requirement for permits under sections 201, 205 or 219 of the FM Act do not apply.

2.2.2 **Fisheries Management Act 1994**

The FM Act provides for the conservation, protection and management of fisheries, aquatic systems and habitats in NSW. The FM Act is administered by Fisheries NSW, which is part of the Department of Regional NSW. The FM Act establishes mechanisms for:

- the listing of threatened species, populations and ecological communities or key threatening processes (KTPs)
- the declaration of critical habitat
- issuing permits for certain works on 'water land'
- requiring the provision of fishways in the construction of weirs (as per section 218 for the FM Act)
- consideration and assessment of threatened species impacts in the development assessment process.

These mechanisms are discussed further below.

Threatened species

Part 7A, Division 12 of the FM Act relates to the environmental assessment of a development under Part 5 of the EP&A Act. Of relevance to this assessment, the following threatened aquatic species, populations and ecological communities which are listed under Schedule 4, 4A and 5 of the FM Act are predicted to occur in the study area:

- Darling River Snail (*Notopala sublineata*) – Critically Endangered
- Silver Perch (*Bidyanus bidyanus*) – Vulnerable
- Western population of Olive Perchlet (*Ambassis agassizii*) – Endangered population
- Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River (Darling River EEC) – Endangered ecological community.

Appendix B of this report assesses likely impacts of the proposal on these listed species, populations and ecological communities in accordance with the 'seven-part test' outlined in sections 221ZV and 221ZX of the FM Act.

Impacts to Critical habitat

While the Darling River (Baaka) within the study area is known to support threatened aquatic species, no areas have been declared to be 'Critical habitat', in accordance with Part 7A, Division 3 of the FM Act.

Permits

With regard to this proposal, works associated with construction of the new weir and partial removal of the existing weir would require 'dredging' (excavation of water land or removal of material from water land) or 'reclamation' (using material to fill/reclaim or depositing material to construct anything other than water land) as defined under section 198A of the FM Act. In addition, construction and operation of the proposal would result in the 'temporary or permanent blockage of fish passage within watercourses' as defined under section 219 of the FM Act.

Part 7 of the FM Act relates to the protection of aquatic habitats, including providing management of dredging and reclamation works within permanently or intermittently flowing watercourses, as well as the temporary or permanent blockage of fish passage within a watercourse. However, by force of section 5.23 of the EP&A Act, the requirement to receive permits for these activities (listed under sections 201, 205 or 219 of the FM Act) do not apply.

Despite the exemption, the proposal aims to maintain fish passage throughout construction and operation through design of an appropriate instream construction methodology and use of fishways for the operational weir structure.

Provision of a fishway

A public authority that proposes to construct, alter or modify a weir on a waterway is subject to the provisions of section 218(5) of the FM Act, which requires that the Minister be notified of the proposal and allows for the Minister to request that the works include a suitable fishway or fish by-pass. The proposal includes a fishway, and Water Infrastructure NSW has consulted with Fisheries NSW as part of its preparation of a concept design for the proposal.

This assessment is based on a concept design of the proposed fishway. The fishway would be subject to further design development in the detailed design phase of the proposal. Water Infrastructure NSW would engage with Fisheries NSW during the further development of the fishway design and seek their agreement on the suitability of the final fishway design.

Key threatening processes

Further, Part 7A of the FM Act states that a threatening process is eligible to be listed as a "key threatening process" (KTP) if, in the opinion of the Fisheries Scientific Committee –

- "It adversely affects threatened species or ecological communities, or
- It could cause species or ecological communities that are not threatened to become threatened".

Schedule 6 of the FM Act outlines the KTPs related to aquatic species and ecological communities. Of the KTPs listed, the proposal is expected to involve the following:

- Installation and operation of instream structure and other mechanisms that alter natural flow regimes of rivers and streams
- Degradation of native riparian vegetation along NSW watercourses
- Removal of large woody debris from NSW rivers and streams.

Impacts due to KTPs are discussed further in **Section 7.1**.

2.3 Regulatory policies/documents

2.3.1 Policy and Guidelines for Fish Habitat Conservation and Management

The *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a) is the guideline applicable to all planning and development proposals and various activities that affect freshwater ecosystems in NSW. The aims of this guideline are to maintain and enhance fish habitat for the benefit of native fish species, including threatened species, in freshwater environments. First published in 1999, the 2013 updated document assists developers, their consultants and government and non-government organisations to ensure their actions comply with legislation, as well as policies and guidelines that relate to fish habitat conservation and management. It is also intended to inform land use and natural resource management planning, development planning and assessment processes, and to improve awareness and understanding of the importance of fish habitats and how impacts can be mitigated, managed and offset. The guidelines outlined in this document are taken into account when Fisheries NSW assess proposals for developments and other activities that affect fish habitats. The document contains:

- Background information on aquatic habitats and fisheries resources in NSW
- An outline of the legislative requirements relevant to planning and development which may affect fisheries or aquatic habitat in NSW
- General policies and classification schemes for the protection and management of fish habitats and an outline of the information that DPE (Regions, Industry, Agriculture and Resources) requires to be included in development proposals that affect habitat
- Specific policies and guidelines aimed at maintaining and enhancing the free passage of fish through instream structures and barriers
- Specific policies and guidelines for foreshore works and waterfront developments
- Specific policies and guidelines for the management of other activities that affect watercourses.

Fisheries NSW is responsible for the application of the FM Act, Fisheries Management (General) Regulation 2019 and the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a) on Key Fish Habitat (KFH), ensuring mitigation and compensation measures are in place to redress any adverse environmental impacts to aquatic systems. The guideline states that *"to ensure "no net loss" of aquatic habitats, NSW DPI requires that proponents should, as a first priority, aim to avoid impacts upon KFH. Where avoidance is impossible or impractical, proponents should then aim to minimise impacts. Any remaining impacts should then be offset with compensatory works".*

In accordance with the definitions of KFH 'Type' outlined in the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a), The Darling River (Baaka) has been identified as 'Type 1 – Highly Sensitive Key Fish Habitat' and the area of the waterway where project impacts are unavoidable, would be offset as outlined in the aquatic biodiversity offset strategy (refer to **Section 9**).

2.3.2 Why Do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings

The DPI guideline *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull and Witheridge, 2003*)* provides practical guidelines for the planning, design, construction and maintenance of watercourse crossings aimed at minimising impacts of fish passage and aquatic ecology in general. It should be used in conjunction with the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a) by outlining potential impacts of instream structures and design specifications/recommendations for crossings to avoid erecting barriers to fish passage.

The new weir structure which is proposed to be built across the watercourse has been designed in accordance with requirements outlined in *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull and Witheridge, 2003*)*. Aquatic habitat assessment has also taken into account requirements of these guidelines.

2.3.3 Aquatic Ecology in Environmental Impact Assessment – EIA Guideline

DPE's *Aquatic Ecology in Environmental Impact Assessment – EIA Guideline* (Department of Planning, 2003) (the EIA guideline) provides a framework to assist proponents of proposals and their consultants, the community and decision-makers in the identification, prediction and assessment of impacts and suggest approaches to the management of impacts that have been predicted or observed through monitoring. The guideline aims to facilitate improvement of the environmental impact process in general by:

- Encouraging a standardised, rigorous approach to aquatic investigations in environmental impact assessment
- Providing information which can be used to understand and manage changes to the aquatic environment in NSW.

The guideline applies to the assessment of impacts on aquatic habitats including coastal waters, estuaries, rivers and streams, natural and artificial lakes and reservoirs and permanent and ephemeral wetlands. The guideline may be applied whenever aquatic ecological assessment is required under the EP&A Act. The guideline provides reference for:

- The extent to which the existing environment needs to be described
- The extent to which a proposal is likely to affect aquatic ecology
- The minimum acceptable standard for assessment of potential impacts on aquatic ecology
- Predicting cumulative impacts within a body of water
- When monitoring should be done and what components of aquatic ecology (biotic and abiotic) should be monitored
- Requirements for adequate information to manage potential impacts and initiate feedback from monitoring to management.

The existing environment, assessment methodology, potential impacts and recommendations/mitigation measures outlined in this report have taken into consideration the EIA guideline.

2.3.4 **NSW Biodiversity Offsets Policy for Major Projects**

The *NSW Biodiversity Offsets Policy for Major Projects* (Office of Environment and Heritage, 2014) clarifies and standardises biodiversity impact assessment and offsetting for major project approvals in NSW. Biodiversity offsets provide benefits to biodiversity to compensate for adverse impacts of a proposed action. They assist in achieving long-term conservation outcomes while providing development proponents with the ability to undertake actions that have unavoidable impacts on biodiversity.

Under the policy, the default position is that impacts must be offset in a like-for-like manner. This means that aquatic habitat that is impacted must be offset with the same aquatic habitat. Where like-for-like is not available (provided reasonable steps have been taken to locate an appropriate measure at that level), variation rules can be applied to allow for aquatic habitat to be offset in similar or more threatened habitat within the same catchment.

Unlike for terrestrial biodiversity offsets, aquatic habitat offsets are not undertaken through biodiversity stewardship agreements, as a method for quantifying aquatic biodiversity using tradable credits is yet to be developed. Aquatic offsets instead use mechanisms outlined in the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a).

The Biodiversity Offset Policy states that *"to meet aquatic biodiversity offset requirements, the Fisheries NSW policy and guidelines (DPI, 2013a) will classify the habitat types being offset. It will then apply a ratio and dollar value to determine the total dollar value of the offset required to be implemented by the proponent via on-ground protection or rehabilitation works, or placed into the aquatic biodiversity offset fund. The proponent will have the opportunity to reduce this cost through direct negotiation with Fisheries NSW, subject to meeting the minimum overall offset ratio requirements"*.

As discussed in **Section 2.3.1**, the area of aquatic habitat required to be offset has been considered in accordance with the relevant guidelines, the *NSW Biodiversity Offset Policy for Major Projects* (Office of Environment and Heritage, 2014) and *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a). This is further discussed in **Section 9**.

2.3.5 **NSW Weirs Policy**

The NSW Weirs Policy provides a framework for the review of weirs across the state, and establishes the goals and principles for the ongoing approval and management of weirs, including making formal allocations to the environment based on the best scientific information available (DPI, 1991). The goal of the NSW Weirs Policy is to halt and, where possible, reduce and remediate the environmental impacts of weirs. The NSW Weirs Policy has three components, the first relates to the approval to build a new, or expand an existing weir, the second is a review of all existing weirs (Weir Review Program) and the third address the provision of fishways. Of relevance to this assessment, the first and third components of the policy have been taken into consideration. The fishway for the proposal has been designed with consideration of factors outlined in the NSW Weirs Policy. This is further discussed in **Section 8**.

3. Methodology

3.1 Study area

The study area (also described as the study reach) for the aquatic ecology assessment is defined as the area directly affected by the proposal and any additional areas likely to be affected by the proposal either directly or indirectly. For the purposes of this report, the study area comprises the construction footprint area, as well as the area which encompasses the new weir pool extent. Potential impacts to the ecology of the Darling River (Baaka) downstream of the proposed weir location is also considered with respect to any alterations in flow regime as a result of the proposed weir operation. The study area is shown in **Figure 3-1**.

3.2 Desktop assessment

The desktop assessment involved a review of public database searches, literature and previous reports relevant to the proposal, as well as the proposal design to assess the likely and potential impacts on aquatic ecology during construction and operation. The following database searches were performed for the study area:

- Protected Matters Search Tool (Department of Agriculture, Water and the Environment (DAWE), 2021) (accessed November 2021) was used to determine whether any Protected Matter listed under schedules of the EPBC Act occurred in a 10 kilometre radius of the proposal footprint
- The Bionet – the Atlas of NSW Wildlife Threatened Species Profile Database (Environment, Energy and Science Group (EESG), 2021) (accessed November 2021) was searched for records of Commonwealth and state listed flora and fauna within a 10 kilometre radius of the proposal footprint
- Atlas of Living Australia (ALA, 2021) (accessed November 2021) was searched for records of Commonwealth and state listed flora and fauna within the study area
- KFH Mapping and threatened species distribution maps (DPIE, 2021) (accessed November 2021) available on the Fisheries NSW Spatial Data Portal were examined for the occurrence of threatened species in the study area.

For the purposes of this report, the assessment considers aquatic fauna species which spend part or all of their lifecycle in the aquatic environments of the Darling River (Baaka) within the study area. A particular focus is given to threatened fish and molluscs, and other aquatic fauna species predicted within the study area (refer to **Section 4.3.2**). Amphibians and reptiles are being considered by other specialists working on the proposal's environmental assessment and were excluded from the search.

Review of recent scientific literature, technical reports, WaterNSW and Murray-Darling Basin Authority data, and fish guides were also completed.

Figure 3-1 Study area - Aquatic ecology impact assessment

Figure 3-1 Study area - Aquatic ecology impact assessment

Figure 3-1 Study area - Aquatic ecology impact assessment

3.3 Field assessment

A visual aquatic habitat assessment of the Darling River (Baaka) within the study area was undertaken by environmental scientists between 17 and 22 November 2020.

The Darling River (Baaka) within the study area has been identified as 'Type 1 – Highly Sensitive KFH' because it is a major waterway in the central western region of NSW and is known to support threatened species listed under the EPBC Act and FM Act (refer to **Section 4.3.2**). As such, the purpose of the field assessment was primarily to characterise the aquatic environment of the Darling River (Baaka) in the reach that would be impacted by the proposal. This involved a visual aquatic habitat assessment at 25 accessible site locations along the length of impacted area of the Darling River (Baaka). Assessment sites are shown on **Figure 3-1**.

Further, while no targeted surveys were undertaken for threatened species that are predicted in the Darling River (Baaka), the inspection additionally involved visual searches of exposed instream bars and riverbanks for evidence of the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*). Rainfall was not recorded within the week prior to the site inspection, however the Darling River (Baaka) in the study area had only recently stopped flowing following floods which had occurred in March 2020 (MBDA, 2020). As such, the weir pool was at the FSL.

3.4 Storage behaviour modelling

Public Works Advisory, on behalf of Water Infrastructure NSW, has carried out storage behaviour modelling of the proposal as detailed in **Technical Report 1** of the EIS. The outputs from the storage behaviour modelling were used to analyse the potential impacts of the predicted hydrological changes on aquatic ecology. An overview of the storage behaviour modelling carried out for the proposal is provided in the following sections.

3.4.1 Future water demand

Public Works Advisory (2021) has forecast that annual unrestricted dry year extraction at Wilcannia would increase from 322 megalitres in 2020 to 362 megalitres in 2050. This includes water production at the water treatment plant, losses at the water treatment plant, and raw water supply. The forecast is based on the population of Wilcannia increasing by three per cent between 2020 and 2050, with the number of dwellings in the town increasing by 12.4 per cent over this same period. This forecast is considered conservative as smart metering of the potable water supply in Wilcannia was implemented in 2020 and there is potential in the future to reduce potable water distribution system losses, which are estimated to be about 20 per cent.

3.4.2 Secure yield analysis

Water Infrastructure NSW engaged NSW Urban Water Services to carry out a secure yield analysis of the proposed new weir to confirm that the new weir is adequately sized to supply Wilcannia's future water demand during the longest drought on record and with the operating rules detailed in **Section 6.1** in operation. The analysis identified that the secure yield of the new weir is 371 megalitres per annum. The secure yield analysis was carried out in accordance with *Assuring Future Urban Water Security, Assessment and Adaptation Guidelines for NSW Local Water Utilities* (draft) (Office of Water, 2013). This guideline contains procedures for considering the effects of climate change in carrying out secure yield analysis based on a greenhouse gas emissions scenario that results in a 0.9 degree Celsius average temperature increase from 1990 to 2030.Barwon-Darling Source River System Model

A simulation of the operation of the proposed new weir has been carried out using the Barwon-Darling Source River System Model operated by WaterNSW and the outputs from this modelling were used to assess the hydrological impacts of the proposal. The Barwon-Darling Source River System Model was used to provide flow time series data at Bourke and Wilcannia in daily time steps for the existing weir and the proposed new weir. A simulation of the operation of the proposed was carried out based on 119 years of flow data from 01 January 1900 to 20 August 2019. The simulation was of the section of the Darling River (Baaka) from upstream of the existing Bourke Weir to downstream of Wilcannia Weir. Data outputs from the simulation included daily inflow volumes to Wilcannia Weir, the daily volume of stored water in the Wilcannia weir pool, the daily level of the Wilcannia weir pool and daily flows downstream of Wilcannia Weir.

A base case was modelled that simulated the existing Wilcannia Weir and existing demand. The proposed new weir was modelled with all operating rules (refer to **Section 6.1**) and future local water demand in Wilcannia. Comparison between these two simulations enables the hydrology impacts of the proposed new weir to be identified.

3.4.3 Downstream spells analysis

A spells analysis of flows downstream of the proposed new weir was undertaken using the outputs of the Source model simulations. Flow-spell analysis is a procedure developed by the UK Institute of Hydrology for the analysis of low flow periods. Flow-spell analysis identifies how long a low flow (below some threshold) or high flow (above some threshold) has been maintained by considering the sequencing of flows (Gordon et al, 2004, p. 218).

The analysis of flow alteration caused by the proposal focussed on changes immediately downstream of the new weir. Downstream flows were analysed by comparing them to the environmental water requirements for key flow categories in the Wilcannia to Lake Wetherell planning unit identified in the *Barwon-Darling Long Term Water Plan Part B* (Department of Planning, Industry and Environment (DPIE), 2020b). The analysis considered changes in a range of spell characteristics for key flow categories for the existing weir and the proposed new weir. The analysis of spells considered both the magnitude of the event, the recommended duration, the interval between events and the percentage of years when an event was recommended as per the *Barwon-Darling Long Term Water Plan Part B* (i.e. spells were only counted if they met both the magnitude and duration requirements of the plan).

3.4.4 Upstream inundation analysis

The outputs for the Source model simulations were also used to analyse changes in upstream inundation associated with the new weir operating at levels above the existing full supply level. This analysis considered the duration of time that the upstream channel would be dry (i.e. no inflows from upstream and not subject to inundation from the weir pool). The analysis was completed for each 25 centimetre incremental increase in water level elevation above the normal FSL. This acknowledges that the channel at the upstream extent of inundation would experience a shorter duration of additional inundation compared to the channel at lower elevations (i.e. as soon as the weir enters drought security operation mode and inflows cease the pool level would start to draw down due to consumptive and evaporative losses, drying the upper reaches first and returning them to a similar hydrological condition that would be experienced under existing operations).

3.5 Hydrodynamic modelling

Flowing water and still water habitats are descriptions of stream hydraulics, and the change in hydraulics (water velocity, water depth and turbulence) over time and space is termed hydrodynamics. Hydrodynamic modelling is required to understand how the new weir would impact flowing water and still water habitats.

Public Works Advisory, on behalf of Water Infrastructure NSW, carried out hydrodynamic modelling of water velocities in the weir pool for both the existing weir and the new weir when it is normal operation mode. Water velocities were modelled at 219 locations (cross sections) along a 105-kilometre long reach of the Darling River (Baaka) upstream of the new weir.

The modelling used mean channel velocity to identify flowing water habitats. The use of mean channel velocity is a simplification of the actual hydraulic complexity of waterways, where water velocities usually vary across a river cross section, with typically lower water velocities along the riverbanks and a higher water velocities midstream.

The hydrodynamic modelling provided water velocities for nine flow scenarios ranging from less than or equal to one megalitre per day up to 5,000 megalitres per day. The difference in water velocities between the new and existing weirs were analysed for each flow scenario. The analysis considered about 100 kilometres of the Darling River (Baaka) upstream of the new weir, which includes the new town pool, the existing weir pool, and about 35 kilometres of the river upstream of the existing weir pool. A focus for the analysis was the impact of the proposal on water velocities during the native fish breeding season at the upstream end of the existing weir pool and the reach of the river upstream of the existing weir pool, which are characterised by higher quality fish habitat than the other areas modelled.

3.6 Risk assessment

A risk assessment approach has been adopted for determining the magnitude of risks to aquatic values. The risk assessment is based on the principles and procedures of the *Australian/New Zealand Standard for Risk Management ISO 31000:2009* (Standards Australia 2009; AZ/NZS 4360:1999) and has been adapted for the types of values present in the study area and the nature of threats associated with the proposed action.

The risk assessment uses a combination of *likelihood* of an impact occurring and the *consequence* of that impact if it occurs. The combination of likelihood and consequence determines the level of risk.

Likelihood is typically based on the chance of an event or impact occurring (refer to **Table 3-1**). Consequence is based on the predicted response if the threat occurs and is based on sensitivity to the threat, specific habitat requirements, life history cues and population size, mobility and ability to resist or recover from an impact (refer to **Table 3-2**). Likelihood and consequence criteria have been adapted from the Threatened Species Status Assessment Manual (https://www.awe.gov.au/environment/biodiversity/threatened/publications/seap-manual) as a way for establishing whether the proposal could have an adverse effect on the population, habitat or life history needs of a threatened species.

Table 3-1 Likelihood criteria for standard risk assessments

Score	Likelihood	Description
1	Rare	The outcome is not expected to occur; no record of occurring but not impossible; may occur in exceptional circumstances
2	Unlikely	The outcome will only occur in a few circumstances; uncommon but know to occur elsewhere
3	Possible	The outcome may occur; some evidence to support it will happen
4	Likely	The outcome will occur in most circumstances
5	Almost certain	The outcome is expected to occur

The combination of likelihood and consequence results in a risk ranking (refer to **Table 3-3**). **Table 3-4** provides a summary description of the risk categories and implications for identified values.

Table 3-2 Consequence criteria (adapted from https://www.awe.gov.au/environment/biodiversity/threatened/publications/seap-manual)

Consequence	Insignificant 1	Minor 2	Moderate 3	Major 4	Critical 5
Impact on population[1]	Minimal impact on local population numbers; area affected negligible compared to total population; minimal or acceptable impact on population size	Minor impact on local population numbers. Population in other locations not impacted	Moderate impact on local population numbers. Some impacts on populations in other locations; moderate and/or short-term effects	Major population reduction or loss of local population; recovery measure takes years to decades; serious and significant impact on species	Population reduction which may results in species extinction; recovery period is greater than decades; very significant and serious impact on high value species
Fragmentation of habitat/loss of habitat connectivity/reduce the areas of occupancy[2]	Minimal losses of local habitat only, recovery likely in a relatively short period of time; threats are covered by current management or legislation	Minor losses of local habitat requiring recovery over short term	Moderate loss of local habitat requiring recovery over a short to medium term and resulting in loss of connectivity between habitats at a local scale	Loss of local habitat with no potential for recovery, or partial loss of habitat across large areas and/or with limited potential for recovery in the medium to long term. Results in a net reduction in connectivity over a large area	Complete loss of local habitat with no potential for recovery and loss of habitat in other locations with limited potential for recovery in the long term resulting in a significant impact on habitat connectivity over a large area
Loss of habitat connectivity/movement	No loss of connectivity at any time	Loss of connectivity at some points in time but not when movement is critical for breeding	Loss of connectivity at some points including occasional periods when movement is critical for breeding	Loss of connectivity at some points in time including frequent periods when movement is critical for breeding	Loss of connectivity at all time
Impact on the habitat critical to the survival of the species[3]	Minimal modification, destruction, removal or decrease of local habitat only, recovery likely in a relatively short period of time; insignificant impact to habitat or threat activity only occurs in a very small areas of habitat; limited damage to minimal area of low significance; minor effects on physical environment	Minor modification, destruction, removal or decrease of local habitat requiring recovery over short term	Moderate modification, destruction, removal or decrease of local habitat requiring recovery over a short to medium term and resulting in loss of connectivity between habitats at a local scale	Modification, destruction, removal or loss of local habitat with no potential for recovery, or partial loss of habitat across large areas and/or with limited potential for recovery in the medium to long term. Results in a net reduction in connectivity over a large area; habitat is affected which may endanger the species and habitat long term survival – 70-90% habitat affected or removed; 30%	Significant impact resulting in the removal, destruction, fragmentation and degradation of habitat; the entire habitat is in danger of being affected or removed, that >90% habitat, >50% fragile habitat, and >30% critical habitat

Consequence	Insignificant 1	Minor 2	Moderate 3	Major 4	Critical 5
				fragile habitat affected or removed; 10-20% critical habitat affected or removed	
Disruption to breeding cycle[4]	Minimal impact on any aspect of the breeding cycle	Minor disruption to the breeding cycle; biota adapted to occasional disturbance and able to recover quickly	Moderate disruption to breeding cycle resulting in modification of behaviour both within the direct impact zone and at nearby locations; long term recruitment and/or population dynamics are not adversely impacted	Direct impacts on breeding cycle resulting in a net decline in size of the population	Complete disruption of breeding cycles over several seasons with significant population decline and possible extinction if breeding no longer occurs within the life span of affected biota
Impact of invasive species and/or disease[5]	Minimal impact on local population numbers or habitat quality	Minor impact on local population numbers or habitat quality. Population in other locations not impacted	Moderate impact on local population numbers or habitat quality. Some impacts on populations in other locations	Major population reduction or loss of local population or loss of habitat quality	Population reduction which may results in species extinction loss of critical habitat extent or quality
Impact on species migration[6]	Minimal impact on species migratory patterns	Results in minor behavioural modification on a local scale or impacts to physical conditions of animal interfering with migration for the short term only. Unlikely to negatively impact on the overall success of migration	Results in modification of behaviour or animal conditions such that there is potential for medium term impacts, with some possibility of individuals failing to complete migration	Results in modification of behaviour or animal condition such that there is potential for medium to long term impacts, both locally and in nearby locations, with some individuals failing to complete migration	Significant impact resulting in either complete failure, or failure of majority of individuals, to complete migration in that cycle

[1] Refers to the proportional changes to the numbers of individuals; change in the size of the population

[2] Refers to the physical destruction of the species habitat and/or alteration to hydrological regime or water quality that makes habitat unsuitable

[3] Refers to species habitat resource includes modify, destroy, isolate or decrease the availability or quality of habitat

[4] Breeding cycle including activities associated with breeding (upstream and/or downstream migration, spawning, recruitment success). Assessment assumes that the species is present in the affected area during the breeding cycle

[5] Refers to any invasive species that is harmful to the species becoming established in the species habitat and introduced disease that may cause the species to decline

[6] Refers to facultative or obligate upstream and/or downstream movement requirements for spawning or dispersal. Note specific spawning movement is also considered under disruptions to breeding cycles

Table 3-3 Risk ranking

Likelihood	Consequence				
	Insignificant	**Minor**	**Moderate**	**Major**	**Critical**
Almost certain	Low	Medium	High	Severe	Severe
Likely	Low	Medium	Medium	High	Severe
Possible	Low	Low	Medium	High	Severe
Unlikely	Very Low	Low	Low	Medium	High
Rare	Very Low	Very Low	Low	Medium	High

Table 3-4 Summary of risk impact descriptions

Risk Rating	Impact
Very low	▪ No reasonable prospect that existing values will be impacted.
Low	▪ Localised impacts on species that are common and widespread across the landscape ▪ No specific risk management actions required.
Medium	▪ Possible impact on species of local or regional conservation significance at the site scale but with no consequence for the species at the regional scale ▪ The threat has the potential to occur, but it is not likely to cause significant environmental harm ▪ Impacts can be easily mitigated.
High	▪ Impact on EPBC Act or FM Act listed species / communities at the site scale but with no consequence for the species at the regional scale ▪ The threat will occur and will have harmful consequences ▪ Risk management is essential but is likely to be successful at mitigating impacts.
Severe	▪ Impact on *EPBC* or *FM* listed species / communities at the site scale and with consequence for the species at the regional scale ▪ The threat is likely to occur and will have very harmful consequences ▪ Risk management may not be sufficient to mitigate impacts.

4. Existing environment

4.1 Darling River (Baaka)

4.1.1 Overview

The Barwon-Darling River (Baaka) is a tenth order stream (Strahler, 1952), formed by the confluence of the Barwon River and the Culgoa River upstream of Bourke and flows in a westerly and southerly direction through Western NSW to join the Murray River at Wentworth. Most reliable runoff to the Darling River comes from the eastern tributaries (Border Rivers, Gwydir, Namoi and Macquarie) that drain the western slopes of the Great Dividing Range. The northern tributaries (Paroo, Warrego and Culgoa) are arid and intermittent, providing only minor and more variable run-off (Mallen-Cooper and Zampatti 2020, Thoms et al. 2004).

Numerous weirs exist along the length of the Barwon-Darling River, mostly located at towns along the river. The distribution of weirs results in a sequence of flowing (lotic) and non-flowing (lentic) reaches along the length of the river (refer to **Figure 4-1**).

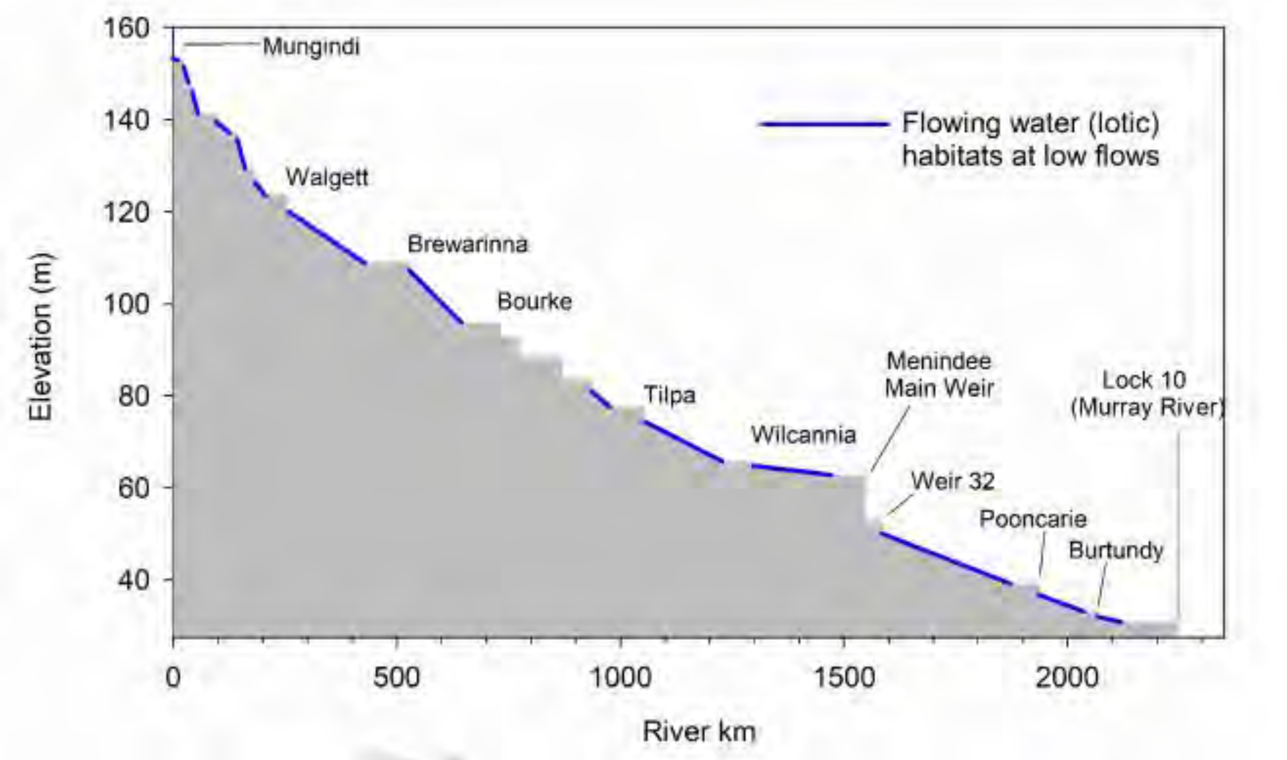


Figure 4-1 Profile of the Barwon-Darling River showing flowing (blue lines) reaches between existing weir pools (Source: Mallen-Cooper and Zampatti 2020)

The Wilcannia Weir is located at the township of Wilcannia, approximately halfway between Bourke and the Murray River and about 50 river kilometres downstream of the confluence with the Paroo River.

The river, including existing weir pools, support a range of ecological, social and cultural values. The following describes aquatic values supported by the river. Terrestrial ecology, Aboriginal cultural heritage and social values and potential impacts are addressed in **Technical Report 2**, **Technical Report 4** and Section16 of the EIS respectively.

4.1.2 Flow regime

The flow regime of the Barwon-Darling River is described as intermittent with long periods of low flow, occasional cease-to-flows and infrequent high flows (refer to **Figure 4-2**). Most recently, Mallen-Cooper and Zampatti (2020) analysed the flow regime of the river, in particular the natural regime and the impacts of regulation on flow intermittency. They concluded that prior to widespread river regulation, the Darling River (Baaka) at Wilcannia flowed for 94 per cent of the time with short (usually less than one month) periods of zero flow but occasional longer periods of cease-to-flow associated with extreme drought conditions. Post-regulation the median flow in the mid-Darling has been reduced by over 70 per cent (Thoms and Sheldon, 2000), and the duration of cease-to-flows is increasing (Mallen-Cooper and Zampatti, 2020).

Figure 4-3 characterises the patterns of cease-to-flows at Wilcannia since 1972 (based on available daily flow records at Wilcannia from the Murray-Darling Basin Authority (MDBA) (2020)). The median cease-to-flow period (assumed to be flow less than one megalitres per day (less than 1 ML/day) is 85 days and the longest duration cease-to-flow was 336 days in 2006. Notably, the number of cease-to-flow events and the total number of cease-to-flow days has become more frequent since 2000, with cease-to-flow events occurring in the majority of years since 2000.

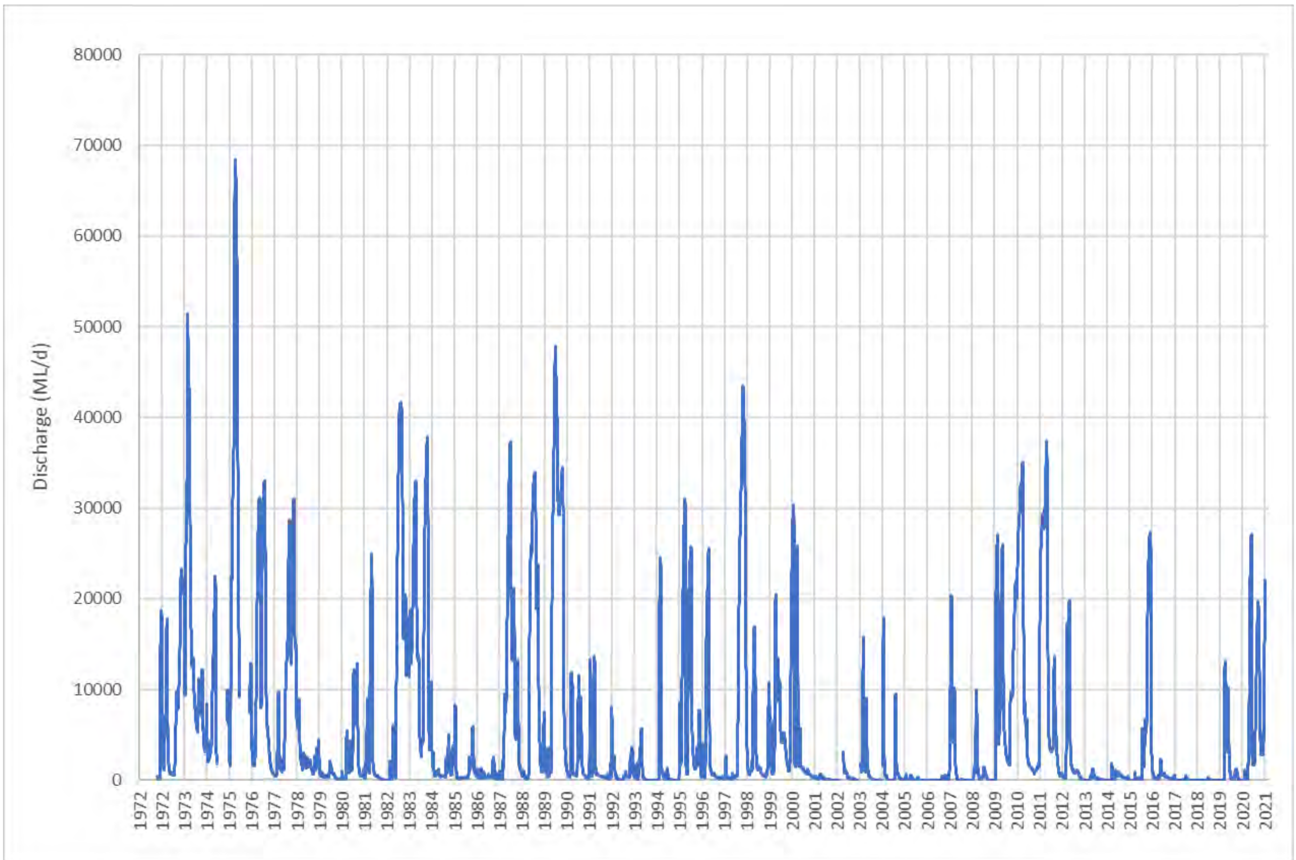


Figure 4-2 Daily flow at Wilcannia (1972-2022) (Data Source: MDBA, 2022)

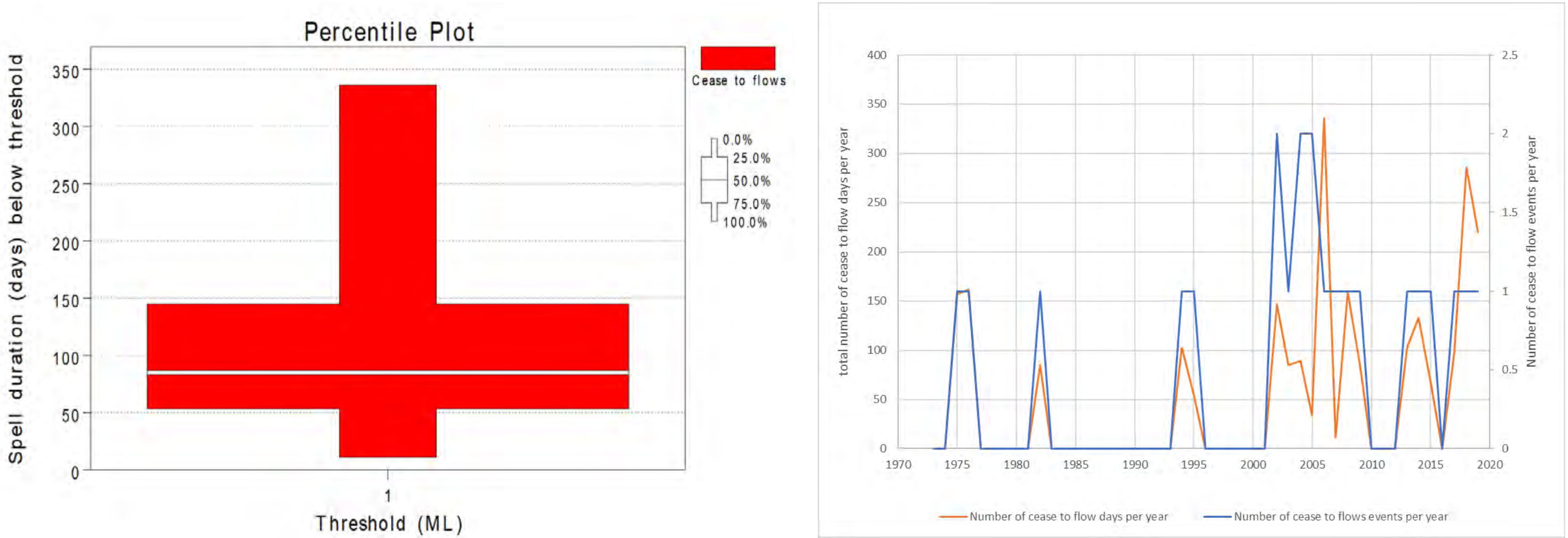


Figure 4-3 Cease-to-flows at Wilcannia (1972-2020). Left panel – summary statistics for all events. Right panel – Time series of number of cease-to-flow events and total number of cease-to-flow days per year (Data Source: MDBA, 2020).

4.1.3 Environmental water requirements

The *Barwon-Darling Long Term Water Plan Part B* (DPIE, 2020a) outlines the environmental water requirements for the Tilpa to Wilcannia Planning Unit and the Wilcannia to Upstream Lake Wetherell Planning Unit, describing various flow categories with corresponding flow rate, timing, duration, frequency and purpose for these flows. Environmental water requirements are consistent across both planning units and are provided in **Figure** 4-4.

Flow category and EWR code[22]		Flow rate	Timing	Duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
Cease-to-flow	CtF	<1 ML/d	Can occur anytime of year, but more common October to March	Maximum duration: Typically, events should not persist for more than 20 days. In very dry years, events should not persist for more than 160 days	CtF events should occur in no more than 50% of years	NA	When managing water to restart flows, avoid harmful water quality impacts, such as de-oxygenation of refuge pools.
Very-low-flow	VLF	>30 ML/d	Anytime	In typical years, at least 340 days per year. In very dry years, at least 165 days per year.	Every year	In accordance with maximum duration of cease-to-flow events	Flows that provide replenishment volumes to refuge pools along the Barwon-Darling. Waterhole persistence can also be supported by groundwater.
Baseflows	BF1	>350 ML/d	Anytime	In typical years, at least 290 days per year. In very dry years, at least 120 days per year.	Every year	155 days	Aiming to provide a depth of 0.3 m to allow fish passage. Also to manage water quality, prevent destratification and reduce risk of blue-green algal blooms.
	BF2	>350 ML/d	September to March	In typical years, at least 185 days per year (within timing window). In very dry years, at least 60 days per year (within timing window).	Every year	200 days	Aiming to provide a depth of 0.3 m to allow fish passage.
Small fresh	SF1	>1,400 ML/d	Anytime – but ideally October to April	10 days minimum	Annual (100% of years)	1 year	Ideal timing is based on preferred temperature range for fish spawning - >20°C for most native fish and >18°C for Murray cod.
							Aiming to provide a depth of greater than 0.5 metres to allow movement of large fish. Flow velocity ideally up to 0.3 to 0.4 m/s (depending on channel form). Ideally shortly after LF2 for increased likelihood of successful recruitment of fish, productivity and dispersal.
	SF2	1,400-14,000 ML/d	September to April	14 days minimum	5–10 years in 10 (75% of years)	2 years	Timing is based on preferred temperature range for fish spawning - >20°C for most native fish and >18°C for Murray cod. Aiming to provide a depth of greater than 0.5 metres to allow movement of large fish. Flow velocity ideally up to 0.3 to 0.4 m/s (depending on channel form).
Large fresh	LF1	>14,000 ML/d	Anytime, but ideally July to September	15 days minimum	5–10 years in 10 (75% of years)	2 years	This flow in Jul to Sep will improve pre-spawning fish condition. Aiming to provide a depth of 2 m to cover in-stream features and trigger response from fish. Flow velocity ideally 0.3 to 0.4 m/s (depending on channel form).
	LF2	>14,000 ML/d	October to April	15 days minimum	3–5 years in 10 (42% of years)	2 years	Aiming to provide a depth of 2 m to cover in-stream features and trigger response from fish.

Figure 4-4 Environmental Water requirements for the Tilpa to Wilcannia and Wilcannia to Upstream Lake Wetherell Planning Units (extract from the *Barwon-Darling Long Term Water Plan Part B* (DPIE, 2020a))

4.1.4 Aquatic habitat

The semi-arid, lowland region of the Darling River (Baaka) is characterised as meandering, slow-flowing and turbid, often surrounded by extensive floodplains containing billabongs, swamps and River Red Gum (*Eucalyptus camaldulensis*) riparian zone and forests (Lintermans, 2007). The freshwater environment of the main Darling River (Baaka) channel is comprised of an extensive range of physical aquatic environments including deep pools, shallow runs/riffles, benches and sand/gravel beds (DPI, 2015). Other aquatic habitat features within the channel include aquatic and riparian vegetation, overhanging banks, fallen trees, snags and woody debris which have fallen instream and now form important niche habitats that provide protection from predatory birds and other fish, feeding and breeding locations, as well as shade and refuge from flows (Lintermans, 2007). Importantly, there are currently 15 major weir structures occurring along the main channel of the Barwon-Darling River (Baaka) upstream of Menindee Lakes, including the existing Wilcannia Weir. These structures have implications for aquatic habitat within the river system as they impede natural flow, resulting in large, inundated areas behind weir structures that lead to submersion of aquatic habitat features (woody debris and aquatic vegetation), reduction in flow or increased occurrence of cease-to-flows below the weir. Pooled water can subsequently lead to reduced water quality, potential increased occurrence of algal blooms, as well as impacts to breeding and spawning conditions of several native species that require flowing conditions. Existing weirs also present barriers to movement along the river, particularly during low flow periods (weirs are drowned at higher/flood flows). Conversely, weir pools may provide refuge habitat for a range of biota during extended periods of cease-to-flow.

As described in **Section 3.3**, the field assessment was undertaken to gain an understanding of the existing conditions of the aquatic environment within the study reach and characterise aquatic habitat values in areas that would be impacted by the proposal. The aquatic environment within the study area has been divided into three sections: upstream of the existing weir pool, within the weir pool and below the existing weir. The overall findings of the aquatic habitat assessment have been summarised below and individual assessment sites are further detailed in **Appendix A**.

4.1.4.1 Upstream of existing weir pool

At the time of inspection, the aquatic environment of the Darling River (Baaka) immediately upstream of the existing weir pool extent was characterised by shallow, slow flowing pools and backwaters and large, mud-rock bars and benches with some gravel beds. The semi-aquatic *Ludwigia peploides* and the flood tolerant sedge *Cyperus gymnocaulos* were present in some areas and could contribute to submerged aquatic habitat under certain flow conditions. No other instream vegetation was observed at any of the upstream sites. There was an abundance of large woody debris that was either submerged or situated on the bank slopes and bars. Algal growth that was free floating in the water column was common at all sites above the weir pool extent.

Bank slopes tended to be moderately steep and mostly bare ground with minimal vegetation except for large River Red Gum which lined the tops of the banks, with native common blown-grass (*Agrostis avenacea*) and minor riparian weed Jersey cudweed (*Pseudognaphlium luteoalbum*) ground cover. Many of the large gumtrees had exposed roots which were protruding from the bank slopes. Three of the five sites above the weir pool had backwater formations. The backwaters at two of those sites were large and dry, and both had a vegetated island between the channel and the backwater. Sites commonly exhibited areas of active erosion including undercutting, past bank failure, fallen trees instream, exposed roots and gully erosion on bank slopes. Typical aquatic environments upstream of the existing weir pool are shown in **Figure 4-5**.

No benthic species were seen in the waterways at these locations (likely due to shallowness of the water column), however there was evidence of River Mussels (*Alathyria jacksoni*) and Darling River Snails (*Notopala sublineata*) at most sites. Live *in-situ* River Mussels and River Mussel shells (dead) were identified at three sites above the weir pool, and Darling River Snail shells (dead) were identified at two sites (A22 – 130m downstream of the upper extent of the proposed weir pool during drought mode and A18 – 5.8 km downstream of the upper extent of the proposed weir pool during drought mode). River Mussels were mostly found on exposed bars and riverbanks in proximity to the water channel. Site A18 had an abundance of bleached Darling River Snail shells present on a dry backwater formation at the northern extent of the river channel. There was no evidence of live snails and dead shells appeared well-weathered. Mallen-Cooper and Zampatti (2020) recorded four populations of Darling River Snails between Tilpa and the Queensland Border, but not in the reaches immediately upstream of the existing Wilcannia Weir pool. The authors noted that all snails were dead, presumably as a result of extended cease to flow conditions, loss of lotic habitat and high temperatures.

Figure 4-5 Aquatic environments above the existing weir pool extent, at site A22 (left) and site A17 (right)

4.1.4.2 Weir pool

A longitudinal profile of the new weir pool is provided in **Figure 4-6**. It shows that the existing weir pool comprises four pools know as Pool 1 (extending upstream from the existing weir), Pool 2, Pool 3 and Pool 4 (at the upstream extent of the existing weir pool).

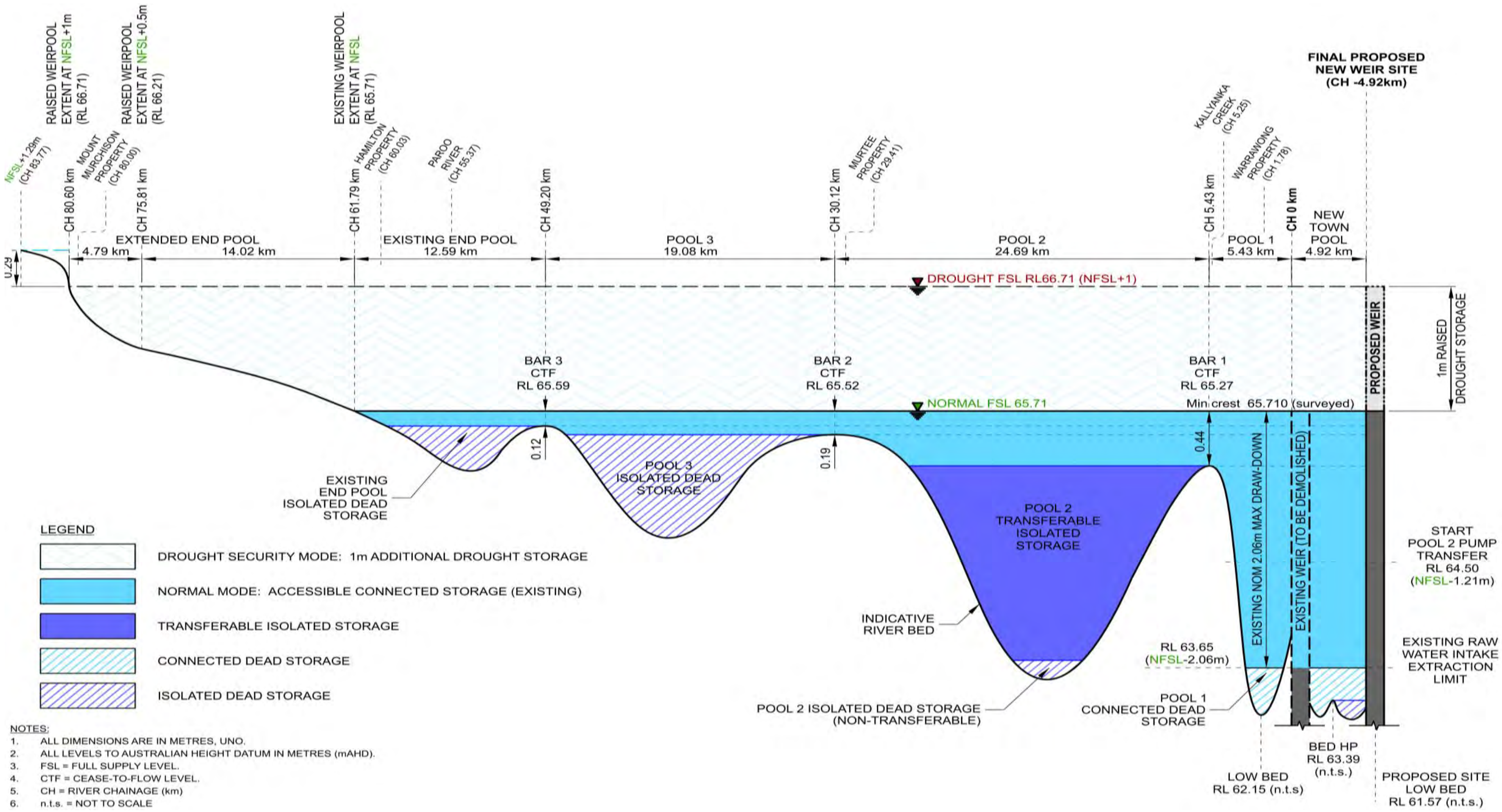


Figure 4-6 Longitudinal profile of the existing weir pool

The existing weir pool mainly consisted of wide, deep pools with no flow (except for some wind generated surface movement). Due to the high water level, there were few observable instream bars within the weir pool, however there were a small number of bars connected to the banks at sites in the lower sections of the weir pool. These bars were generally covered in spiny flatsedge (*Cyperus gymnocaulos*). Algal growth that was free floating in the water column was present at some sites within the weir pool. There was generally no visible instream vegetation at the upstream area of the weir pool, although there was some instream vegetation in the lower sections of the weir pool, particularly at Site A9 and A10 where there was some patches of Floating primrose-willow (*Ludwigia peploides*). All sites had an abundance of large woody debris that was either submerged or situated on the bank slopes and bars (if present).

Banks slopes were moderately steep and mostly bare ground with minimal vegetation except for large River Red Gums that lined the tops of the banks, some groundcover of the native common blown-grass and the minor riparian weed Jersey cudweed. Many of the large gumtrees had exposed roots which were protruding from the bank slopes. Most sites showed areas of active erosion including undercutting, past bank failure, fallen trees instream, exposed roots and gully erosion on bank slopes. Typical aquatic environments within the existing weir pool are shown in **Figure 4-7**.

The only benthic species identified at sites within the weir pool was the Common Carp (*Cyprinus carpio*). River Mussels were mostly absent from the weir pool except for a few sites where some dead shells were present. There was no evidence of any live or dead Darling River Snails at sites within the weir pool extent. No sites had live mussels or snails within the pools as far as could be observed.

Figure 4-7 Aquatic environments within the weir pool, at site A11 (left) and site A10 (right)

4.1.4.3 Downstream of existing weir

Darling (Baaka) River downstream of the existing weir structure was substantially more degraded than the upstream area, likely due to being situated adjacent and immediately downstream of the urban town centre of Wilcannia.

There was no flow over the existing weir and downstream of the weir the river comprised a series of isolated pools and vegetated bars either instream or connected to the banks. Vegetated bars and the riverbanks had a mixture of native riparian sedges (e.g. C*yperus gymnocaulos*) and riparian weed species. Some reaches of the river had very large bars that spanned several kilometres in length and the majority of the width of the channel. These bars had some shallow, low flowing water. Algal growth was less common downstream of the weir structure however there was often scum or an oily sheen present on the surface of the water, and more gross pollutants (litter) instream and on the banks. There appeared to be some emergent instream vegetation within the river, including small patches of Floating primrose-willow growing at some sites and lots of dead woody vegetation instream. There was also an abundance of large woody debris that was either submerged or situated on the bank slopes and bars.

Banks slopes were moderately steep or near vertical. The tops of the banks were generally vegetated with large, mature River Red Gum, with groundcover on the banks dominated by riparian weed species including Noogoora burr (*Xanthium occidentale*), Flaxleaf fleabane (*Conyza bonariensis*), Jersey cudweed and Prickly lettuce (*Lactuca cerriola*). Many of the large gumtrees had exposed roots which were protruding from the bank slopes. Sites usually showed areas of active erosion including undercutting, past bank failure, fallen trees instream, exposed roots, and gully erosion on bank slopes. Typical aquatic environments downstream of the existing weir pool are shown in **Figure 4-8.**

Aquatic species observed at sites below the weir were Common Carp (in refuge pools) and live and dead River Mussels (on channel margins). Well-weathered Darling River Snail shells were also observed on the riverbanks and on exposed instream bars. The presence of dead Darling River Snails at site upstream and downstream of the existing weir suggest the potential for snails to be present. However, there was no evidence of any live Darling River Snails (all dead shells were well bleached with no evidence of recently dead shells).

Figure 4-8 Aquatic environments downstream of the existing weir pool, at site A5 (left) and site A1 (right)

4.2 Water quality

The Barwon-Darling system is a large dryland river system that drains a catchment of 650,000 square kilometres. Although it is considered an unregulated river, the Barwon-Darling River upstream of Menindee has been subject to significant impacts from headwater dams in the tributary systems and water extraction. Water quality degradation occurring within the Barwon-Darling catchment is the result of a combination of factors such as the alteration to the natural flow regime, changes to catchment conditions and land-use activities. The water quality condition of the Darling River (Baaka) at Wilcannia was assessed as 'poor' during the development of the Barwon-Darling Watercourse Water Resource Plan (DPIE, 2019). Key water quality issues are attributable to flow, both high and low flow. High flow from rainfall and runoff results in increased sediment thereby resulting in higher turbidity, nutrients, pathogens and possibly pesticides. The Darling River (Baaka) at Wilcannia, generally recorded the highest turbidity, which reflects the general trend towards increasing turbidity and nutrient concentration with distance down the catchment as cumulative impacts increase (DPIE, 2019).

Low flow also poses a risk to water quality which occurs not only due to the climatic conditions and low annual rainfall, but as result of headwater dams and water extraction which has seen over one third of the average annual flow being diverted (DPI, 2018). This can result in the Darling River (Baaka) drying up to a series of standing pools, particularly over extended periods of no tributary inflows. The water quality of these standing pools is generally poor with elevated nutrients, sediments and salinity, and reductions in dissolved oxygen, which can further impact on water quality and aquatic ecosystems both within the remnant pools and in downstream reaches, when upstream flows recommence and flush poor quality water further downstream. The most severe impacts associated with low flows and poor water quality are fish kills caused by long durations of cease-to-flow coupled with algal blooms within the remnant pools that when mixed through the water column cause a rapid decline in dissolved oxygen that leads to anoxic conditions and the death of aquatic biota, as occurred in the summer of 2018-19 in the lower Darling River (Baaka) around Menindee (AAS, 2019).

Routine water quality data collected in the catchment and spot samples collected for the proposal within the proposal footprint area have been analysed to identify water quality issues and their cause (Jacobs, 2021). Results of the analysis and further discussion about regional water quality are presented in **Technical Report 1** of the environmental impact statement).

4.3 Aquatic biodiversity

4.3.1 Regional aquatic biodiversity

The Darling River (Baaka) is designated as Key Fish Habitat (KFH) (DPIE, 2021) and supports a diverse assemblage of native and introduced aquatic species. A total of 19 fish species are known to inhabit the system, including 15 native species and four alien species (DPI, 2015). Five of the native species are Commonwealth (EPBC) and state (FM) listed threatened species including Murray Cod (*Maccullochella peelii)*, Silver Perch (*Bidyanus bidyanus)*, Purple Spotted Gudgeon (*Mogurnda adspersa)*, Freshwater catfish of the Murray-Darling Basin (*Tandanus tandanus)* and the western population of the Olive Perchlet (*Ambassis agassizi*i). Of these, Murray Cod, Silver Perch and Olive Perchlet are predicted to occur within the study area, the others being located in habitats further upstream and in tributary streams on the western side of the Great Dividing Range (DPIE, 2021; DAWE, 2021; EESG, 2021; ALA, 2021) (refer to **Section 4.3.2**). The Darling River Snail (*Notopala sublineata)*, which is listed as a critically endangered aquatic species under the FM Act, is also predicted within the system (although no live specimens have been recently recorded in the Darling River), as is the River Mussel (Mallen-Cooper and Zampatti, 2020). Turtle species which may occur in the area and have been recorded upstream and downstream of Wilcannia include the Eastern Long-necked Turtle (*Chelodina longicollis*), Broad-shelled Turtle (*Chelodina expansa*) and Murray River Turtle (*Emydura macquarii)*. The four alien species which are known to occupy the waterway include Common Carp (*Cyrinus carpio*), Eastern Gambusia (*Gambusia holbrooki*), Redfin Perch (*Perca fluviatilis*) and Goldfish (*Carassius auratus*). Importantly, Carp is the most common alien fish in the catchment and there are several mapped 'Carp hot spots' immediately upstream and downstream of the town of Wilcannia (DPI, 2015) (refer to **Figure 4-9**). An assessment of fish community status of the Barwon-Darling valley by Fisheries NSW in 2015 suggested that the fish community in the region (Tilpa to Menindee Lakes) was in moderate health and fish condition status is mapped as fair to good in the main channel and good in anabranches and inflowing unregulated creek and rivers, with minimal reaches below poor condition and some parts in good to very good condition (DPI, 2015) (refer to **Figure 4-9**).

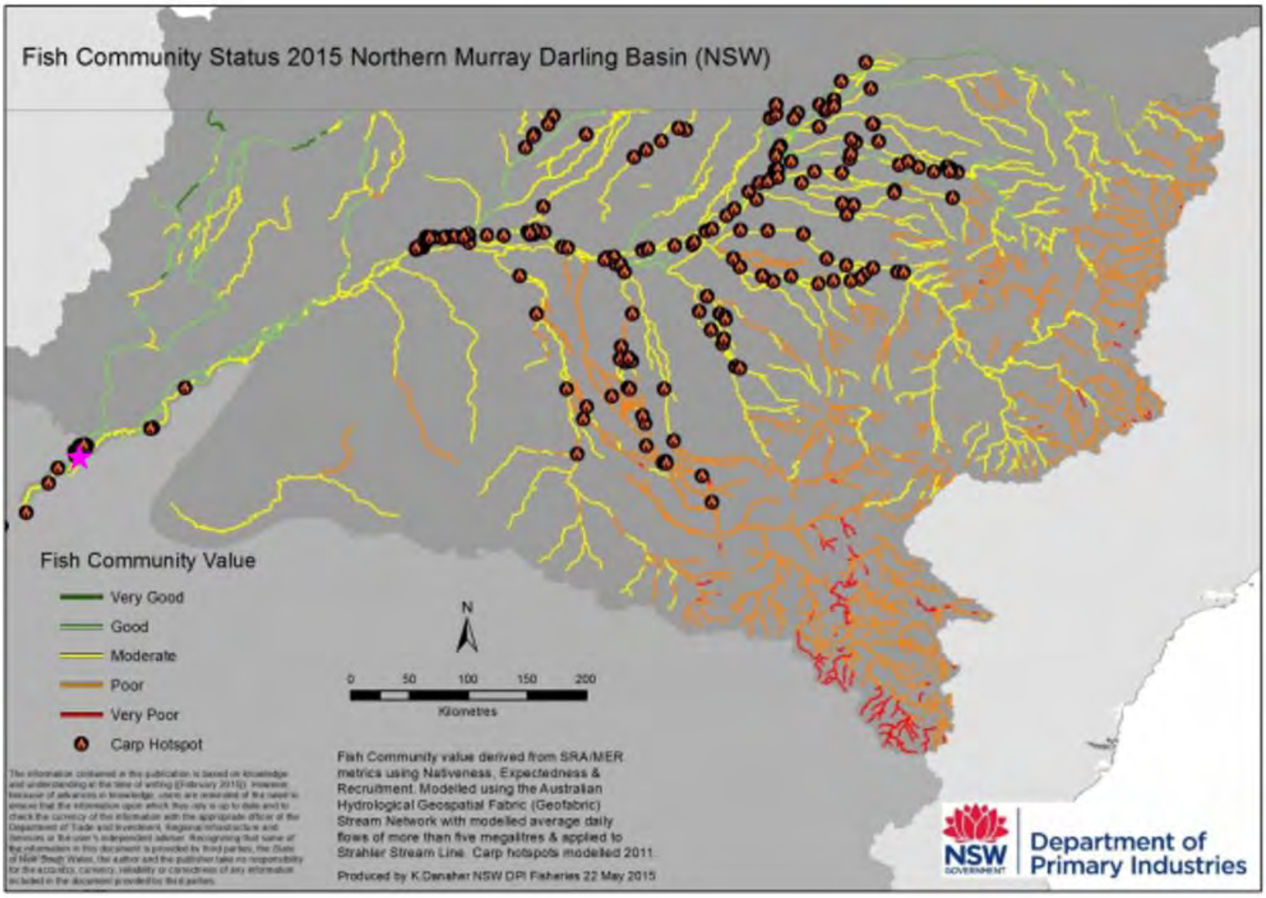


Figure 4-9 Fish Community Status for the NSW section of the Northern Murray-Darling Basin, highlighting condition of fish communities and Carp hotspots. The pink star indicates the location of Wilcannia Weir. (Adapted from DPI, 2015)

4.3.2 Threatened species

Table 4-1 outlines the Commonwealth and state listed aquatic species that are predicted to occur within the study reach. The Darling River (Baaka) is not expected to support any other threatened aquatic species listed under the FM Act, or EPBC Act, according to database searches (DAWE, 2021; EESG, 2021; ALA, 2021), and the predicted distribution maps for threatened species listed under the FM Act (DPIE, 2021).

Table 4-1 Likelihood of occurrence of commonwealth and state listed threatened aquatic species

Common Name	Species Name	EPBC Act	FM Act	Distribution	Likelihood of occurrence
Murray Cod	*Maccullochella peelii*	V	-	The Murray Cod occurs naturally in the watercourses of the Murray-Darling Basin (ACT, SA, NSW and Vic) and was formerly widespread in lower and mid altitudes of the Murray Daring Basin, however the species now has patchy distribution.	Likely – Recordings within the study area based on database searches (DAWE, 2021; EESG, 2021; ALA, 2021). Further assessment is provided in **Section 7** and an assessment of significance has been undertaken for the species which is detailed in **Appendix B**.

Common Name	Species Name	EPBC Act	FM Act	Distribution	Likelihood of occurrence
Silver Perch	*Bidyanus bidyanus*	CE	V	The Silver Perch was once widespread with a distribution range including most of the Murray-Darling Basin and extending through drainage lines within western NSW. The species has experienced dramatic decline throughout the region. It is suggested that the current species distribution is likely to be limited to a portion of the mid-Murray River below Yarrawonga Weir, as well as several of its anabranches and tributaries including Edward River, an anabranch of the Murray River that flows through Deniliquin, and the Murrumbidgee River.	Unlikely – Historic recordings within the study area based on database searches (DAWE, 2021; EESG, 2021; ALA, 2021) and the species has predicted distribution within the study area (DPIE, 2021). It is suggested however, that the current species distribution is likely to be limited to sections of the mid-Murray River as well as its associated tributaries and anabranches. Further assessment is provided in **Section 7** and an assessment of significance has been undertaken for the species which is detailed in **Appendix B**.
Western population of the Olive Perchlet	*Ambassis agassizii*	-	EP	In NSW, the species was formally widespread in the Darling, lower Murrumbidgee, lower Murray and Lachlan Rivers. However, is now known in few localities which include Darling drainage and upstream of Bourke.	Likely – Recordings within the study area based on database searches (DAWE, 2021; EESG, 2021; ALA, 2021) and the species has predicted distribution within the study area (DPIE, 2021). Further assessment is provided in **Section 7** and an assessment of significance has been undertaken for the species which is detailed in **Appendix B**.

Common Name	Species Name	EPBC Act	FM Act	Distribution	Likelihood of occurrence
Darling River Snail	*Notopala sublineata*	-	CE	The Darling River Snail is endemic to the Darling River and its tributaries. The species was once common and widespread in the river system however populations have declined rapidly over the last few decades. Populations are now thought to only occur in a small number of locations in artificial environments (irrigation pipelines) in southern NSW.	Possible – No live recordings within the study area based on database searches (DAWE, 2021; EESG, 2021; ALA, 2021), however evidence of the species has been found in the paleo record (Aboriginal middens) (Mallen-Cooper and Zampatti, 2020) and empty, well bleached shells were found along the study reach during the site visit (refer to **Section 4.1.3** and **Appendix A**). The species also has predicted distribution within the study area (DPIE, 2021). Further assessment is provided in **Section 7** and an assessment of significance has been undertaken for the species which is detailed in **Appendix B**.
River Mussel^	*Alathyria jacksoni*	-	-	The River Mussel occurs in main channels of the Murray-Darling river system in New South Wales, Victoria and South Australia. Although not listed as threatened, the River Mussel is considered an important species in the ecosystem and should be treated as a sensitive species.	Likely – Recordings within the study area based on database searches (DAWE, 2021; EESG, 2021; ALA, 2021), and observed during site inspection upstream, within and downstream of the existing weir pool. Further assessment is provided in **Section 5**.

Species listings; CE (Critically Endangered), E (Endangered), EP (Endangered Population), V (Vulnerable), P (Protected).

^ - The River Mussel is not listed under any legislation, however it is listed as Data Deficient (DD) on the IUCN Red List of Threatened Species (Köhler, 2011).

Further discussion about the characteristics and preferred habitat of threatened and important aquatic species is provided below.

4.3.2.1 Murray Cod

The Murray Cod (*Maccullochella peelii*) is the largest Australian freshwater fish, reaching up to 113.6 kilograms and 1800 millimetres in length. Its distinguishing features include its large mouth, cream to white belly and green mottled pattern on its body and head. The species are long-lived, with the oldest cod that has been accurately aged found to be 48 years old (Lintermans, 2007).

Preferred habitat for both juvenile and adult Murray Cod generally consists of deep holes in low-flowing rivers, and particularly around instream rocks, woody debris, fallen trees or undercut banks which provide shelter and protection from predators. They tend to rest in hollows in rock or wood. Adults will mostly feed on other fish, invertebrates and frogs, and will generally hide in aquatic vegetation and wait for unsuspecting prey to approach.

Larvae will feed on crustaceans, insects and zooplankton found in main channels of rivers or streams (Kalatzis and Baker, 2010).

The breeding cycle for the Murray Cod consists of spawning in spring and early summer when water temperatures exceed about 15° Celsius. Further, it has only recently been discovered that Murray Cod make an upstream migration to spawn. This movement can be up to 120 kilometres and generally occurs in late winter/early spring when river levels are high. After spawning the fish will move downstream again, often returning to the same area they occupied before the migration (usually to exactly the same snag). The spawning process involves depositing large, adhesive eggs on hard surfaces such as submerged logs, rocks or clay banks. The male will guard the eggs during incubation and they hatch after 5-13 days. The larvae are about 5-8 mm long at hatching and have a large yolk sac. Larvae drift downstream for 5-7 days, particularly at night in spring and summer (late-October – mid-January, peaking from mid-November to mid-December) (Lintermans, 2007).

The Murray Cod was once abundant throughout the Darling River system but overfishing and changes to habitat has drastically reduced their numbers. The key activities related to river modification and regulation which have resulted in the decline of the species include introduction of artificial barriers (such as dams and weirs), de-snagging rivers, clearing riparian and aquatic vegetation, erosion, reduced river flows, introduced species and cold-water pollution (Kalatzis and Baker, 2010).

4.3.2.2 Silver Perch

Silver Perch (*Bidyanus bidyanus*) is a medium to large freshwater fish, reaching a maximum length of approximately 500 millimetres and maximum weight of eight kilograms. The species is relatively long-lived, with the maximum age recorded for an individual fish being 27 years. Its body colour is grey to grey-brown along the top, changing to silvery on the sides and lower area, and lighter on the belly. The scales are much smaller than those on Golden or Macquarie Perch, and the head and mouth are small. The tail is weakly forked (Lintermans, 2007).

The species are found in a wide range of habitats in the Murray-Darling system. Their preferred habitat is generally found in fast-flowing, more open sections of river (DPI, 2017) but they can also be found in lowland, turbid and slow-flowing rivers (Lintermans, 2007). Silver perch are an omnivorous species, with a diet including aquatic plants, snails, shrimps and aquatic insect larvae (Lintermans, 2007).

Silver Perch tend to spawn in spring and summer after migrating long distances upstream. Spawning is thought to occurs at night, just after dusk. The species spawn naturally in response to a change in conditions; usually a rise in water levels (rainfall) coinciding with water temperatures above 23° Celsius. Each female will lay 300,000 or more eggs that are about 2.7 millimetres in diameter, which hatch within 36 hours (DPIE 2017). Eggs and larvae passively drift with the river current for a number of days. After about 5 days the yolk sac is absorbed and the larvae will start to feed on zooplankton. Juveniles disperse over large distances, and are often seen in fishways travelling upstream in large schools (DPI, 2017).

The species was once widespread and abundant throughout most of the Murray-Darling Basin and had a significant enough population to be a commercially harvested species in the 1900s. Overfishing led to consistent decline of Silver Perch which resulted in the collapse of the fishery in the 1980s. Capture and sale of Silver Perch from riverine habitats is now prohibited however it is legal for anglers who comply with the recreational fishing rules to catch and keep Silver Perch from stocked impoundments and private dams. Harvesting Silver Perch from fish farms is also permitted (DPI, 2017).

The key activities related to river modification and regulation which have resulted in the decline of the species include introduction of artificial barriers (such as dams and weirs) that lead to disrupted cues for migration and spawning and reduce opportunities for dispersal and availability for food. Further to this, clearing riparian and aquatic vegetation, erosion, competition and disease from introduced species (particularly Epizootic Haematopoietic Necrosis Virus carried by Red Fin Perch) and cold-water pollution are major threats to the lifecycle and survival of Silver Perch.

4.3.2.3 Olive Perchlet

The Olive Perchlet (*Ambassis agassizii)* is a small, oval fish with a laterally compressed body, moderately large oblique mouth and large eyes. The species is relatively short-lived, with the maximum age recorded to be about four years. The species can grow up to 70-80 millimetres but is usually less than 40 millimetres (DPI, 2013b). The body is olive to semitransparent and the scales have brownish margins, giving it a reticulated appearance. Fins are clear (Lintermans, 2007).

The Olive Perchlet prefers to inhabit the vegetated edges of lakes, creeks, swamps, wetlands and rivers and is usually found in sheltered areas around overhanging vegetation, woody debris, aquatic macrophyte beds, dead branches and boulders in slow-moving or still waters and particularly backwaters (Lintermans, 2007). It forms almost stationary, small schools during daylight hours in areas close to instream cover, then will disperse to feed at night (DPI, 2013b).

The species is carnivorous, with a diet that consists of microcrustaceans, aquatic and terrestrial insects, and occasionally, small fish. The species will mainly feed during daylight hours (Lintermans, 2007).

Spawning occurs from October to December, when water temperatures reach 22-23^{o} Celsius. Females will lay between 200 and 700 eggs that are about 0.7 mm in diameter. The eggs are adhesive and will attach to aquatic plants and rocks on the streambed. Hatching occurs in 5-7 days at 22^{o} Celsius, and larvae are approximately 3 mm long at hatching (DPI, 2013b).

The precise reasons for the decline of this species are unknown, but predation by alien species (particularly Eastern Gambusia and Redfin Perch), cold-water pollution that restricts spawning, habitat degradation, river regulation and related decline in wetland condition (e.g. loss of macrophyte beds) are thought to be significant (DPI, 2013b).

4.3.2.4 Darling River Snail

The Darling River Snail **(***Notopala sublineata*) is a medium-sized freshwater snail. It has a round shell that ends in a conical spire. The outer shell is generally dark green but may also be greenish brown or dark brown, without banding. The body is similar to other snails but possesses a prominent snout and short eye stalks on the outside of the tentacles (DPI, 2018).

The species was once abundant in flowing rivers of the Murray-Darling System, along the banks, attached to logs and rocks, or crawling in the mud. They are now virtually extinct throughout their natural range however artificially introduced hard surfaces now provide habitat for the species, with populations being recorded as surviving in irrigation pipelines in southern NSW. The pipeline environment is thought to promote microbial production and organic accumulation, which is a highly nutritious food source for the species. In open environments, the species also feeds on the bacteria and microflora associated with detritus (DPI, 2018).

The species gives birth to live young rather than laying eggs. As such, the species has limited dispersal capabilities as dispersal via drifting or by dislodged egg capsule is not possible. Fertilisation is internal, and the young remain with the female until they are large enough to survive independently (DPI, 2018).

The species has become threatened due to changes in the nature of their food source as a result of altered flow regimes (principally weir and dam building). Algal blooms that grow in reduced flow environments impact on the species due to the environment becoming nutrient deficient. Further, the decline in the species occurred around the time of the incursion of Common Carp into the Darling River system and may be associated with predation by these fish or habitat degradation caused by them. De-snagging and removal of large-woody debris from rivers has also resulted in direct habitat loss for the species (DPI, 2018).

4.3.3 Other species

4.3.3.1 River Mussel

The River Mussel (*Alathyria jacksoni*), has a sub-oval shell, with its anterior end comparatively narrow and the ventral edge is straight. The maximum length of the shell is about 200 mm. This species occurs as different growth forms in moderate to strong currents: the moderate current form has a distinct dorsal blade or 'wing', whereas the fast-current form has a dorsal arch, apparently permitting greater foot extension and a more secure anchorage (Ponder, et al, 2020).

The species occupies the shallow region of silty mud and sand bars and banks of the main channels of the Murray-Darling system, generally in regions of flowing water. The River Mussel is a suspension feeder and therefore relies on flow to feed on nutrients (Ponder, et al, 2020).

Larvae are brooded in marsupia in the gills of females and, when released, become parasitic on fish gills and fins where they undergo metamorphosis before dropping to the sediment as free-living juvenile mussels (Ponder, et al, 2020).

River mussels are known to occupy the permanently flowing sections of the main channels of the Murray-Darling river system. Whilst not considered threatened by Commonwealth or state legislation, the species is listed as Data deficient on the IUCN Red List of Threatened Species (Köhler, 2011).

Threats to the River Mussel is predominantly related to reduced flows, including cease to flow, and submersion/drowning of the habitat (instream bars and banks).

4.3.3.2 Eastern Long-necked Turtle

The Eastern Long-necked Turtle (*Chelodina longicollis*) is a medium sized turtle which is oval-shaped, has a black to light brown coloured carapace with a shallow groove on its centre. The long and narrow neck is brown to gray dorsally and yellow – ventrally. The Eastern Long-necked Turtle has nostrils on the tip of its snout, so it can breathe while partially submerged in water searching for worms, snails and insect larvae. The turtle is a side-necked turtle, which means that its head bends sideways into its shell, rather than directly back. If threatened, it will withdraw its head and expel a pungent odour to repel predators (Animalia, 2021).

The Eastern Long-necked Turtle is the most widespread species of freshwater turtle in Australia. It lives in slow-moving rivers, lakes and waterways across most of NSW, but is often found on land. Eastern long-necked turtles are carnivorous animals, feeding upon fish, crustaceans, molluscs, amphibians, worms and insects (Animalia, 2021).

These turtles have a polygynous mating system, where a male can mate with many females. The breeding season takes place during the autumn months, from September to October, while the nesting period is October-December. Their nesting sites are situated nearby water. Usually, the female lays 8-24 eggs, which have a form of ellipse and are hard-shelled. The eggs are incubated for 120-150 days, after which, between January and late April, the young hatch out. The newly hatched turtles are fully independent, receiving no parental care from their mother, who may breed again if the conditions are favorable. It takes quite a long time for the Eastern long-necked turtle to become sexually mature. Typically, males are mature at 7-8 years old, whereas female turtles reach maturity at 10-12 years old (Animalia, 2021).

Threats to the Eastern Long-necked Turtle are predominantly related to hunting and predation by humans and foxes, as well as degradation of habitat condition (Animalia, 2021).

4.3.3.3 Broad-shelled Turtle

The Broad-Shelled Turtle (*Chelodina expansa*) has a broad, oval and flattened carapace with a length of around 50 cm. The carapace length is often greater in females than males. The turtle has a rich brown to blackish-brown carapace above, typically displaying fine dark flecks or reticulations, and a whitish or cream-colored belly. The plastron is narrow and the shell does not display any noticeable expansion anteriorly. The shell is usually twice as long as wide and is broadest at the level of the bridge. The head is broad and highly depressed, and the eyes are directly dorsolateral. When extended, the neck may be longer than the carapace (Cogger, 2014).

The Broad-Shelled Turtle (*Chelodina expansa*) is mostly found in turbid waters of depths greater than three metres. It is mostly a riverine turtle, generally inhabiting permanent streams but is also found in oxbows, ponds in floodplains, backwaters, and swamps across its distributed region. The Broad-Shelled Turtle will tend to inhabit environments that are undisturbed and have moderate vegetation cover for nest construction. The turtle has shown a preference of aquatic habitats in structured environments, where submerged logs, root systems and dead trees occur. Factors such as shelter from predators and food availability may influence the habitat preference of the species. Seasonal changes including water level and flow may also influence the selected the habitat (Cogger, 2014).

This species usually nests during autumn or in early winter when soils decrease in temperature. It will also sometimes nest during spring. Although the female broad-shelled river turtle will travel up to one kilometre away from the bank to lay her eggs, it is more common for them to nest within 100 m of the water's edge. The female turtle constructs a nest by excavating a nesting chamber with her hind legs to a depth of around 20 cm. She then deposits between 5 and 28 eggs before backfilling the nest with soil. These turtles will nest any time of the day or night with nesting being initiated by rain. The incubation period will take between 324 and 360 days and the young will usually hatch during spring. Upon hatching, the young remain in the egg chamber awaiting heavy rain to trigger their release. The soil surrounding the nest, which becomes compacted and relatively hard during the long incubation, is softened by the rains and allows the hatchlings to dig their way out through the softened soil (Cogger, 2014).

Threats to the Broad-Shelled Turtle are predominantly related to hunting and predation by birds and foxes, as well as nest predators such as monitor lizards, ibis and feral pigs (Cogger, 2014).

4.3.3.4 Murray River turtle

Murray River turtle (*Emydura macquarii)* is a short-necked turtle with a carapace that is predominantly medium to dark brown above, and cream coloured below. There male has a larger and longer tail than the female. The skin is greyish and there is a distinctive creamy-yellow stripe running along the side of the head from the corner of the mouth. The eyes are small and yellow with a round black pupil (Marshall, 2005).

The Murray River turtle occurs primarily in rivers and waterbodies associated with rivers such as backwaters, oxbows, anabranches and deep, permanent waterholes on the floodplains. This species appears to avoid shallow water (Marshall, 2005).

Turtles are slow growing and typically do not reach sexual maturity until about 15 years of age. Courtship and mating in captivity is known to occur from March to April. Nesting occurs between mid and late spring to early summer (late October – mid December). Females generally lay two or three clutches of eggs in a season, each clutch consisting of about 10 – 15 eggs, and taking six weeks to four months to hatch (Marshall, 2005).

Threats to the Broad-Shelled Turtle are predominantly related to hunting and predation as well as habitat degradation and climate change impacts such as reduction in rainfall and drought (Marshall, 2005).

4.3.4 Threatened Ecological Communities

The proposal lies wholly within the endangered ecological community (EEC) known as '*the natural drainage system of the lowland catchment of the Darling River*' (Darling River EEC). The Darling River EEC encompasses a large area of inland NSW including the Barwon-Darling River (DPI, 2007) (refer to **Figure 4-10**). This aquatic EEC comprises all native fish and aquatic invertebrates within all natural creeks, rivers, streams and associated lagoons, billabongs, lakes, anabranches, flow diversions to anabranches and floodplains of the Darling River within NSW. Artificial canals, water distribution and drainage works, farm dams and off-stream reservoirs are excluded from this aquatic EEC.

The Darling River EEC system is characterised by highly variable flows and unpredictable patterns which has led to reliance of many native aquatic species on seasonal flows to trigger spawning events (DPI, 2007). Since European settlement, the Darling River EEC has experienced significant modification due to anthropogenic-related activities of land clearing, agriculture, water regulation and pollution, and introduction of invasive species. These activities have caused a significant amount of the aquatic habitat to become degraded and as a result, many of the native species have greatly declined in both their distributions and abundance.

As such, the Darling River EEC has been protected under the FM Act. In accordance with the EP&A Act, legal penalties apply to unapproved activities which may harm a feature of this EEC. Potential impacts of the proposal on the Darling River EEC have been considered in this assessment and are documented in an 'seven-part test of significance' for the Darling River EEC in **Appendix B** of this report.

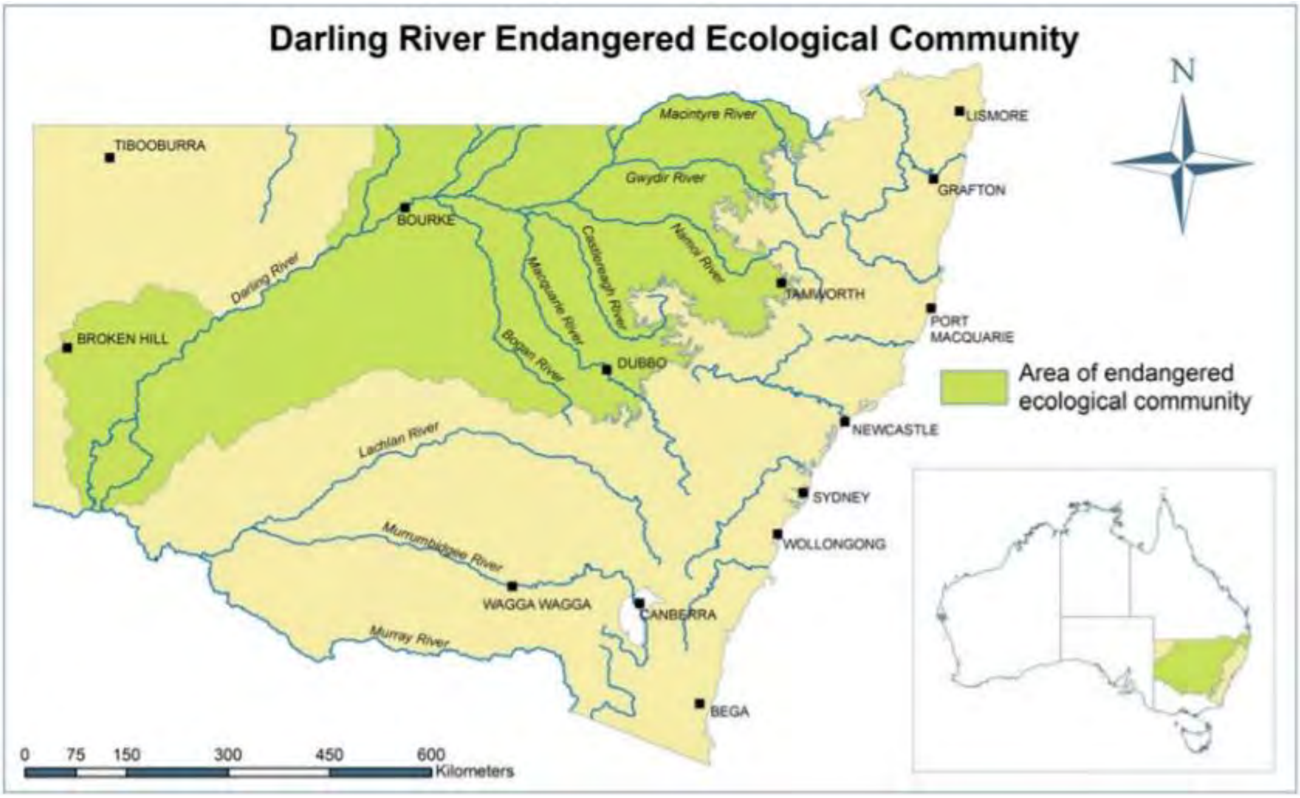


Figure 4-10 Darling River Endangered Ecological Community (Source: DPI, 2007)

5. Impact assessment – Construction

Construction activities have the potential to directly and indirectly impact on aquatic habitats and aquatic species within the Darling River environment. The main potential impacts relate to instream construction activities which may directly harm aquatic species, mobilisation of poor water quality to the downstream receiving environment, temporary barriers to fish passage, as well as the removal, disturbance and degradation of instream habitat features and riparian vegetation. The surface water quality impact assessment for the proposal (Jacobs, 2021), which is available in **Technical Report 1** of the EIS, has identified the potential impacts and associated management and mitigation measures with respect to anticipated changes to water quality. This aquatic ecology impact assessment has considered the consequences to aquatic biota and ecosystem processes of any water quality changes associated with construction activities identified in the surface water assessment report.

The construction phase will involve a range of activities including de-snagging, riparian vegetation clearance, earthworks, bank excavation, instream works and concrete works for the construction of proposal elements, as well as establishment of construction laydown areas and access tracks. Activities related to construction are further summarised in **Section 1.2** and detailed in Section 2 of the EIS. As detailed below, these activities have potential to result in impacts to aquatic ecology without the implementation of appropriate management and environmental control measures. A risk assessment of the identified impacts has been undertaken and provided in **Section 5.2**.

5.1 Potential impacts

5.1.1 Instream works

Instream works are required for the construction of the new weir and partial removal of the existing weir. For the construction of the new weir, the following instream works would be required:

- Construction and dewatering of temporary cofferdams
- Streambed levelling
- Sheet piling to a depth of 12 metres below the level of the riverbed, and potentially shallower sheet piling to support the toe of the downstream embankment to a depth of about 6 metres
- Instream construction of design features including rock fill embankments and the fishway.

The partial removal of the existing weir would mainly consist of demolition works using an excavator with rock grab and teeth bucket, and hammer and teeth bucket.

Without implementation of appropriate management and mitigation measures, instream construction activities may directly harm aquatic species if they come into contact with equipment or machinery, or by smothering aquatic vegetation and species (i.e. clogging fish gills) from the disturbance and mobilisation of riverbed sediment within the works area.

Indirect impacts to aquatic species as a result of instream works are related to potential streambed disturbance and subsequent water quality impacts that are associated with the increased risk of exposed sediment being mobilised downstream. Water quality impacts could lead to a breach of a range of chemical and physio-chemical parameters that support healthy aquatic communities. The ecological effects can range from direct fatality to organisms, to alteration of ecosystem structure and function through changes in the abundance, composition and diversity of communities and habitat. Changes to nutrient loads mobilising to the waterway and increased turbidity can lead to algal blooms and reduced visibility for fish. Increased turbidity and algal blooms can also lead to clogging fish gills, smothering benthic invertebrates and infilling of benthic habitat, smothering of aquatic vegetation, or may cause a reduction of light penetration which can limit the growth of macrophytes.

5.1.2 Construction runoff and dewatering

The establishment and use of construction areas and access roads within proximity of the Darling River, and within the river itself (dry sites), have the potential to impact water quality due to mobilisation of sediments and other contaminants via wind, stormwater runoff or construction discharges/dewatering. Potential causes of impacts may be:

- transportation of dust, litter and other pollutants associated with establishment and use of construction sites, construction compounds and access tracks
- transportation of loose sediment associated with vegetation clearing and earthworks, including riverbank excavation and vehicle movement across exposed earth
- transportation of pollutants from accidental spills or leaks of fuels and/or oils from the maintenance, refuelling and use of construction plant equipment and vehicle movement travelling to and from site
- transportation of stormwater runoff contaminated with by-products of activities occurring on sites, such as stockpiling, concreting and material laydown
- transportation of cement dust, concrete slurries or washout water
- mobilisation of poor-quality water from dewatering instream (dry site) areas or discharge from construction sediment basins.

Mobilisation of sediments and poor water quality have the potential to directly harm native species that are unable to tolerate changes to water quality or can favour the proliferation of pest species that may be able to tolerate poorer water quality (i.e. Common Carp). Indirect impacts from the disturbance and mobilisation of sediments may result in:

- Deposition of sediment within aquatic habitat such as deep pools
- A decrease in trophic interactions due to decreased visibility
- Reduced light penetration which can limit growth of aquatic vegetation
- Algal blooms which could result in areas having little to no oxygen where aquatic life cannot survive. Algal blooms may also negatively impact aquatic life by blocking out sunlight and clogging fish gills
- Potential loss of habitat or reduced suitability of habitat for native fauna that are sensitive to changes in water quality.

In addition to sedimentation impacts, concrete works which are required for building the new weir can result in concrete dust, concrete slurries or washout water entering downstream waters. Concrete by-products are alkaline, with a pH of around 12, and therefore have the potential to alter the pH of downstream watercourses which can be harmful to aquatic life that are sensitive to changes in water quality. Additionally, concrete washout water contains high levels of chromium that can accumulate in the gills and intestines of fish.

5.1.3 Removal of instream habitat features

The construction of the new weir and partial removal of the existing weir would require clearance of instream vegetation and displacement of aquatic habitat features, particularly large woody debris and rocks, which may be within the construction footprint area or immediately adjacent to the instream footprint on the bank slopes.

Removing aquatic habitat features has potential to directly impact aquatic species that depend on them for food supply, shelter, spawning and recruitment processes. Aquatic habitat features are often used as breeding habitat and provide protection for juveniles. As described in **Section 4.3.2**, adult and juvenile Murray Codd and Olive Perchlet may live within or around these features as they are their preferred habitat. Removal of habitat features therefore has the potential to result in habitat loss, reduced reproductivity or direct mortality of adults, larvae and young-of-year native species.

5.1.4 Removal of riparian vegetation and bank excavation

The proposed construction of the new weir is anticipated to require removal of approximately 0.35 hectares of riparian vegetation and significant bank excavation works on both sides of the Darling River (Baaka). The partial removal of the existing weir would also require a small amount of riparian vegetation clearance to allow construction plant and equipment to access the site.

Riparian vegetation clearance and excavation can result in indirect impact on aquatic species as it can affect water quality if runoff is able to mobilise exposed soils into the waterway or may reduce channel stability which could result in increased bank erosion and subsequent sediment deposition downstream of the works. Sedimentation and erosion can impact the geomorphology of a stream through deposition of sediment and changes to flow rate, thus altering habitat structure.

5.1.5 Temporary barriers to fish passage

The installation of temporary structures during construction has the potential to temporarily hinder or possibly prevent movement of fish within the Darling River (Baaka) main channel. Potential barriers may be caused by the following:

- Silt curtains – to be erected around instream work sites at the new weir site and upstream and downstream of the instream work site for partial removal of the existing weir removal site
- Cofferdams – to be constructed and used to create a dry area for construction of the new weir. Cofferdams would be constructed in two key stages:
  - For the construction of the fishway: A temporary cofferdam would be built along the right side of the river (northern side) around the work site for the fishway. The cofferdam would extend to about half way across the river from the right (northern) bank and be about 12 metres longer than the fishway at both ends, making it about 144 metres long
  - For the construction of the weir wall: Temporary cofferdam walls would be built upstream and downstream of the proposed weir site. These cofferdams would extend from the western riverbank to the left wall of the fishway. A temporary cofferdam would be built across about half the width of the river on the left bank upstream and downstream of the proposed weir wall and extending around the work site for the weir wall.

Barriers to fish passage are dependent on how complete the barrier is. At the new weir construction site, the floating silt curtains would be located around instream activities and cofferdams have been designed to only span about half the width of the waterway at any one time so that no damming or weir effect is created. This is because construction will be carried out in two stages; the first stage will be construction of the fishway and the second stage will be construction of the weir wall once the fishway becomes operational.

A cofferdam and silt curtain area also proposed around a temporary in-stream work site at the existing weir, however, this is not considered to be a risk at this location as the existing weir structure already completely obstructs fish passage. Therefore there would be no change in existing conditions until partial removal of the existing weir structure is complete. At completion, fish passage would be improved as the new fishway at the new weir site would allow fish passage.

5.2 Risk assessment

A risk assessment of potential impacts outlined in **Section 5.1** has been carried out to consider the consequence and likelihood of impacts:

1. without the implementation of environmental management and mitigation measures (risk)
2. with the implementation of proposed measures (residual risk).

The risk assessment is provided in **Table 5-1**.

Table 5-1 Risk assessment of identified impacts - Construction

Activity	Potential impact	Consequence	Likelihood	Risk	Proposed measures	Consequence	Likelihood	Residual risk
Instream works	▪ Direct harm or mortality of fauna ▪ Downstream sedimentation leading to increased turbidity and nutrients which may reduce visibility for fish, clog fish gills, smother aquatic vegetation, smother benthic invertebrates, infill habitat features and increase algal productivity.	Moderate	Likely	Medium	▪ Floating silt curtains will be placed around isolated work areas at the new weir site ▪ Floating silt curtains will also be placed around isolated work areas at the existing weir site ▪ Work sites will be inspected for fauna prior to the start of work each day ▪ Fauna salvage will be undertaken within the enclosed work areas prior to commencement of any instream works ▪ Water pumped out of temporary cofferdam areas (dry sites) will be treated and discharged in accordance with the *Australian and New Zealand Guidelines for Fresh and Marine Water* Quality (Australian and New Zealand Governments (ANZG), 2018).	Insignificant	Rare	Very low
Construction runoff and dewatering	▪ Direct harm to native species that are unable to tolerate changes to water quality	Moderate	Likely	Medium	▪ Erosion and sediment controls such as construction sediment basins, sediment fencing, diversion drains and bunding will be constructed within and around temporary construction	Minor	Rare	Very low

Activity	Potential impact	Consequence	Likelihood	Risk	Proposed measures	Consequence	Likelihood	Residual risk
	▪ Favouring the establishment and proliferation of pest species that may be able to tolerate poorer water quality ▪ Erosion and sedimentation downstream, leading to increased turbidity and nutrients which may reduce visibility for fish, clog of fish gills, smother aquatic vegetation, smothering of benthic invertebrates, infill habitat features and increase algal productivity.				sites, compounds and access tracks prior to any vegetation clearing or ground disturbance ▪ Fuels and oils for construction equipment, machinery and vehicles will be stored in a bunded area, greater than 50 metres away from the Darling River. All refuelling and maintenance will be undertaken within bunded areas ▪ Runoff captured in construction sediment basins will be treated and discharged in accordance with ANZG (2018) guidelines and procedures outlined in the Blue Book (Landcom, 2004) ▪ Water pumped out of temporary cofferdam areas (dry sites) will similarly be treated and discharged in accordance with ANZG (2018) water quality guidelines ▪ To avoid dispersal of aquatic pest species during dewatering, fauna salvage will be undertaken prior to water being pumped out. If any aquatic pest species are present, the appropriate management procedures would be			

Activity	Potential impact	Consequence	Likelihood	Risk	Proposed measures	Consequence	Likelihood	Residual risk
					undertaken in accordance with the FM Act.			
Removal of instream habitat features within the construction footprint	▪ Direct habitat loss or reduced quality of habitat ▪ Direct mortality of individuals, particularly threatened native species which have potential to live within and around large woody debris and aquatic vegetation (Murray Codd and Olive Perchlet) ▪ Reduced productivity of the aquatic ecosystem ▪ Disturbance of the streambed which may result in downstream sedimentation. Sedimentation can lead to increased turbidity and nutrients which may reduce visibility for fish, clog of fish gills, smother aquatic vegetation,	Moderate	Likely	Medium	▪ Compensatory habitat should be provided upstream and downstream of construction areas prior to habitat removal and commencement of construction. ▪ Large woody debris will be relocated from the construction footprint area to a suitable location upstream or downstream of the site in consultation with a qualified ecologist and WaterNSW ▪ Habitat features, such as large woody debris and aquatic vegetation, will be removed as a final step from the dry site following fauna salvage and dewatering ▪ To minimise any impact of construction on the breeding processes of species, removal of habitat features should be undertaken outside of the breeding season if possible (spring and summer) of threatened native fish species that may utilise these features	Minor	Unlikely	Low

Activity	Potential impact	Consequence	Likelihood	Risk	Proposed measures	Consequence	Likelihood	Residual risk
	infill habitat features and increase algal productivity.				for spawning. Noting that compensatory habitat is to be provided prior to habitat removal within the construction footprint.			
Removal of riparian vegetation and bank excavation	▪ Reduced bank stability which may lead to erosion and downstream sedimentation. Sedimentation can lead to increased turbidity and nutrients which may reduce visibility for fish, clog of fish gills, smother aquatic vegetation, infill habitat features and increase algal productivity. ▪ Bank erosion may also result in geomorphic impacts which can lead to changes in flow rate, thus altering habitat structure and features	Moderate	Possible	Medium	▪ Riparian vegetation clearing on the slopes of the banks will be undertaken within the enclosed dry site areas ▪ Bank excavation works have been designed to ensure the integrity of the bank structure is retained.	Insignificant	Unlikely	Low

Activity	Potential impact	Consequence	Likelihood	Risk	Proposed measures	Consequence	Likelihood	Residual risk
Installation of temporary instream structures	Temporarily preventing movement of fish within the Darling River channel which may lead to: ▪ Barriers to individual migration ▪ Decreased trophic interactions ▪ Disruption of spawning processes and potentially mortality of free-flowing eggs.	Moderate	Possible	Medium	▪ The cofferdams have been designed to only span about half the width of the waterway at any one time ▪ Construction staging has aimed to minimise obstruction of passage by choosing to construct the fishway first and subsequently completing the weir wall when the fishway becomes operational ▪ To minimise any impact of construction on the breeding processes of species, construction of the new weir should be undertaken outside of the breeding season (spring and summer) of threatened native fish species that may utilise these features for spawning.	Insignificant	Rare	Very low

6. Impact assessment – Operation

The existing weir is a fixed crest weir that has no ability to respond to flows in the river to optimise water security for Wilcannia or downstream environmental conditions. The inclusion of fishway gates and weir gates at the new weir would enable its operation to be managed to optimise water security for Wilcannia as well as reduce environmental impacts to the river. A summary of the how the new weir would operate and the rules that would govern its operation is provided in **Section 6.1**.

During the operational phase of the proposal, potential risks to the aquatic community of the Darling River (Baaka) are associated with changes to water level, velocity and flows due to the new position and height of the weir, in particular the areas of new permanent and intermittent inundation in the weir pool, as well as changes to flows downstream of the new weir. **Section 6.2** outlines potential impacts which may occur to the Darling River (Baaka) aquatic environment based on hydrological changes that are expected to occur, and **Section 6.4** provides a risk assessment for the potential impacts.

6.1 Overview of the operation of the new weir

6.1.1 Modes of operation

The new weir would have dual modes of operation comprising a normal operation mode when it would operate as close to the normal FSL (65.71 metres AHD) as possible depending on gate and fishway operation, and a drought security operation mode when it would operate at the drought FSL of 66.71 metres AHD i.e. one metre above the normal FSL.

When the new weir is at the normal FSL it would result in a weir pool of about 66.71 river kilometres comprising the existing 61.79 river kilometres of weir pool upstream of the existing weir plus a new section of weir pool of about 4.92 river kilometres between the new and existing weirs, which is referred to as the 'new town pool'. Noting that operation of the gates and fishway would result in an elevation in water level above the existing FSL under certain flow conditions – these are assessed in more detail in **Section 6.2.1**.

The temporary increase in the FSL of one metre during drought security operation mode would result in a weir pool that is one metre deeper and extends about 18.81 river kilometres further upstream than the existing weir pool, to create a weir pool that is about 85.52 river kilometres long.

Table 6-1 identifies the maximum volume of water that can be stored in the existing weir pool and how much of this is accessible to Wilcannia, and the maximum volume of water that can be stored in the new weir pool and how much of this would be accessible when the new weir is in normal and drought security operation modes.

Table 6-1 Maximum total and accessible storage volumes in the existing and new weir pools

Weir pool		Maximum storage volume (megalitres)	
Description	**Full supply level**	**Total**	**Accessible**
Existing weir pool	65.71 metres AHD	4207	2173
New weir pool – normal operation mode	66.71 metres AHD	4755	2577
New weir pool – drought security operation mode	66.71 metres AHD	7832	5654

6.1.2 Dynamic storage during normal operation mode

Preliminary operating rules for the new weir have been developed with the objective of minimising upstream headwater levels. The preliminary operating rules would create a dynamic storage where the storage capacity of the weir would vary as the weir gates are raised (closed) or lowered (opened) as follows:

- At low flows the crest of the weir gates would be set at the normal FSL and a maximum flow depth of 0.5 metres (533 megalitres per day) would be allowed to pass over the top of the weir gates. This maximum gate opening of 0.5 metres has been applied for headwater levels up to 67.21 metres AHD (drought FSL plus 0.5 metres) to control downstream energy dissipation at lower flows and tailwater depths. The minimum fishway flow discharge would be 60 megalitres per day when the crest of the weir gates is at the normal FSL
- If flows over the weir gates increase above a flow depth of 0.5 metres, the weir gates would start to be raised (closed) to limit the maximum overtopping of the weir gates to 0.5 metres. i.e. the weir gate crest level would be equal to the headwater level minus 0.5 metres. Raising (closing) of the weir gates would occur progressively in sync with headwater level increases. Flows over the weir gates would peak at 350 megalitres per day when the headwater level is between 66.21 metres AHD and 66.71 metres AHD
- For headwater levels above 67.21 metres AHD, the weir gates are unable to be raised above the drought FSL (66.71 metres AHD) and hence gate overflows would become greater than 0.5 metres. For the preliminary concept design, this is assumed to be manageable considering the expected relatively high total discharge and significant associated tailwater depths.

The preliminary operating rules for dynamic storage have been selected as they are less operationally intensive and complex than if the weir gates were operated so as to maintain a weir pool at the normal FSL during periods of increasing inflows. The effects of the proposed operation on weir pool levels and velocity are discussed in **Section 6.2.1.**

6.1.3 Transition phases and trigger levels

The new weir would transition from normal operation mode to drought security operation mode via a filling phase, while the transition back to normal operation mode from drought security operation mode would occur via a reset phase. Transitions between the normal and drought security operation modes would be triggered by monitoring upstream flows to assess risks to Wilcannia's water security. The following trigger levels were adopted for the purposes of simulating the operation of the proposal using the Barwon-Darling Source River System Model:

- Trigger for the filling phase to start — flows over Bourke Weir falling below 250 megalitres per day
- Trigger for the reset phase to start — flows over Bourke Weir rising above 300 megalitres per day.

An operations plan for the new weir is being prepared in consultation with DPE Water, Fisheries NSW, DPE Environment and Heritage, MDBA and WaterNSW. The operating plan will need to consider interactions and potential effects of the proposed Western Weirs Program on the proposed Wilcannia Weir operations (see Section 6.3). A draft operations plan is provided in Appendix I of the EIS. The operations plan will continue to be developed with the stakeholder agencies, and will clearly define the triggers for starting the filling and reset phases. Moreover, in accordance with mitigation and management measures for hydrology impacts opportunities to refine triggers for the filling phase will be investigated with the aim of reducing the frequency of filling while ensuring that water security is maintained (refer to mitigation measures HY02 in **Table 10-1**).

6.1.4 Progressive gate closure during the filling phase

When the new weir enters the filling phase the weir and fishway gates would be closed progressively to mitigate downstream flow impacts. For the purposes of modelling, the following gate closure logic was adopted:

- The discharge is reduced by 50 per cent of the previous day's discharge every day
- The discharge cannot exceed the inflow to the weir pool

- The weir gates would close (and discharges cease) when the discharges reduces to 30 megalitres per day.

The operations plan will include details on how the weir and fishway gates are to be closed during the filling phase.

6.1.5 Reset phase

The actions taken in the reset phase to transition the new weir from drought security operation mode to normal operation mode would depend on the headwater level when the reset phase is triggered:

- If the reset phase is triggered when the headwater level is below the normal full supply level then refilling of the storage to the normal full supply level would occur. Once the headwater level reaches the normal full supply level the weir would start normal operation mode. There are very few events in the modelled record where the weir pool level was below the normal fully supply level at the recommencement of flow.
- If the reset phase is triggered when the headwater level is above the normal full supply level then the fishway gates would be lowered and the weir gates managed so that the maximum overtopping is 0.5 metres. The reset operation would enable downstream flows to recommence more quickly than current conditions because under current conditions every cease to flow event results in the pool being drawn down below the existing weir crest and hence there is always a delay in flows recommencing downstream as the current pool refills.
- During the reset phase lowering of the gate crest would be limited to 100 millimetres per day or less, which is similar to the current drawdown rate following high flow events (refer to the geomorphology impact assessment in **Technical Report 1**).

The operations plan will include details on how the weir and fishway gates are to be opened during the reset phase.

6.1.6 Translucency discharges during drought security operation mode

The new weir would have an accessible storage volume of about 5,654 megalitres at the drought FSL compared to about 2,173 megalitres for the existing weir at the normal FSL. This extra 3,481 megalitres of storage capacity is equal to the volume of water in the upper 1.17 metres of the weir pool. A translucency rule would apply when the weir is in drought security operation mode and the weir pool level is within the range of the increased accessible storage i.e. when the weir pool level is between the drought FSL (66.71 metres AHD) and 65.54 metres AHD (the drought FSL minus 1.17 metres). The translucency rule therefore applies across the additional one metre of water stored when the new weir is in drought security operation mode plus 17 centimetres of storage below the normal FSL.

Translucency discharges would only occur when there are inflows to the combined new town pool and Pool 1. The discharge rate would aim to match the rate of inflow to the combined new town pool and Pool 1, so as to maximise downstream flows. The translucency discharge would enable the passing of small unregulated inflows and environmental water flows during drought security operation mode. The existing weir operation does not allow for such passing flows, which would be captured in the weir pool until it fills and spills.

The translucency discharges would result in a dynamic storage that would be managed through operation of the fishway gates and weir gates. When the weir pool level is above the normal FSL translucency discharges could occur via the fishway and the weir gates. It is not proposed to lower the weir gates below the normal FSL while the weir is in drought security operation mode, which means that when the weir pool level is below the normal FSL translucency discharges could only occur via the fishway.

The implementation of the translucency rule will be detailed in the operations plan.

In accordance with mitigation and management measures for hydrology impacts. the initial downstream flows resulting from the implementation of the translucency rule will be monitored to identify opportunities to optimise these flows (refer to mitigation measure HY3 in **Table 10-1**). Based on the findings of this monitoring, the operations plan for the new weir may be revised if opportunities are identified to increase downstream flows by modifying how the translucency rule is implemented. Any proposed revisions to the implementation of the translucency rule will be discussed with key stakeholders prior to the operations plan being updated.

6.1.7 Planned environmental water

Planned environmental water is addressed in Section 4.2.7 of **Technical Report 1**. A planned environmental water nominal minimum discharge of 350 megalitres per day would be able to be discharged over the top two metres of the storage when it is in drought security operation mode i.e. between the drought full supply level (66.71 metres AHD) and 64.71 metres AHD. Passage of planned environmental water past the new weir would need to be coordinated with WaterNSW as the operator.

6.1.8 Fish entrainment by water supply pumps

During water extractions, under both normal and drought security operation modes, there is potential for the entrainment of fish, larvae and eggs into the pumps. A fish screen on the pump inlets would avoid this impact is . A fish screen on the pump inlets is being considered as part of the aquatic biodiversity offset for the proposal being negotiated with Fisheries NSW (refer to **Section 9.2**).

6.2 Potential impacts

The following sections describe potential impacts for the new intermittent inundation area upstream of the existing weir pool, the permanent inundation area at the 'new town pool' and changes to flows downstream of the new weir structure. For each reach the hydrological and hydraulic changes are described under normal and drought security operation modes. The potential impacts on biota of the combined changes are then assessed.

6.2.1 Existing weir pool and upstream of existing FSL

Potential hydrological and hydraulic effects on the existing weir pool and the reach upstream of the existing FSL vary depending on the operation mode. During normal operating mode the weir pool would be operated as close to the existing FSL as possible in order to maintain flowing conditions as close as possible to existing conditions (depending on flow rate and gate settings). During drought security operation mode the water level will be raised above the existing FSL and areas of river channel that would otherwise be dry or contracted to residual refuge pools would be inundated to a greater depth and extent. The effects associated with each of these operation modes are discussed in the following sections. The length of river reach between the existing FSL and the new FSL during drought mode is 18.81 kilometres. This represents around 10 per cent of the flowing habitat between the current FSL and the next upstream weir at Tilpa (about180 kilometres).

6.2.1.1 Normal operation mode

Hydraulic changes

Hydrodynamic modelling was carried out by Public Works Advisory, on behalf of Water Infrastructure NSW, with the involvement of Dr Martin Mallen-Cooper. The modelling considered nine flow rates ranging from 100 megalitres per day to 5,000 megalitres per day, when the new weir is in normal operation mode. Water velocities were modelled at 439 locations (cross sections) along a 105-kilometre long reach of the Darling River (Baaka) upstream of the new weir.

Longitudinal profiles of the modelled reach of the river are provided in **Figure 6-1** to **Figure 6-9** for each flow rate modelled. Each longitudinal profile shows the existing water level (light blue coloured line) and predicted water level (dark blue) for the existing and new weirs respectively. The level of the riverbed (black) is also shown to provide a reference for the water levels. The existing water velocity (light red) is shown in each longitudinal profile together with the difference between the existing and predicted water velocities (bold red), with a positive difference indicating a reduction in water velocity.

For the existing weir (Crest level 65.71 metres AHD), the figures show that water velocity is typically greater and more variable upstream of the existing weir pool FSL (upstream of chainage 61790, bed level 65.71 metres

AHD) and slows and becomes less variable when water enters the weir pool, with the velocity gradually reducing further as water flows through the weir pool to the existing weir crest at chainage 0. The water velocity spikes (increases) as water flows over Bar 3 (chainage 49200, bed level 65.59 metres AHD), Bar 2 (chainage 30120, bed level 65.52 metres AHD) and Bar 1 (chainage 5430, bed level 65.27 metres AHD), particularly at flows above about 600ML/day.

Under proposed normal operating mode, the longitudinal profiles show that for the existing weir pool and upstream of the existing weir pool:

- At flows up to 350 ML/day (the *Barwon-Darling Long Term Water Plan* recommended base flow) result in very little difference in water level, weir pool extent or velocity profile in the existing and upstream weir pool.
- At flows of 600-1,400 ML/day the water level elevation under proposed operations increases relative to the current water level in the lower reaches of the existing weir and velocity starts to decrease over the Bars. At and above the existing FSL there is a slight increase in water level, but velocity does not decline substantially.
- At flows above 2,000 ML/day both current and proposed water level increases along the entire weir pool relative to low flow levels, although the increase in water level is greater under proposed conditions. At higher flows the velocity differential decreases, especially at Bars 2 and 3 and upstream of the existing FSL. As river flows continue to increase past the modelled 5,000 ML/day and completely submerge the new weir, the backwater effect would progressively reduce and become negligible before any overtopping of riverbanks occurs during flood conditions.

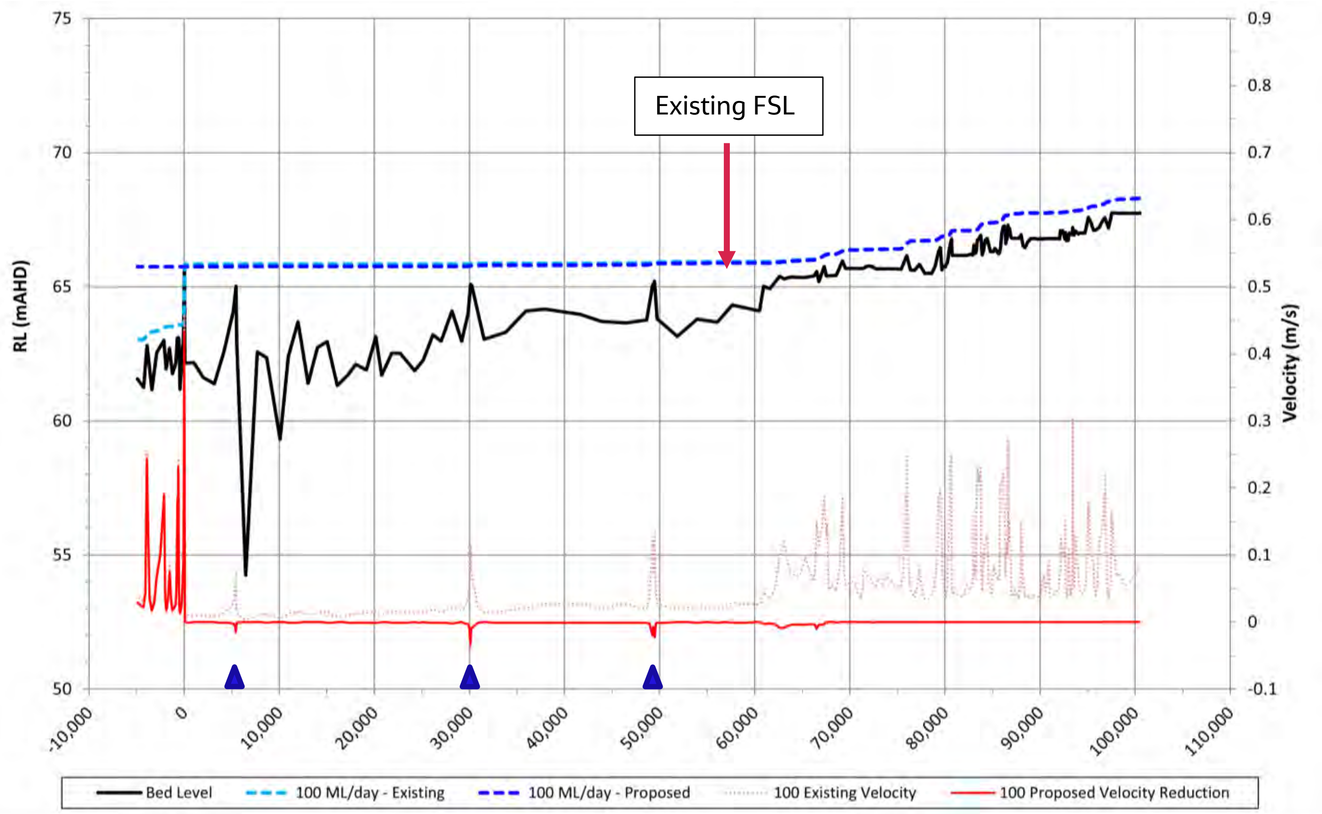


Figure 6-1 Predicted change in water velocity for flows of 100 megalitres per day. Blue triangles are rock bars

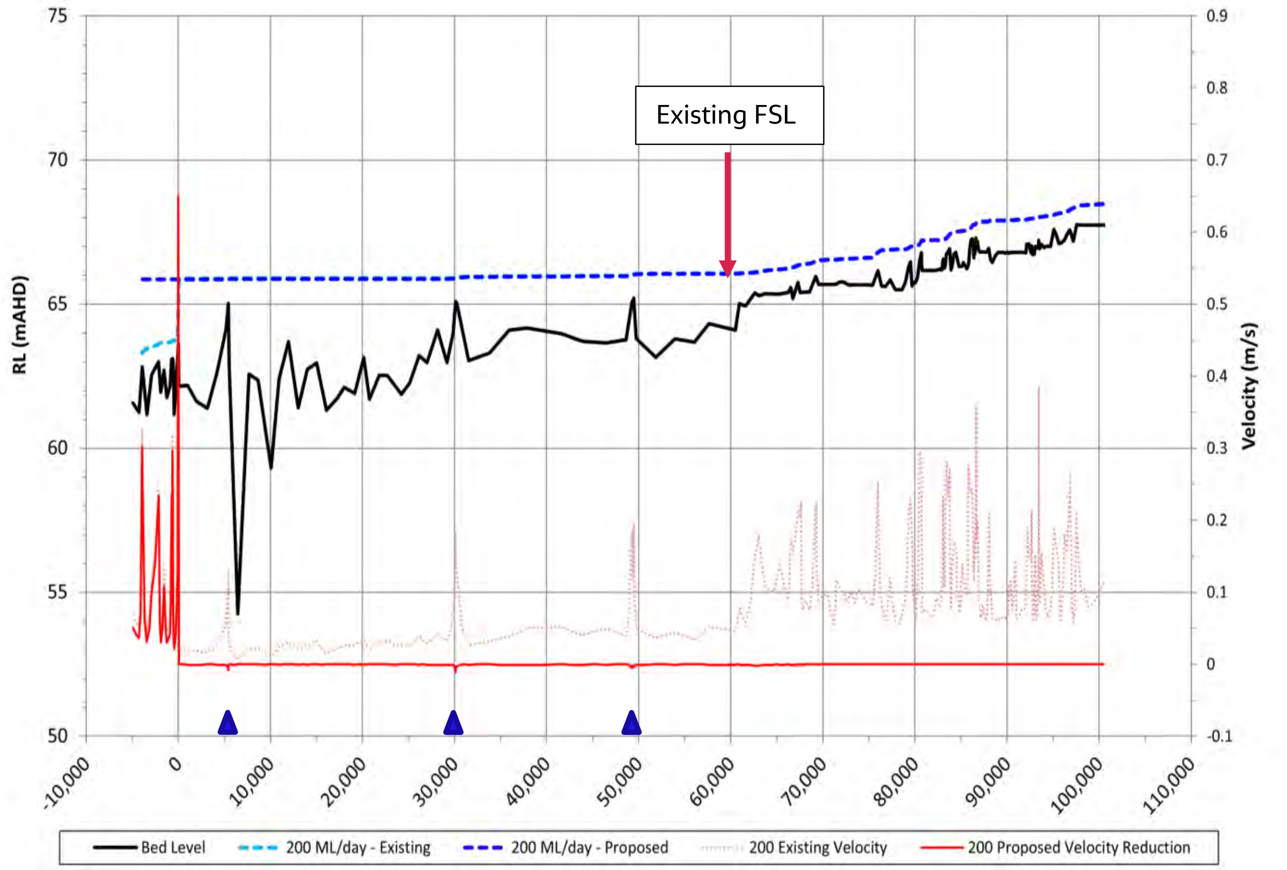


Figure 6-2 Predicted change in water velocity for flows of 200 megalitres per day. Blue triangles are rock bars

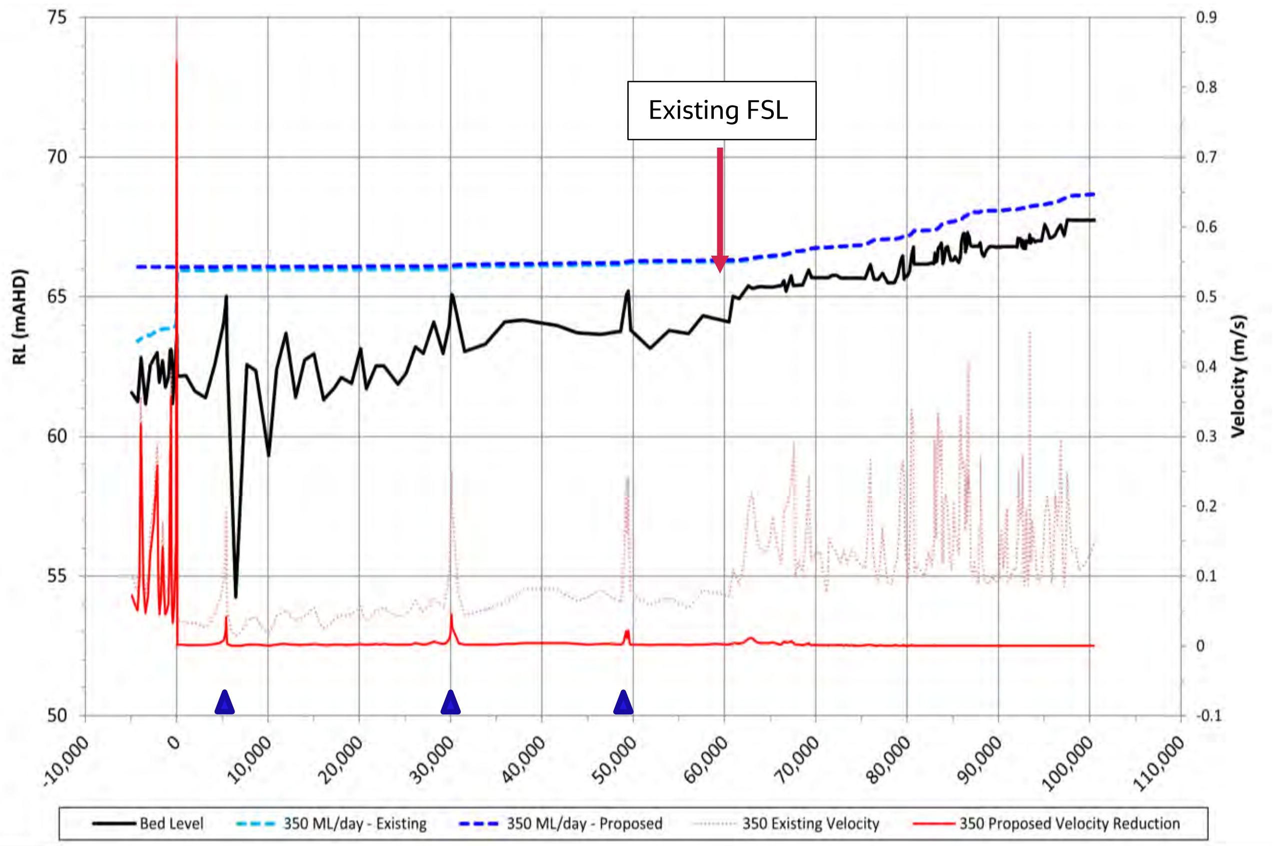


Figure 6-3 Predicted change in water velocity for flows of 350 megalitres per day. Blue triangles are rock bars

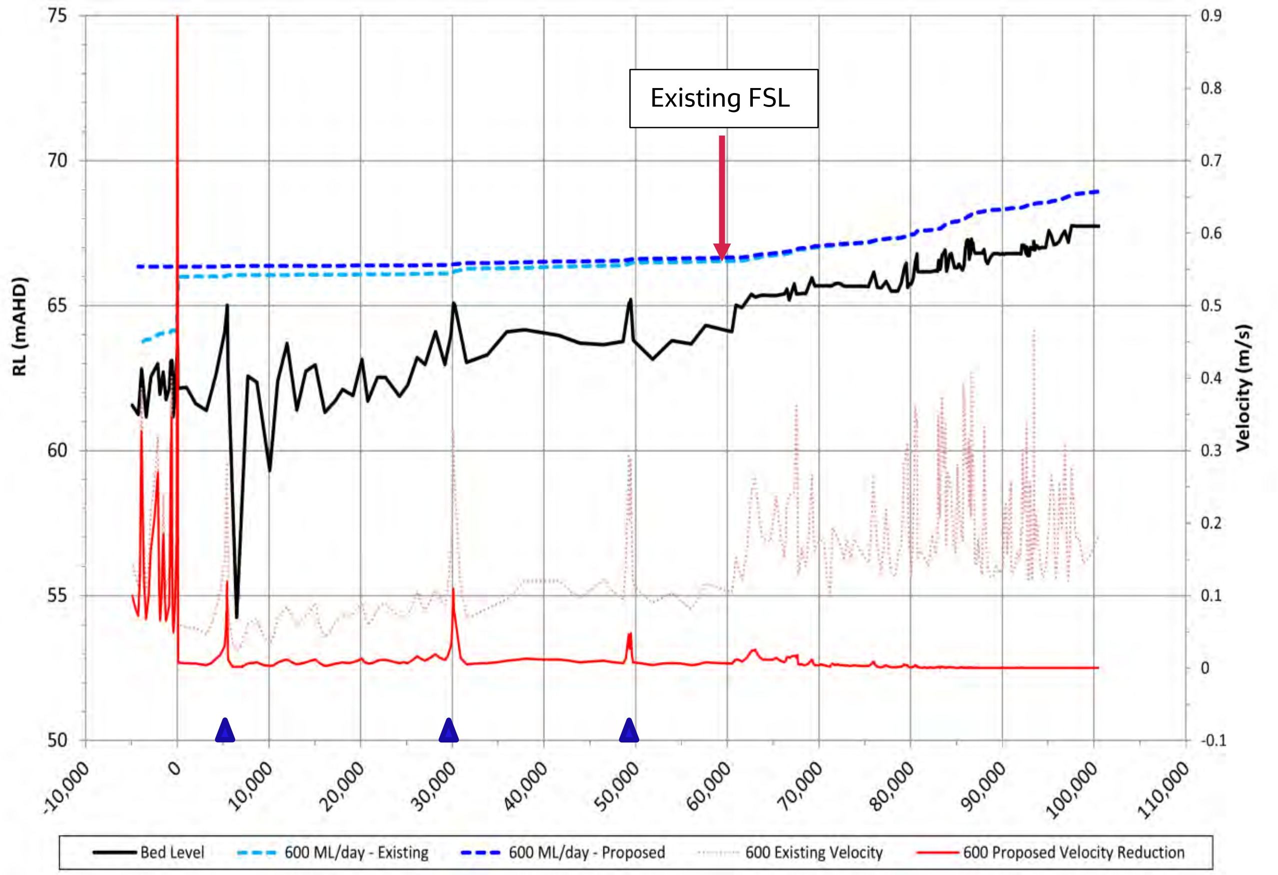


Figure 6-4 Predicted change in water velocity for flows of 600 megalitres per day. Blue triangles are rock bars

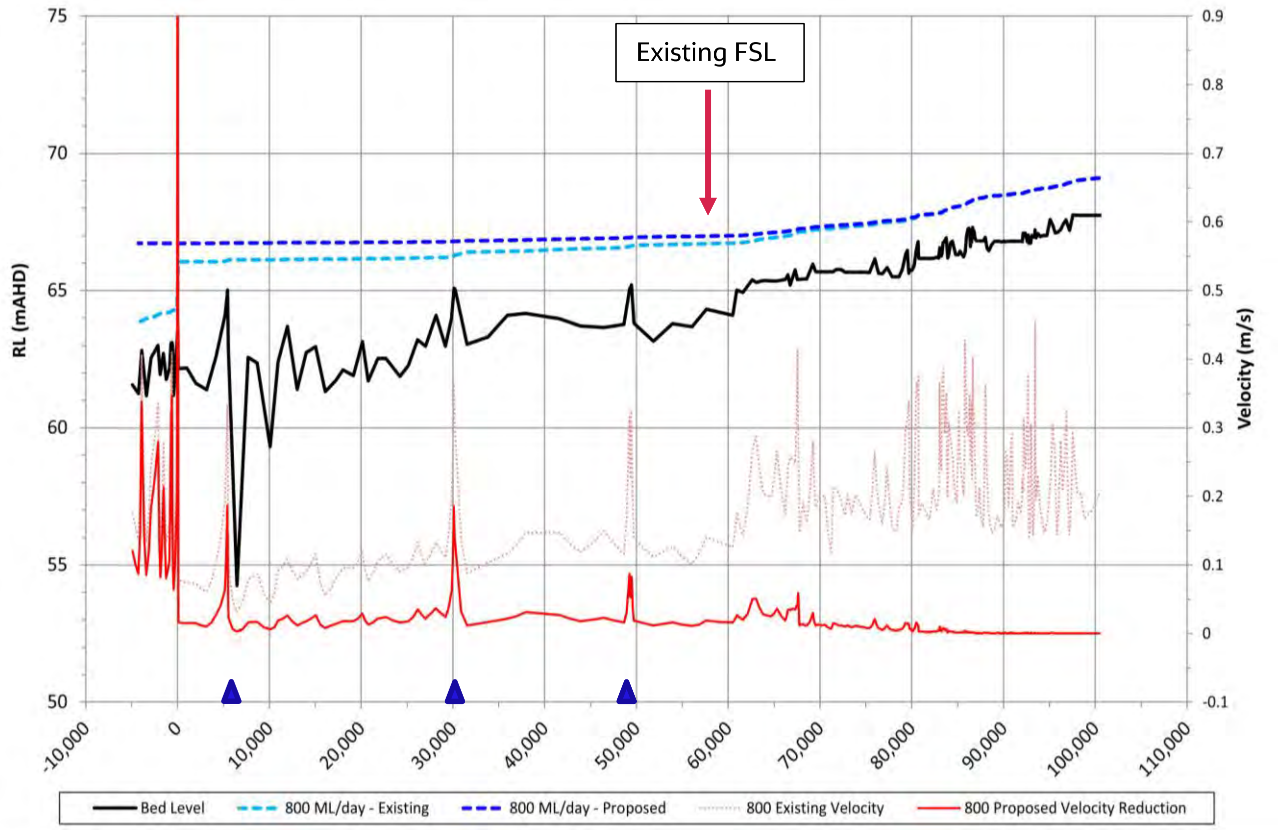


Figure 6-5 Predicted change in water velocity for flows of 800 megalitres per day. Blue triangles are rock bars

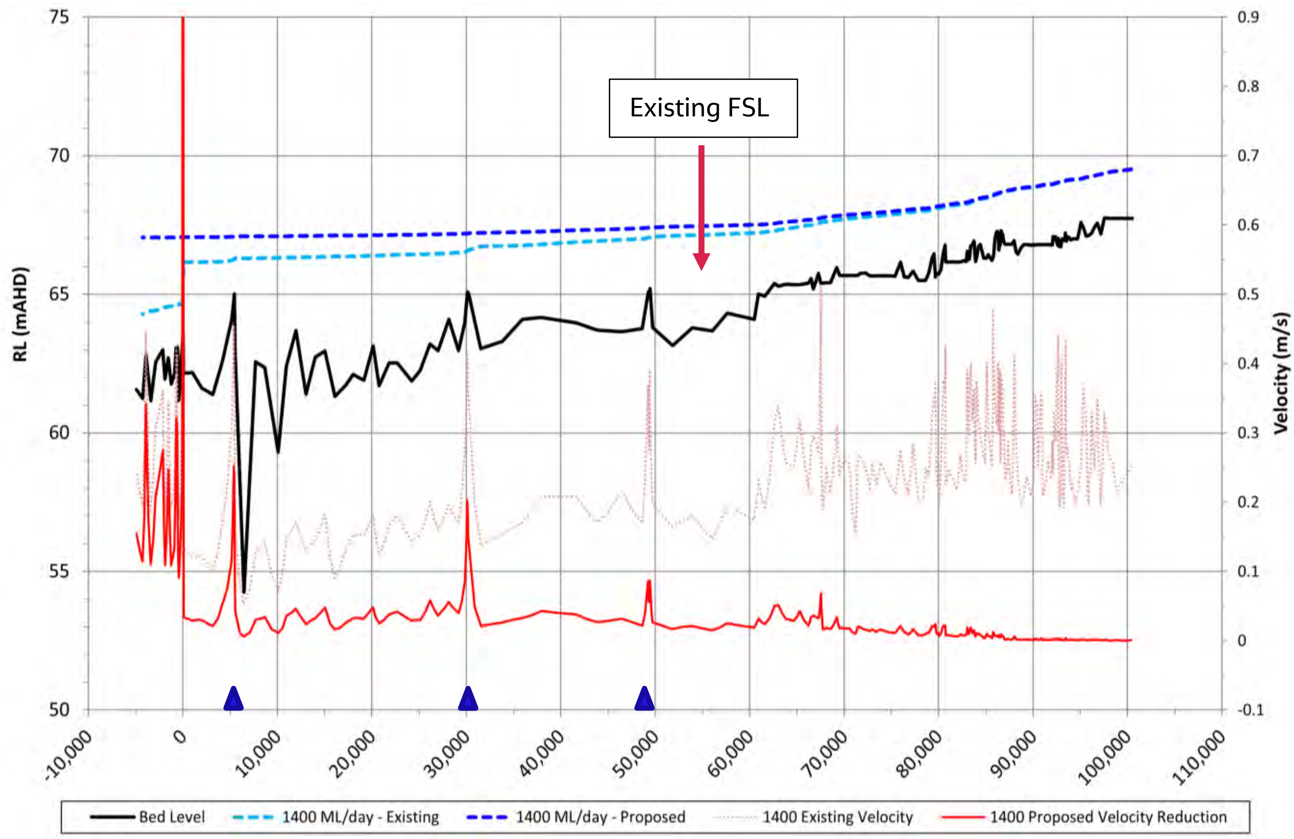


Figure 6-6 Predicted change in water velocity for flows of 1,400 megalitres per day. Blue triangles are rock bars

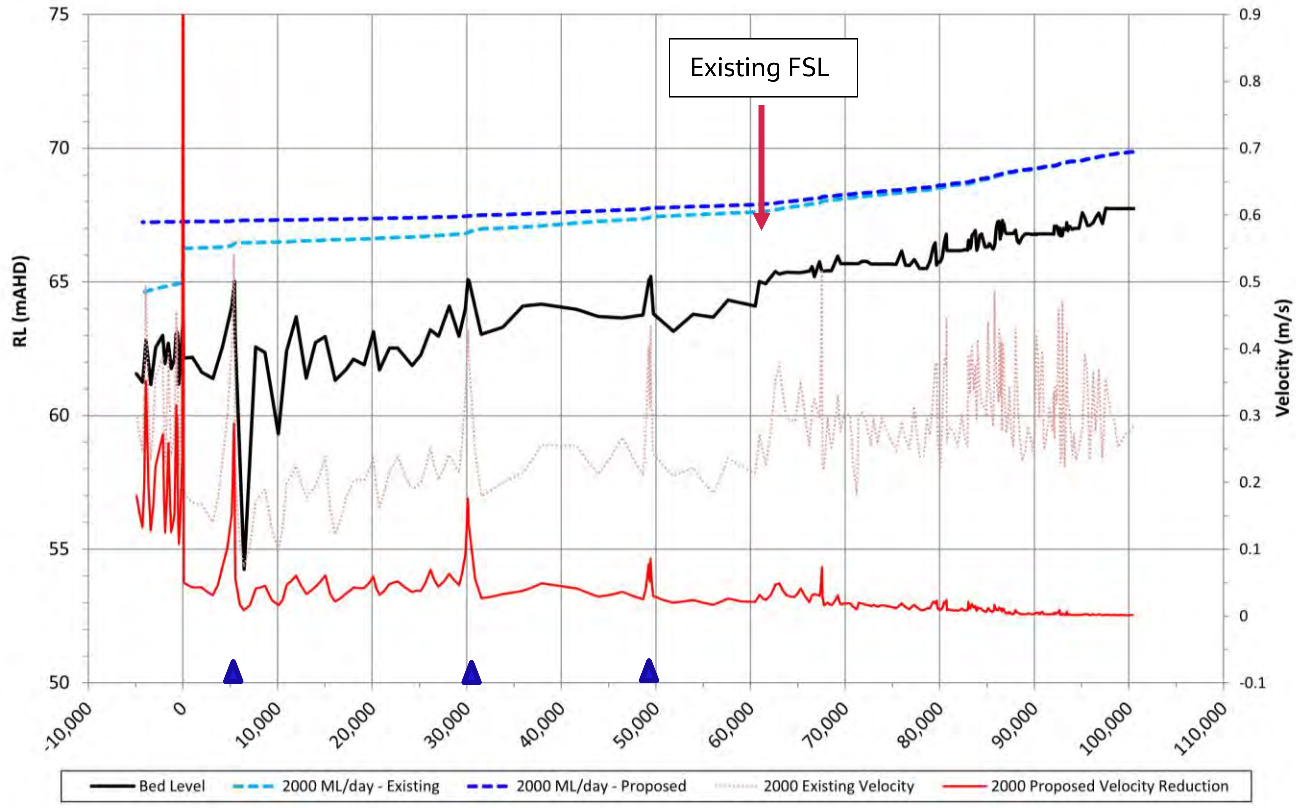


Figure 6-7 Predicted change in water velocity for flows of 2,000 megalitres per day. Blue triangles are rock bars

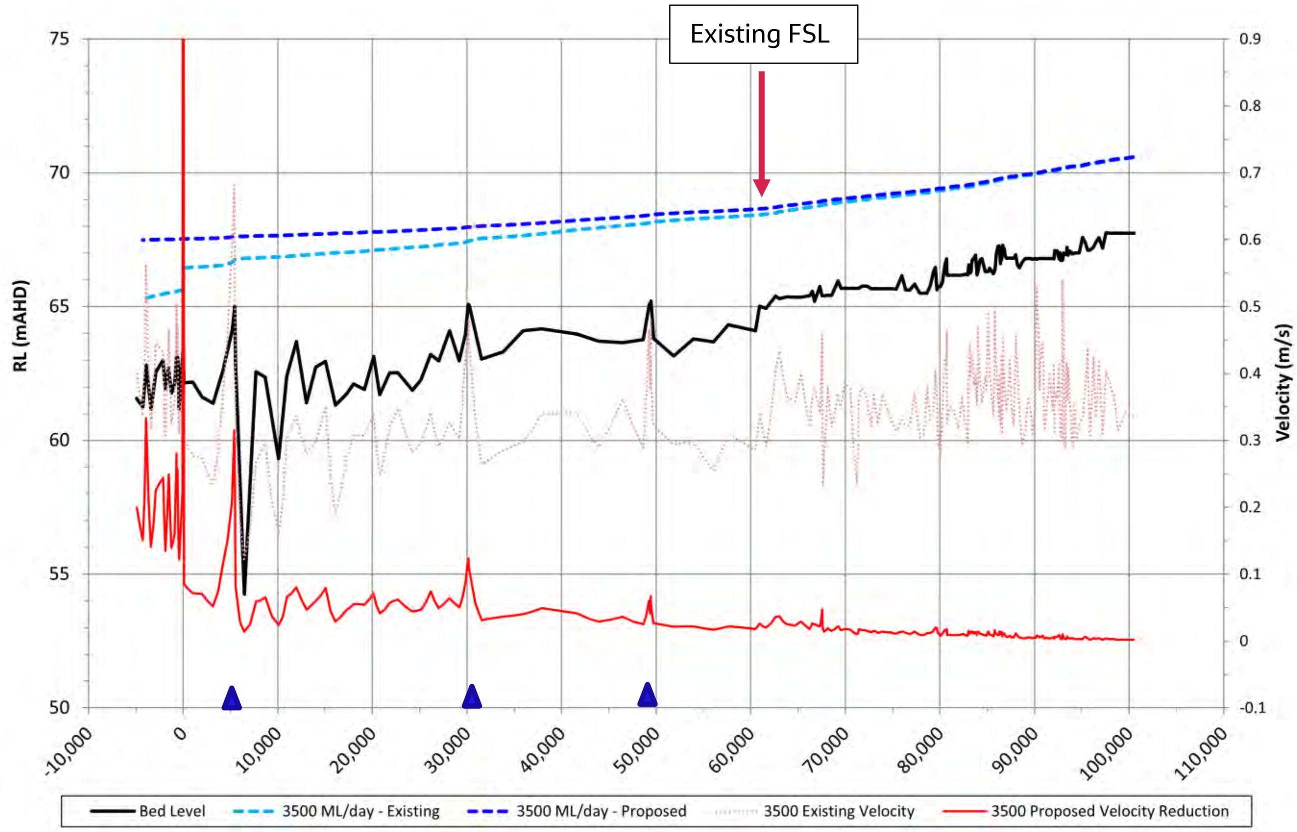


Figure 6-8 Predicted change in water velocity for flows of 3,500 megalitres per day. Blue triangles are rock bars

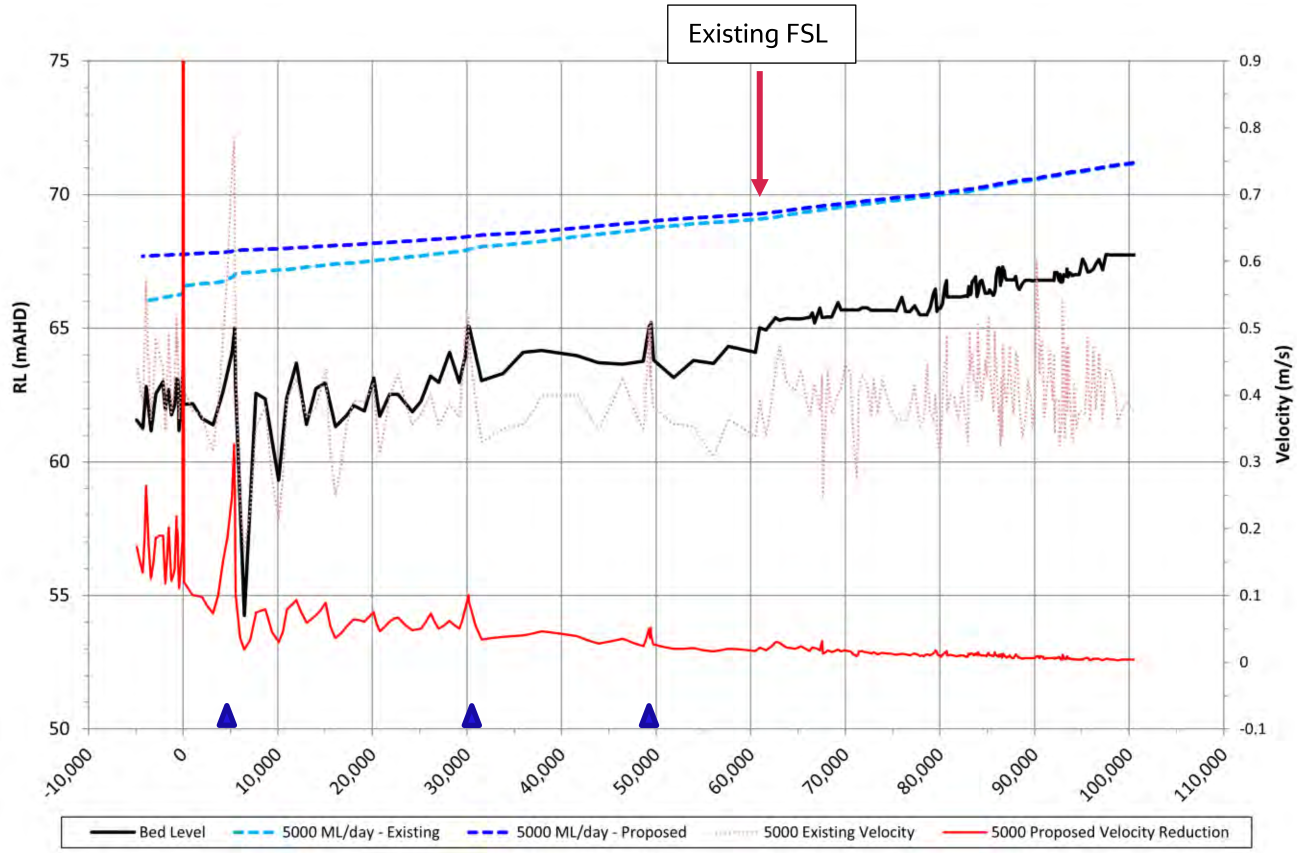


Figure 6-9 Predicted change in water velocity for flows of 5,000 megalitres per day. Blue triangles are rock bars

Figure 6-10 and **Figure 6-11**, show the water level in the weir pool upstream of the existing and new weirs respectively at different flow rates and **Figure 6-12** shows the relative difference in water level between proposed and existing conditions. As shown in these figures, the backwater effect and upstream river slope increase as the flow rate increases, with the greatest increase in water level occurring between the new and existing weirs. The increase in weir pool levels upstream of the existing weir are much less than immediately upstream of the new weir and are generally confined to the FSL extent of the existing weir pool (chainage 61790).

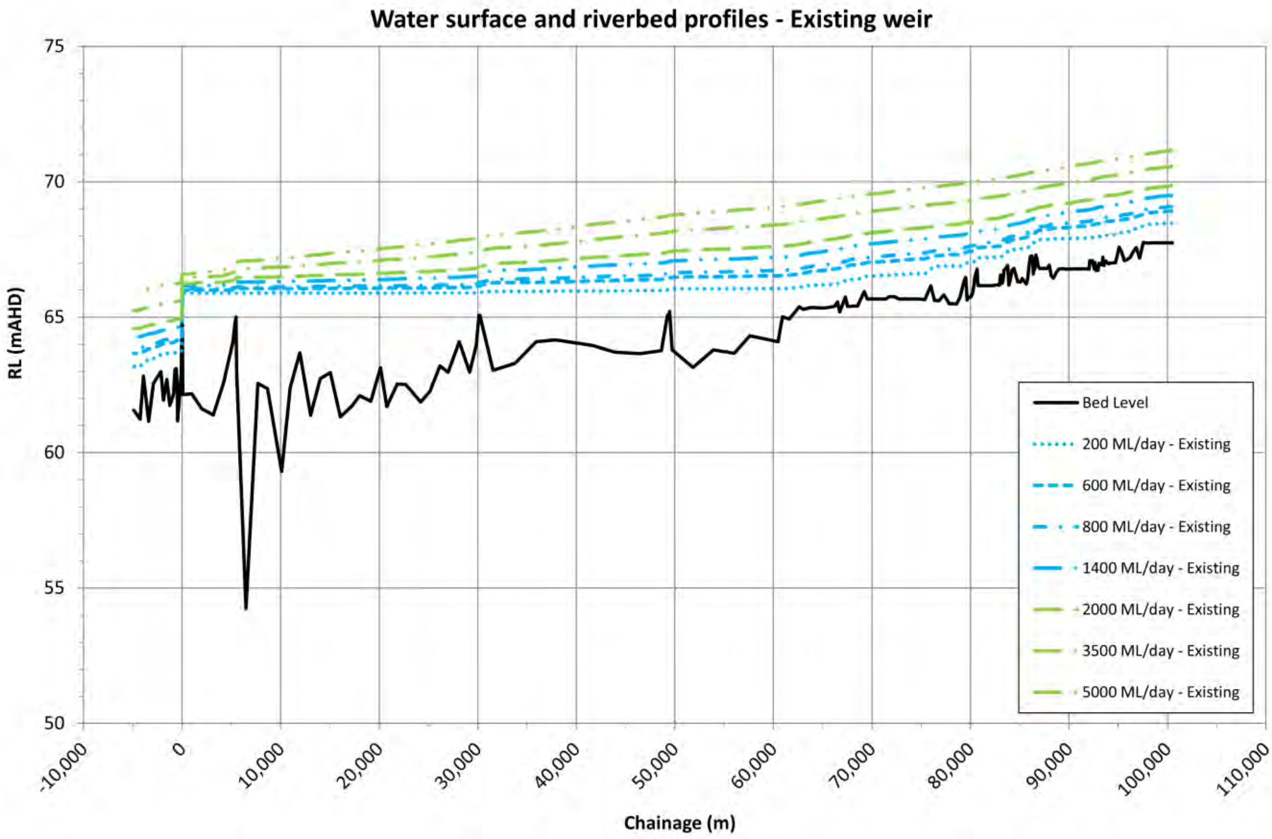


Figure 6-10 Existing water surface level downstream and upstream of the existing weir (chainage 0)

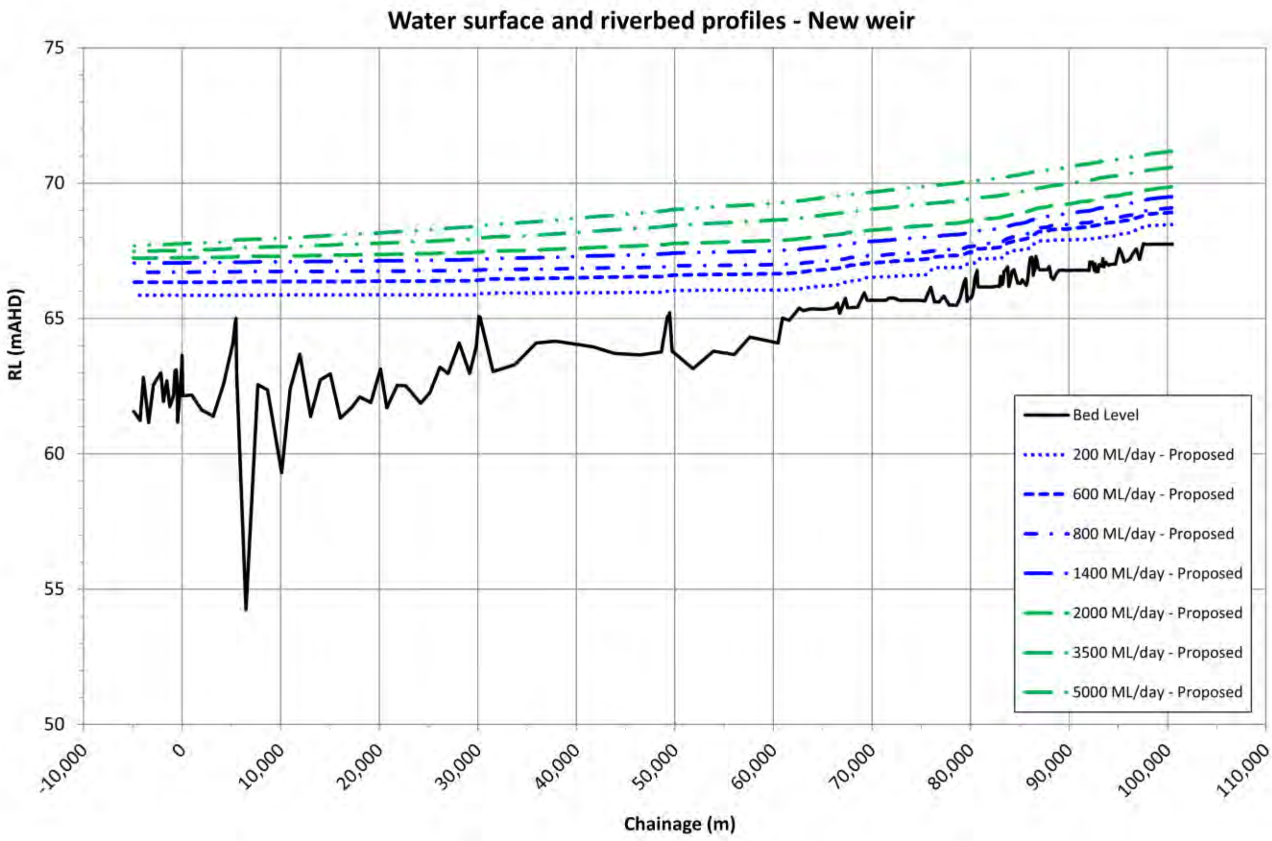


Figure 6-11 Predicted water surface level upstream of the new weir (chainage -4970)

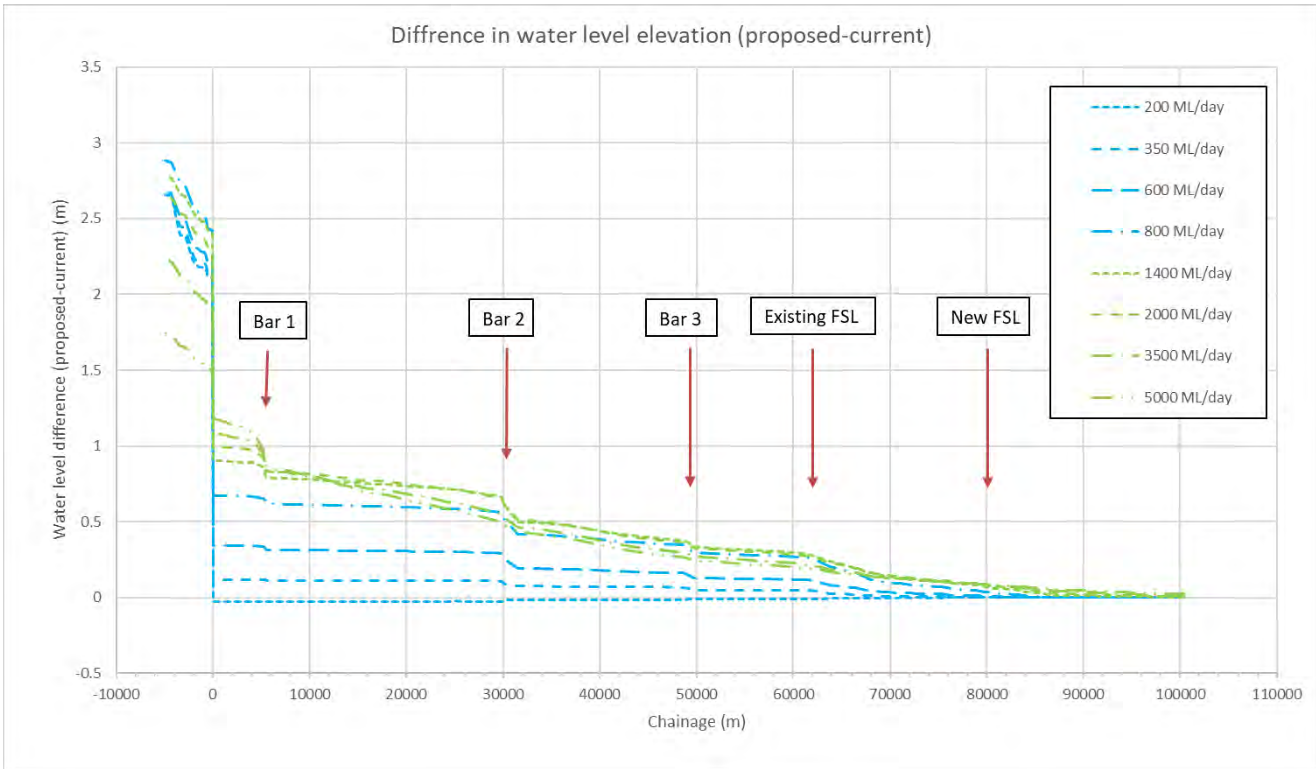


Figure 6-12 Difference in water surface level between proposed and existing conditions downstream and upstream of the existing weir (chainage 0)

To further assess the changes in water level and velocity across the weir pool analysis of the hydrodynamic modelling results was carried out at specific locations (cross sections) known to represent good quality flowing habitat (i.e. Bars 1, 2 and 3 and the reaches upstream of the existing FSL). Changes in velocity were compared with critical velocities thresholds that define flowing and non-flowing habitat for aquatic biota (refer to **Table 6-2**).

Table 6-2 Classes of mean channel velocity (from Mallen-Cooper and Zampatti, 2018)

Mean channel velocity (m/s)	Description	
0.50 – 0.55	Lotic (flowing water)	High quality flowing water habitat
0.45 – 0.50		
0.40 – 045		
0.35 -0.40		
0.30- 0.35		
0.25 – 0.30	Transition	Medium quality flowing water habitat
0.20 – 0.25		Minimum to maintain flowing water (lotic) refugia
0.15 – 0.20		Below the threshold to maintain flowing water habitats. Short-term exposure (less than seven days) is potentially tolerable for lotic refugia (in addition to natural zero flow conditions)
0.10 – 0.15	Lentic (still water)	Slow-moving pool habitat
0.05 – 0.10		Pool habitat
0 – 0.05		

Appendix D contains mapping of the 105-kilometre river reach upstream of the new weir showing existing mean channel water velocities at each of the 439 river cross-sections modelled. Additional mapping is included showing the predicted change in mean channel water velocities at each of these cross-sections for the nine flow rates investigates from 100 megalitres per day to 5,000 megalitres per day.

For the purposes of the assessment velocity comparison are made for:

- 0.3 m/s – high quality flowing water habitat
- 0.2 m/s – minimum to maintain flowing water habitat
- 0.15 m/s – tolerable short-term habitat.

The analysis considered the impact of the new weir on flowing water habitat in four reaches of the river upstream of the existing weir (impacts downstream of the existing weir are discussed in **Section 6.2.2**):

- The existing weir pool (chainage 0 to 61790 upstream)
- Bars 1, 2 and 3 (chainages 5430, 30120 and 49200)
- Between Bar 3 and the existing weir pool extent (chainage 49200 to 61790)
- Upstream of the existing weir pool to the new FSL (chainage 61790 to 80683).

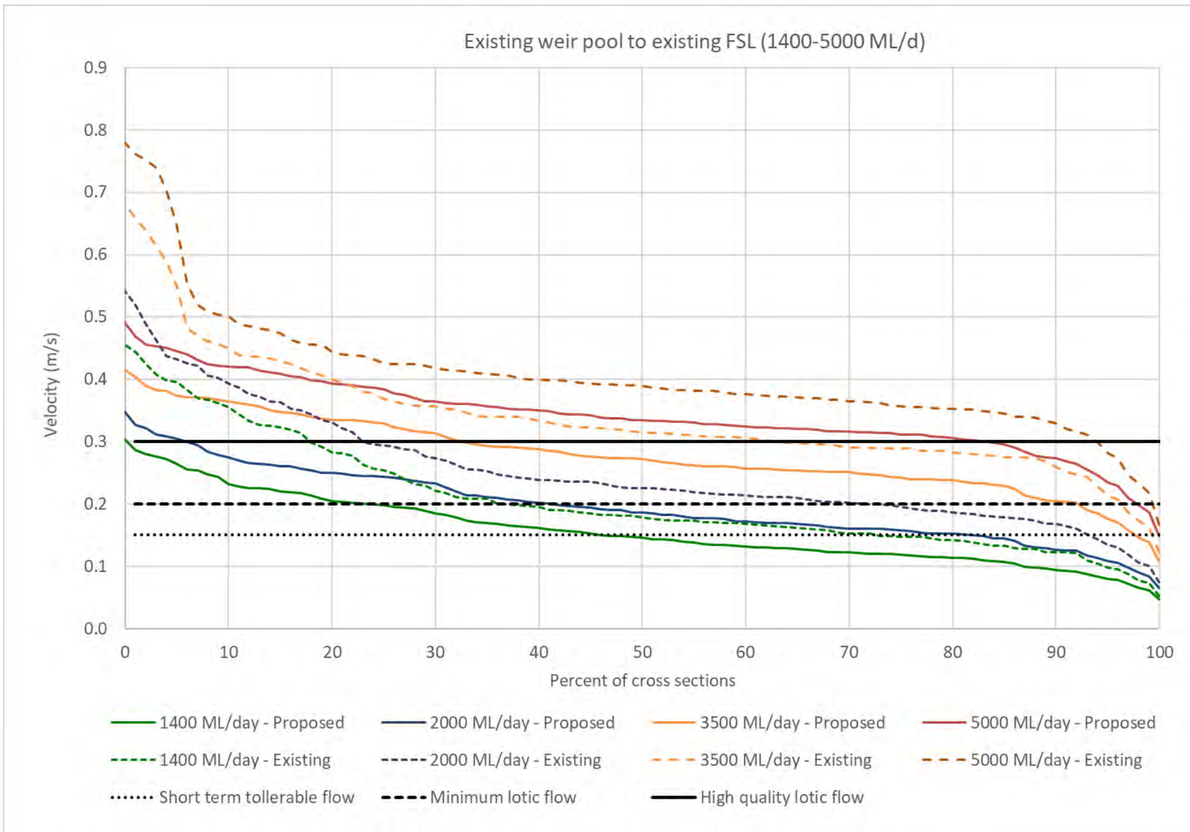
The analysis compared the existing and predicted water velocities to the flowing water habitat criteria across each reach and at critical habitat locations. Flow rates included in the analysis include the Base Flow (350 ML/day) and Small Fresh Flow (1,400 ML/day) recommendations in the *Barwon Darling Long Term Water Management Plan Part B* (DPIE, 2020a), and the median river flow (800 ML/day).

The analysis shows for each reach that:

- **Existing weir pool** — There is little change in the velocity profiles between existing and proposed conditions for flow rates up to 350 ML/day (refer to **Figure 6-13**). For flows in the range 600-3,500 ML/day there is a reduction in the number of cross sections that experience high quality flowing conditions, although minimum and high quality lotic conditions would still be present at some locations across the weir pool. At flows of 5,000 ML/day the majority of cross-sections would retain high quality flowing habitat
- **Rock Bars 1, 2 and 3 —** Water velocities at Bars 1, 2 and 3 are an important consideration as they provide flowing habitat during lower flows as well as providing hydraulic complexity or variability. The proposal would result in a reduction in velocity over Bars 1, 2 and 3, especially at intermediate flows (in the range 600-1,400 ML/day). The velocity reduction is small at low flows (less than 350 ML/day) and under both current and proposed operation velocity at Bars 2 and 3 would experience flows around the moderate flow threshold (refer to **Figure 6-14**). As flow increases the velocity differential increases with more substantial velocity reductions under proposed conditions compared to current conditions at flows of 600-1,400 ML/day (**Figure 6-14**, **Figure 6-15** and **Figure 6-16**). At these flows, velocity declines from high quality habitat to the minimum required to maintain lotic habitat at Bars 1 and 2 but remains above moderate velocity habitat at Bar 3. At flows of 2,000-5,000 ML/day the velocities under proposed conditions are still lower than those under current conditions but the differential decreases and even under proposed conditions velocities remain above the minimum required to maintain lotic habitat at all three bars (refer to **Figure 6-15**). Notably, the velocity differential is less at Bar 3 compared to Bars 1 and 2 – Bar 3 would continue to provide access to flowing habitat for biota within the existing weir pool across a range of flows and Bars 1 and 2 would provide flowing habitat at higher flows (refer to **Figure 6-16**). Overall, the predicted reduction in water velocities at Bars 1 and 2 and, to a lesser extent, Bar 3 would reduce hydraulic complexity/variability within the weir pool
- **Bar 3 to existing FSL and upstream existing FSL to new FSL** — The proposal would result in a reduction in high quality flowing water habitat conditions upstream of Bar 3 to the existing weir pool extent for flows less than 5,000 ML/day and particularly flows less than 2,000 ML/day (refer to **Figure 6-17**). Minimum lotic conditions would be maintained in this reach for all flows of 3,500 ML/day and above, and for most of this reach for flows between 1,400 and 3,500 ML/day. The proposal would not significantly reduce flowing

water habitat conditions upstream of the existing weir pool (refer to **Figure 6-18**). While there would be a small decrease in high quality flowing habitat, suitable flowing habitat would still exist at many locations in this reach of the river.

The ecological effects of the changes in velocity are discussed below.



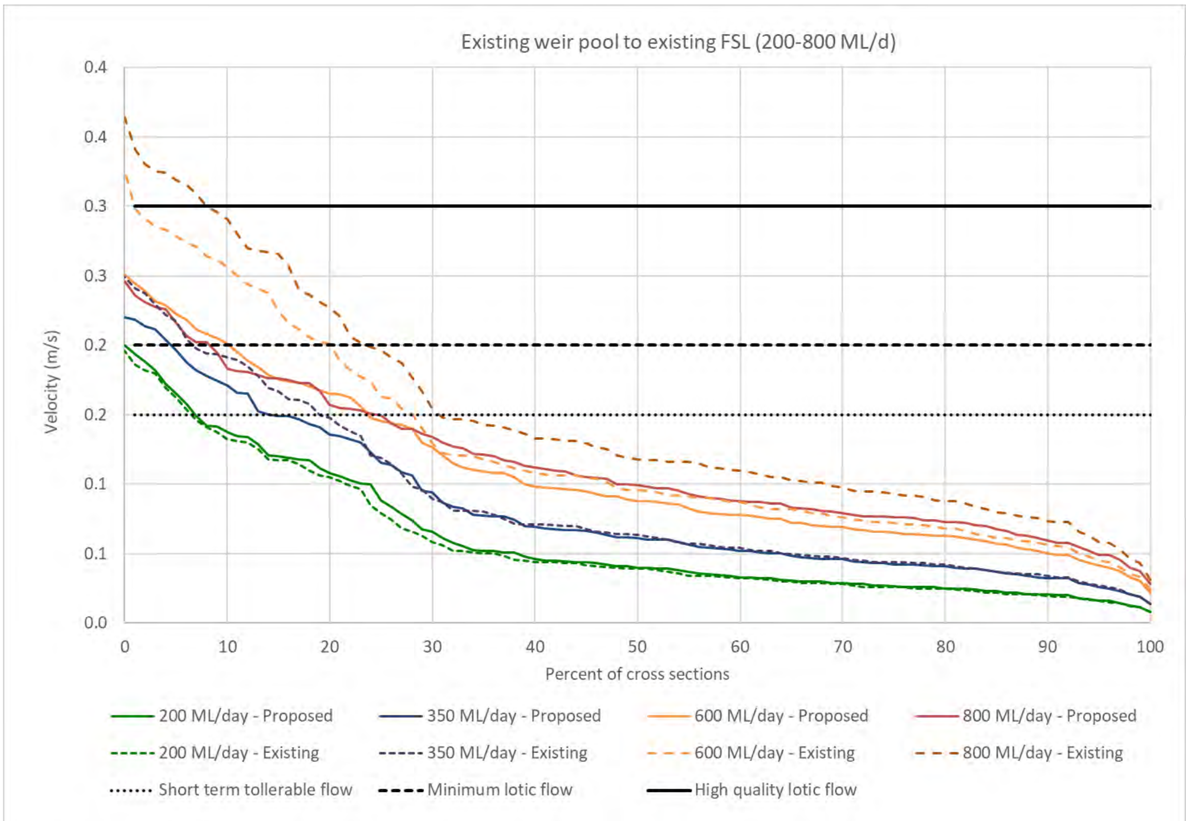


Figure 6-13 Comparison of water velocities to the flowing water habitat criteria in the existing weir pool (chainage 0 to 61790)

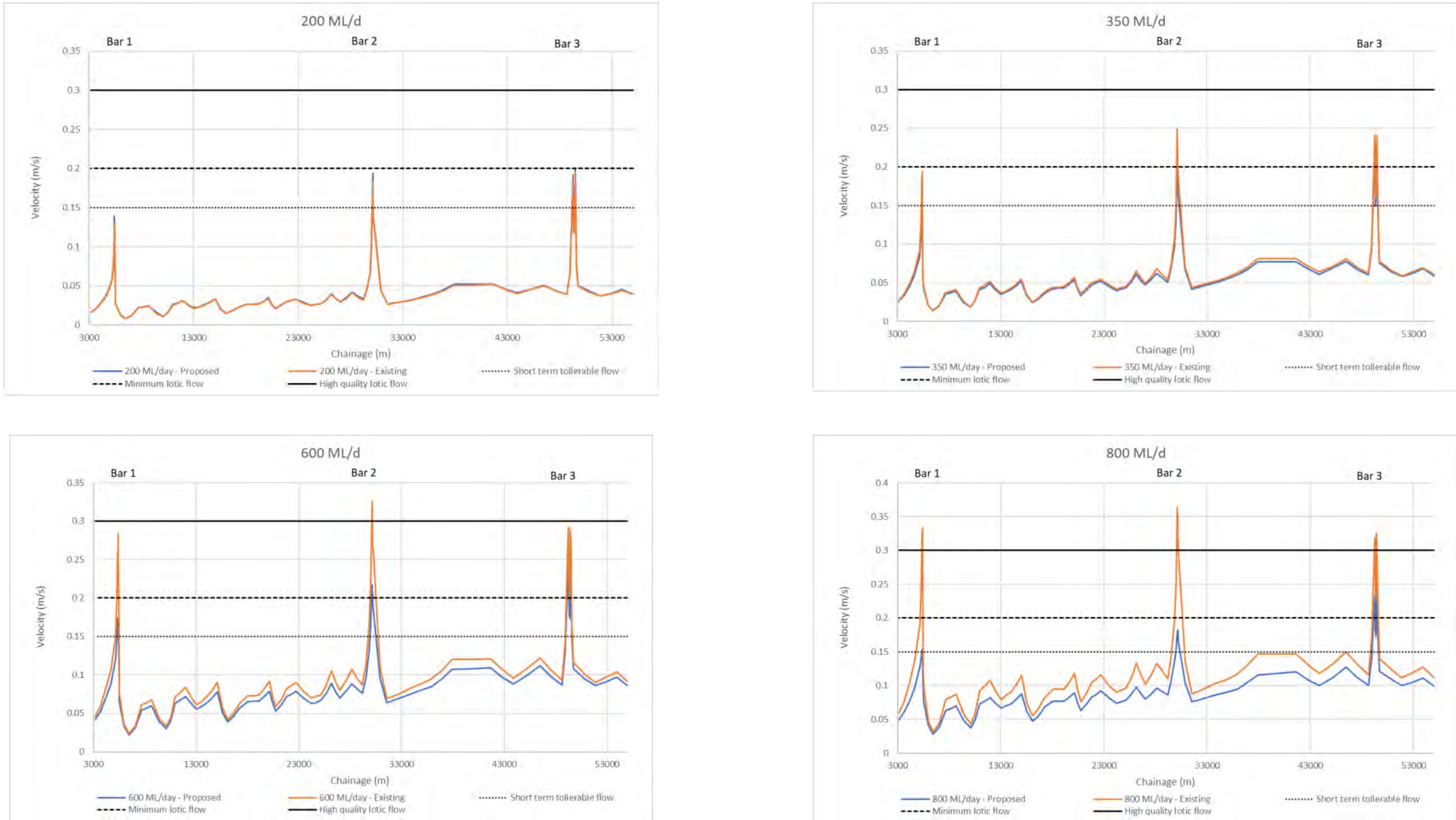


Figure 6-14 Comparison of water velocities to the flowing water habitat criteria at bars 1, 2 and 3 for flow rates, 200 ML/day to 800 ML/day

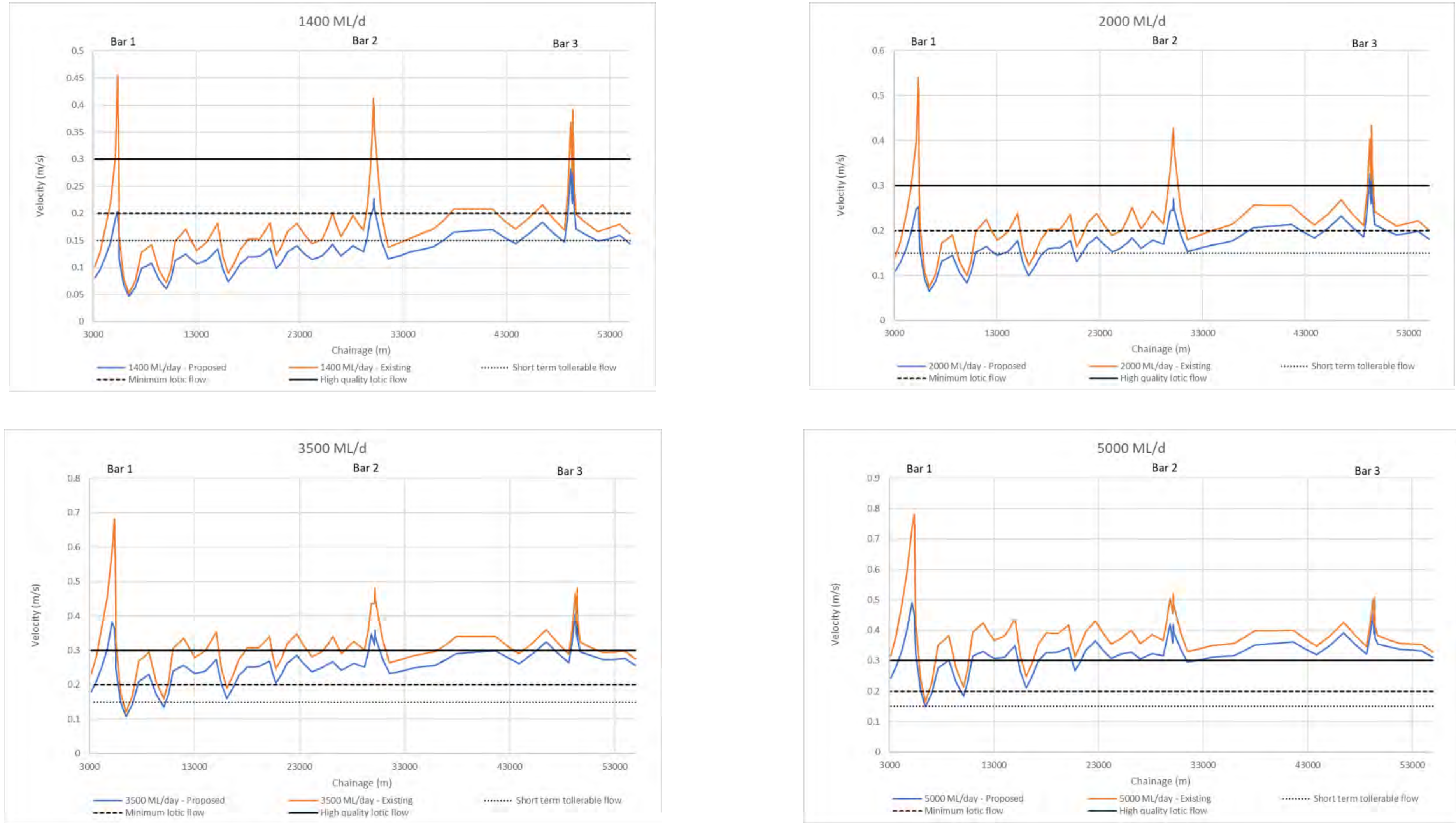


Figure 6-15 Comparison of water velocities to the flowing water habitat criteria at Bars 1, 2 and 3 for flow rates 1,400 ML/day to 5,000 ML/day

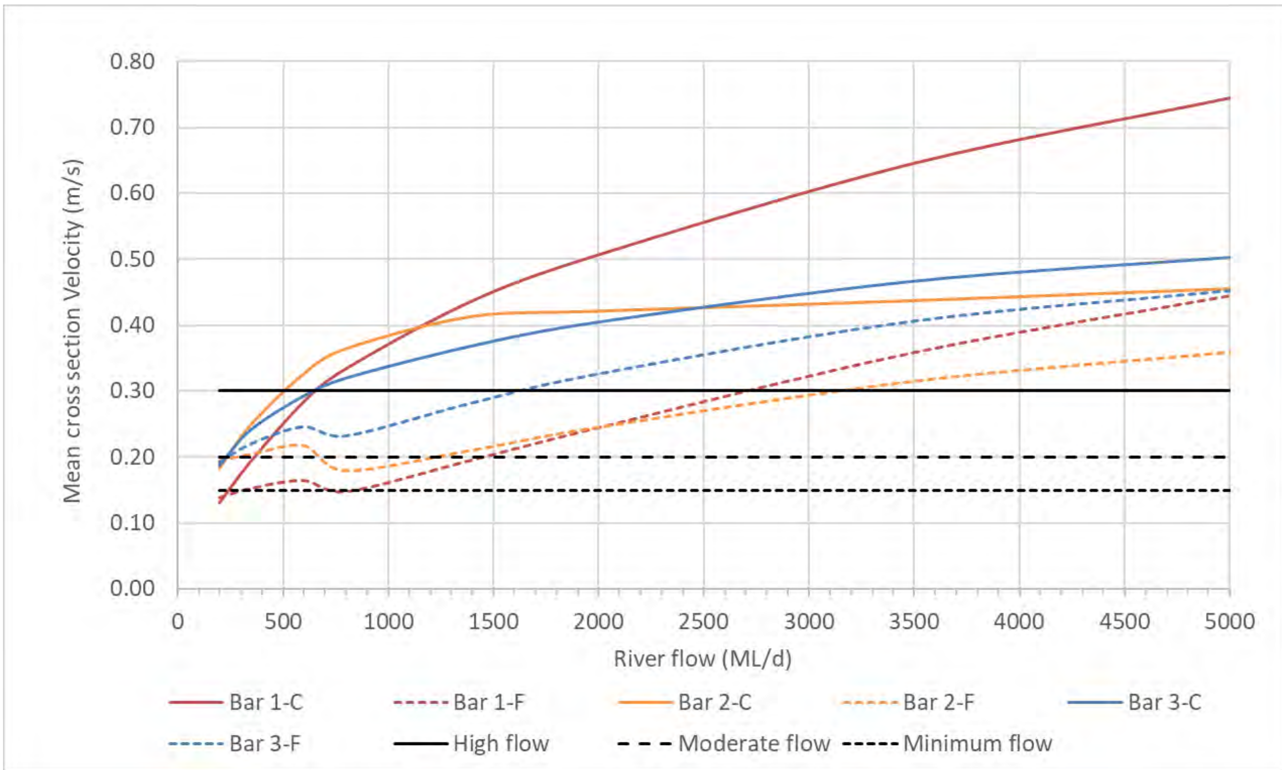
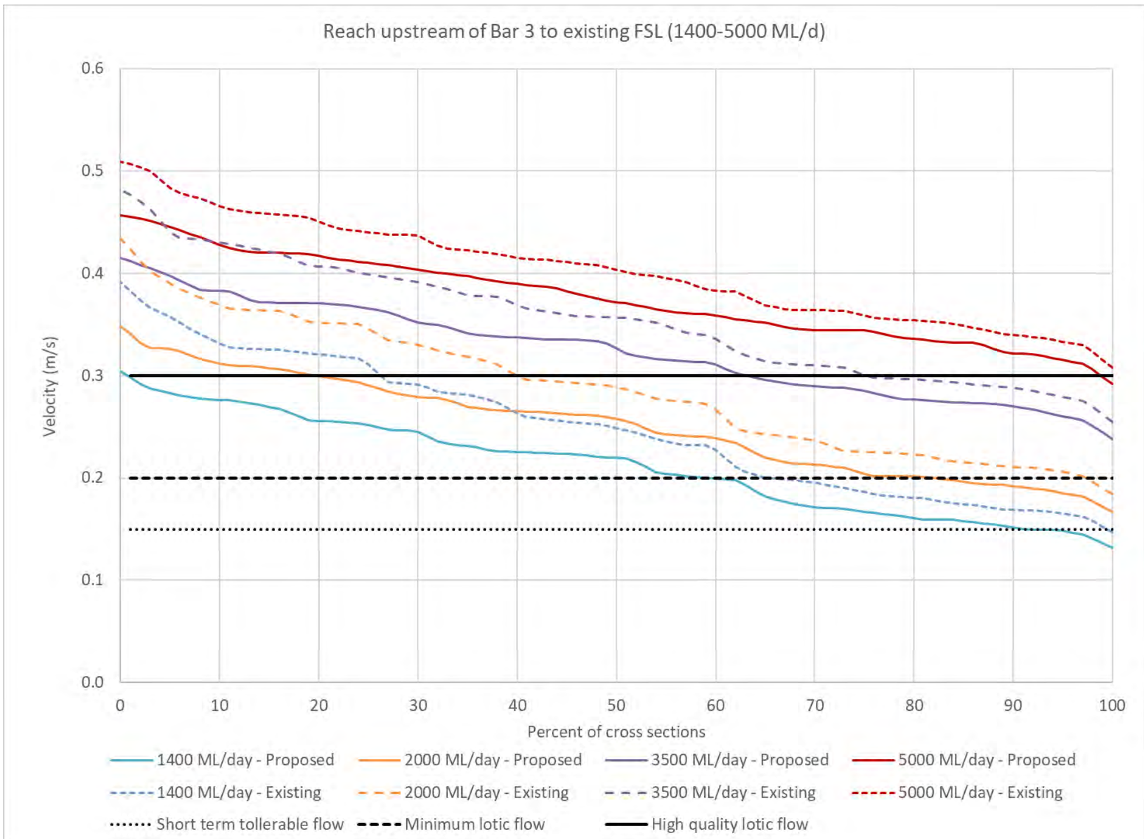


Figure 6-16 Summary of flow velocity change with river flow at Bars 1, 2 and 3 between current (C) and future (F) conditions during normal operation mode



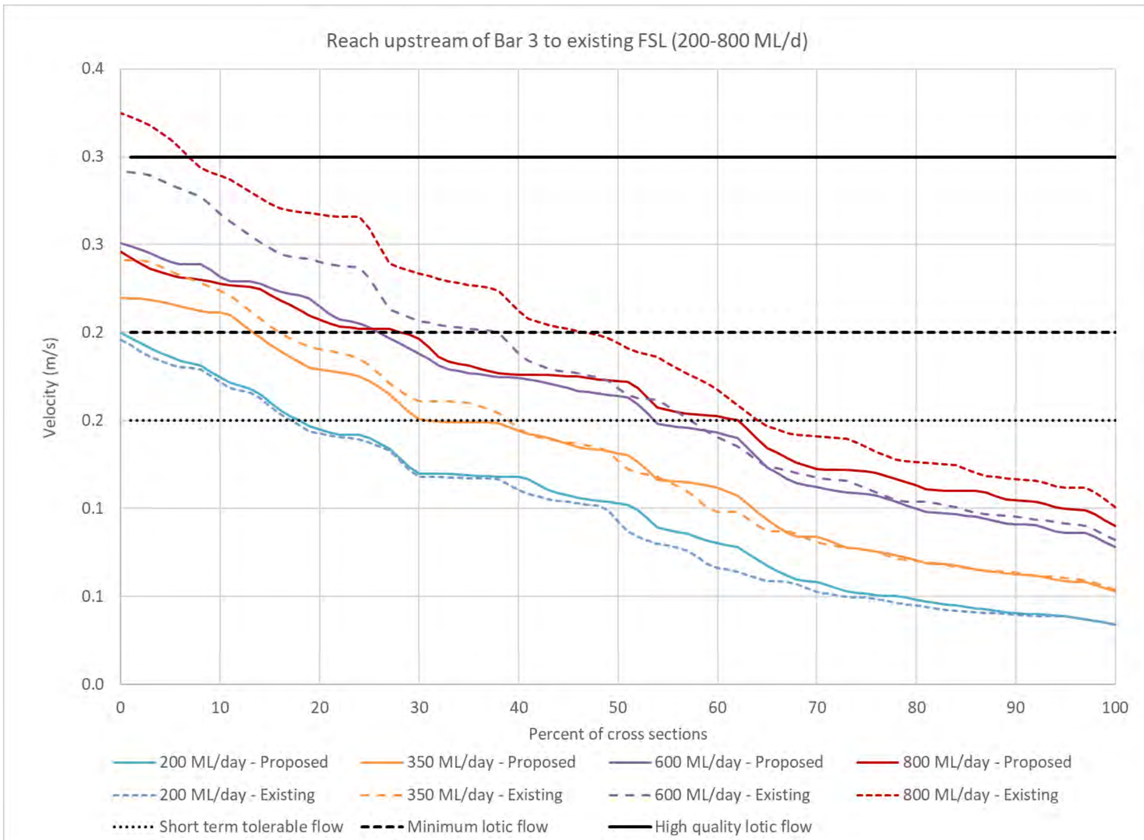
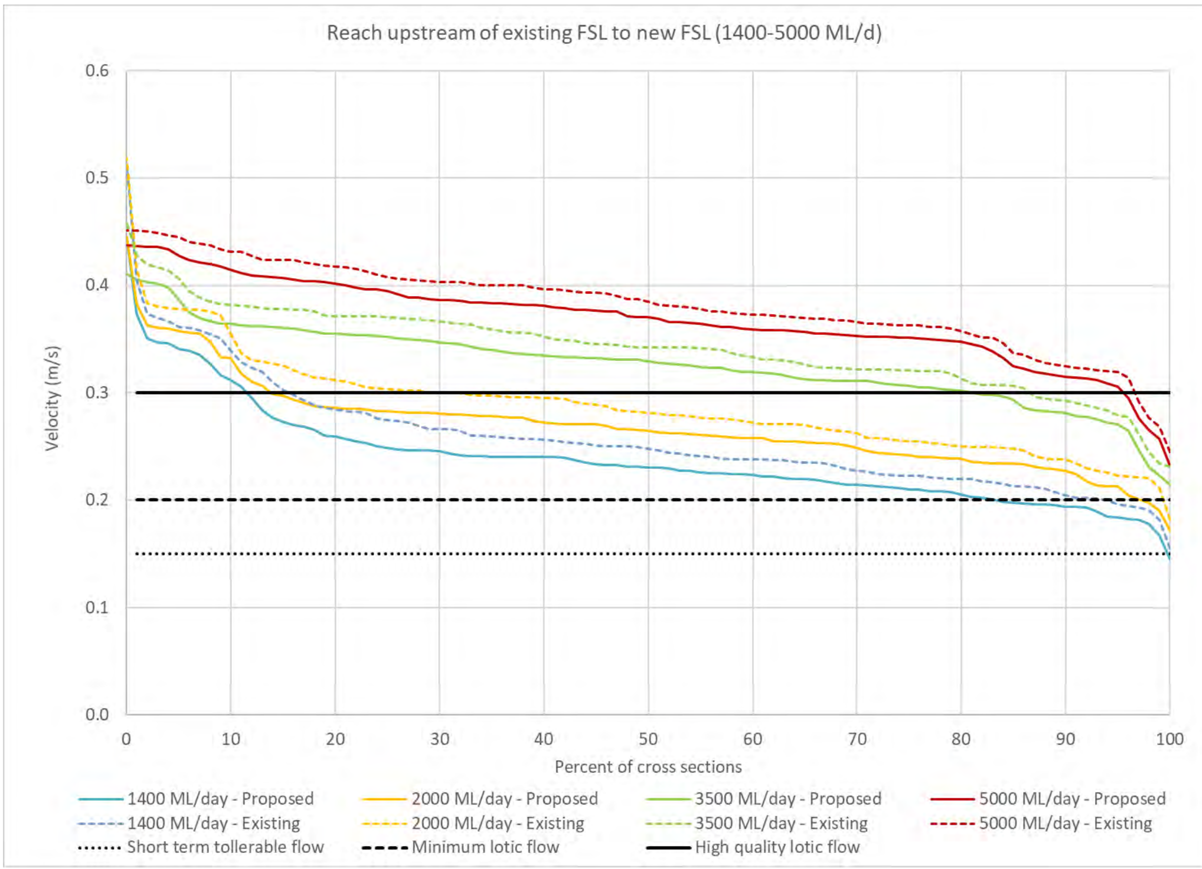


Figure 6-17 Comparison of water velocities to the flowing water habitat criteria between Bar 3 and the existing weir pool extent (chainage 49200 to 61790)



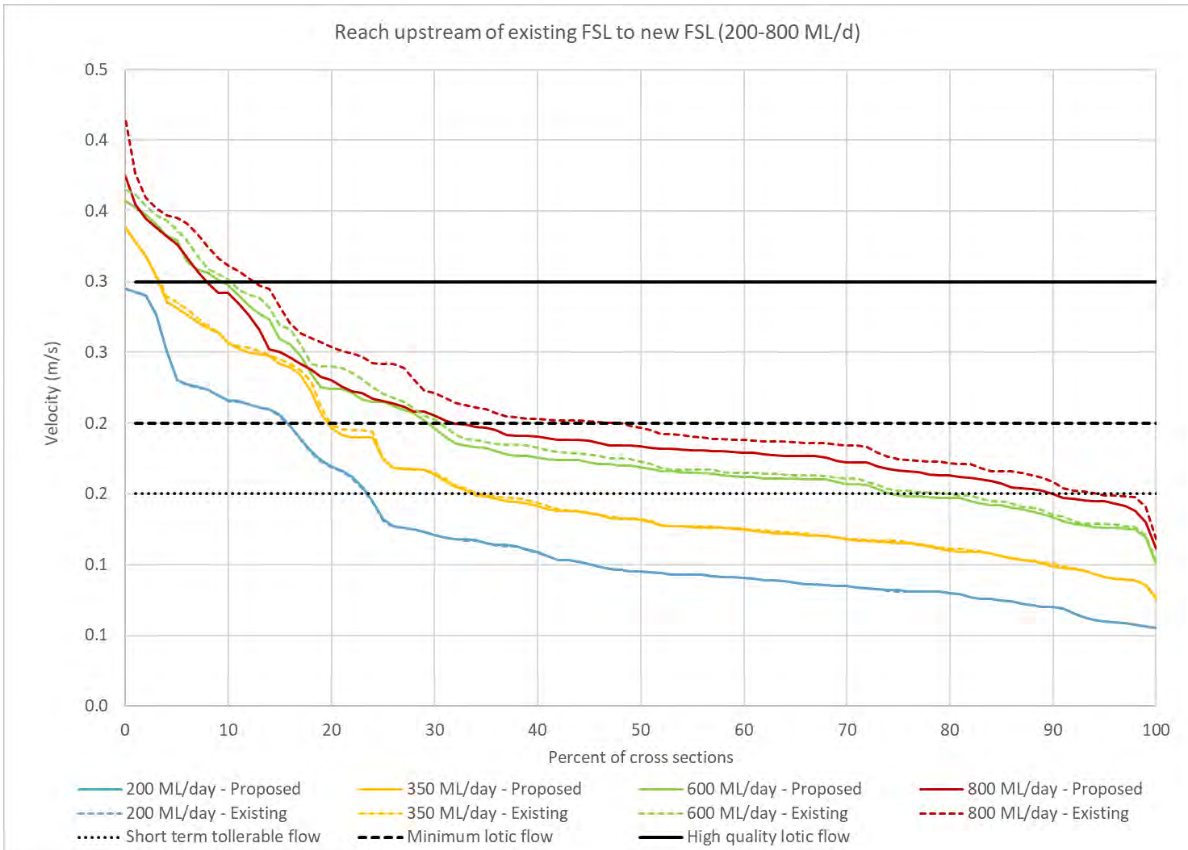


Figure 6-18 Comparison of water velocities to the flowing water habitat criteria upstream of the existing weir pool FSL to the new FSL (chainage 61790 to 80683)

Impact on aquatic biota during normal operating mode

A reduction in velocity that results in the conversion of flowing to non-flowing habitat has the potential to impact on aquatic biota. Flowing water habitat supports biodiversity and ecosystem integrity in the Darling River (Baaka). The need for flowing water habitat differs between aquatic species, for example (Mallen-Cooper unpublished):

- Species such as Golden Perch and Silver Perch migrate long distances upstream (100 to 1000 kilometres) and produce small larvae that drift back downstream over these same long distances. Successful spawning for these species requires flowing water that can be short-term (e.g. weeks) but must be continuous over long distances (e.g. more than 100 kilometres) and occur in spring or summer. The location of this flowing water reach is not site specific and can vary along the river system between years. The dependence of Golden Perch and Silver Perch on river-scale flows for spawning means the success of their spawning would not be affected by the proposal's more localised impact on water velocities
- Species such as Murray Cod produce large larvae that only drift short distances (two to 100 kilometres) and require flowing water that is near perennial and generally within the same river reach each year (as return migrations and site fidelity are common); within a larger scale (greater than 50-kilometre) of heterogenous hydraulic habitats. Populations are maintained in some locations where flowing water occurs during the spawning season from September to December, while it may be inconsistent in other months
- Lotic gastropods (snails and mussels) and other invertebrates that are not very mobile, with a typical home range of less than 20 metres, require near perennial flowing water, fixed at a specific site, which can be quite small (five to 100 metres).

Water velocity is important at all times for the majority of aquatic fauna, particularly those that have limited movement potential and require flowing water for the provision of food and maintenance of suitable water quality conditions (i.e. invertebrates, notably snails and mussels). Water velocity can also be more important at different times of the year to support different life history requirements, for example, native fish spawning, which generally occurs from September to December. It is therefore necessary to consider the impact of the proposal on flowing water habitat at different times of the year.

Flow data is presented in **Figure 6-19** from the Darling River (Baaka) at Wilcannia flow gauging station 425008 for the period from 1972 to July 2022. This period has been selected as it follows the completion of most of the major (greater than 50 gigalitres storage) upstream dams. The period from 1 January 2000 onwards is also shown as it is characterised by major drought periods and could be representative of a potential future drying climate. The flow data is presented as monthly box plots covering the critical native fish spawning and juvenile development periods.

The plots show that over the entire data period the median flow in fish spawning months (September to December) was greater than 500-600 ML/day and tended to be even higher in the months that followed spawning when larvae would be developing into juvenile and young-of-year fish. The fish spawning months would therefore typically be associated with at least minimum flowing water habitat at Bar 3 (refer to **Figure** 6-14) and in the reach upstream of the existing FSL (refer to **Figure 6-18**).

However, over the past 20 years the median flow in both the spawning and juvenile development phases has substantially decreased, which under both current and future conditions represents a reduction in the availability of flowing habitat at critical life history stages.

Based on long-term climate conditions the proposed weir operating rules during normal operating mode would retain flowing habitat during critical life history stages of native fish and for other instream biota above minimum flow velocity thresholds at various locations within the existing weir pool and in the critical habitat reach upstream of the existing FSL. However, under a drying climate the availability of flowing habitat above critical thresholds would decline under both current and proposed operations.

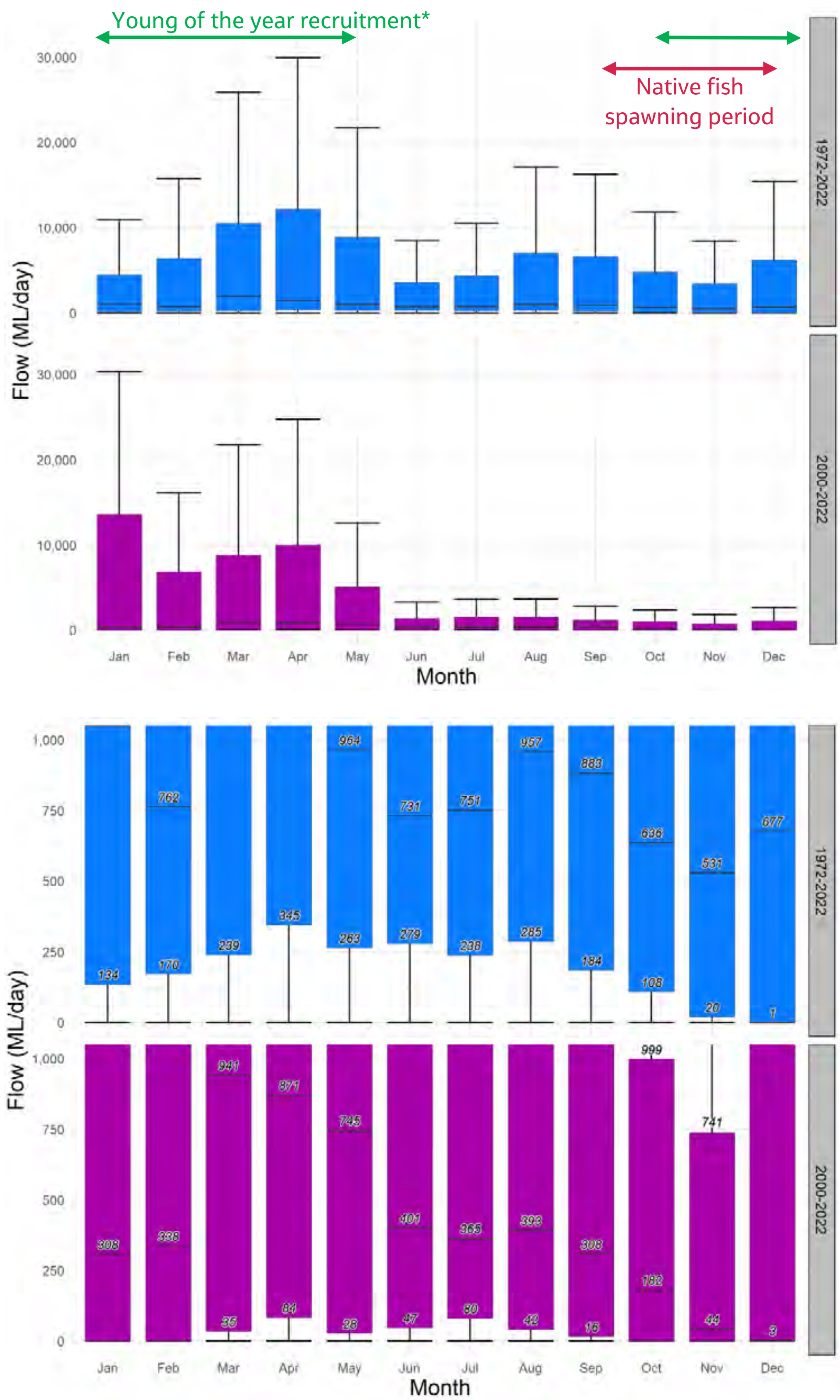


Figure 6-19 Monthly flow at Wilcannia (gauge 425008) for the period 1972-2022 and 2000-2022 representing more recent drought conditions. Upper panel shows the full flow range, lower panel highlights low flows (less than 1,000 ML/day)

Notes:

* Young of the year recruitment refers to fish transforming from planktonic larval stage to juvenile stage (fingerling), which takes several weeks.

6.2.1.2 Drought security operation mode

Hydraulic changes

There are two weir inflow scenarios when in drought security operation mode. Upon the triggering of filling the weir pool is raised to the drought security operation mode FSL while inflows are still occurring. The weir is then maintained at this level for a period of time, while inflows are still occurring, but receding, until inflow ceases. For the remainder of the drought security operation mode the weir pool slowly draws down until upstream inflows recommence and the weir level is restored to the normal operation mode level.

Modelling shows the duration of time in each operating mode (normal operation mode, drought security operation mode with inflows still occurring, and drought security operation mode once inflows have ceased). Based on the model rules there are large number of occasions when the filling is triggered and the weir pool is filled, however, inflows never cease (refer to **Figure 6-20** upper panel). These represent false or unnecessary fillings that could result in a temporary reduction in flow velocity in the upper reaches of the weir pool (between the existing FSL and drought security operation mode FSL and at rock bars). Real time adaptive operations are likely to be able to avoid many false fillings by considering upstream flows, flow forecasts and climate conditions before a decision is made to enter drought security operation mode (refer to **Figure 6-20** lower panel). This would substantially reduce the number of unnecessary filling events. Moreover, real time adaptive operations would enable a more nuanced progressive gate closure during the filling phase that could further reduce the duration of times when the weir pool level is raised. For example, by delaying filling based on actual inflow volumes and forecasts rather than a fixed filling trigger.

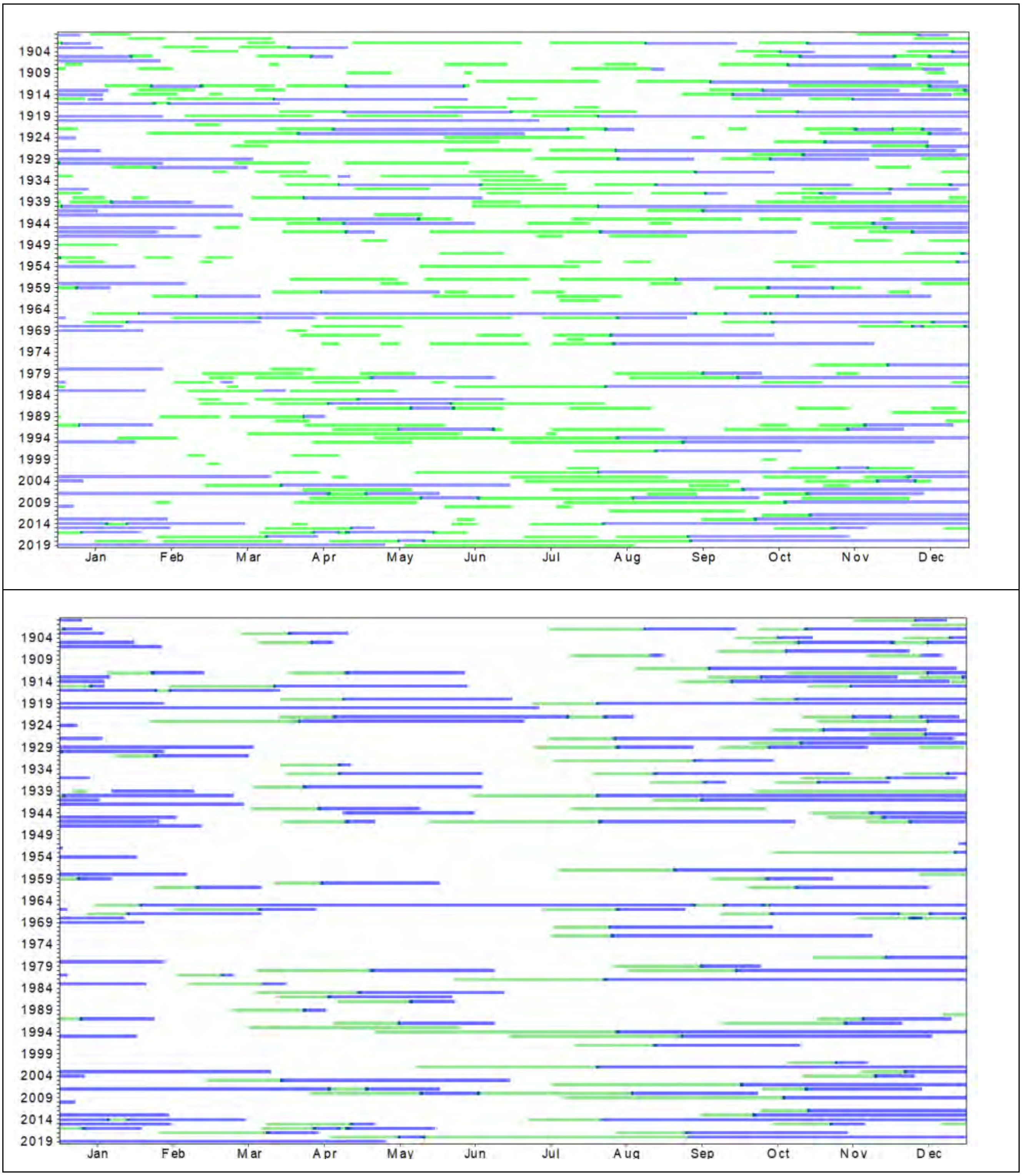


Figure 6-20 Durations of time in drought security operation mode when inflows are still occurring (green) and when inflows have ceased (blue) (white spaces are normal operation mode). Upper panel as modelled, lower panel based on proposed real time operational optimisation

Under proposed conditions when drought security operation mode is in place and inflows have ceased the water level would increase and what would be existing isolated refuge pools and short sections of dry riverbed would become connected in one continuous and deeper pool. This is conceptually demonstrated in **Figure 6-21**, which shows shallow isolated pools defined by dotted green lines that would become a continuous deeper pool. During drought security operation mode the water level of the pool would slowly drawdown and the upstream reaches would incrementally dry out and revert to isolated pools and dry riverbed as the water level declines. Once upstream inflow recommences the operating mode would transition to the normal operating mode, water level would be reduced to close to the existing FSL and flowing conditions would be restored to the reach between the existing and drought mode FSL.

Figure 6-21 Conceptual demonstration of shift in habitat at Cease to Flow from dry river bed and isolated refuge pools to a continuous deeper pool

This intermittent and highly variable hydrological regime is common within the central portion of the Barwon-Darling system (DPI, 2020a). The discussion below describes the modelled changes for the hydraulic and hydrological conditions for the proposed weir in drought security operation mode in comparison to existing operation. The potential impacts to the aquatic ecosystem system as a consequence of these changes are described in the following section.

Figure 6-22 shows the number of days at incremental elevation level above the normal FSL that would be *dry* (i.e. in drought security operation mode when the pool has drawn down and there is no inflow,) or *wet but not flowing* (i.e. inundated above the normal FSL as a result of new weir operations). The results indicate that the number of *dry days* under current conditions (noting that under current conditions some sections of the existing channel classified as *dry* would comprise refuge pools that would persist through cease to flow periods as conceptualised in **Figure 6-21**) is the same across all increments above the normal FSL. This is because when the river is not flowing the maximum inundation extent is defined by the normal FSL, meaning there would be the same number of *dry days* at all increments above the normal FSL. Under future conditions, some of those *dry days* would be altered to *wet but not flowing days* because as flow ceases and dry periods begin, the new weir would be inundated to the maximum extent of the new weir pool (drought FSL= normal FLS + 1.0 m). However, as soon as in-flows to the pool cease, the pool would begin to be drawn down, therefore at the exact level of 'drought FSL= existing FLS + 1.0 m', the number of *dry days* would remain the same as current operations. The difference in conditions under future operations is that below this level the channel would be wet (inundated for a period of time) rather than dry or isolated refuge pool for periods when there are no inflows. The lower the elevation level, the greater the total number of *wet but not flowing days* and fewer *dry days* at each decreasing elevation such that at the equivalent of the normal FSL there would be very few *dry days* in the future – the pool would nearly always be inundated at or above this level.

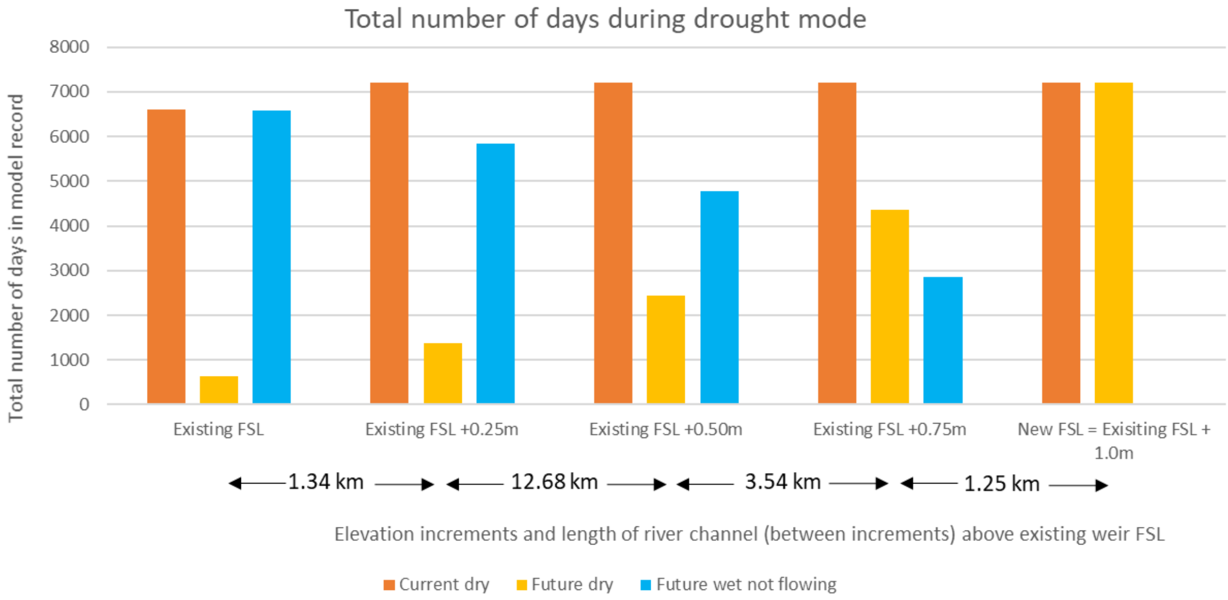


Figure 6-22 Total number of days in modelled record (1900-2019) for each flow category at incremental water level heights for the reach from the normal FSL to the new FSL. Left side of graph shows the number of days experiencing each flow condition at the location of the existing weir FSL. Distance increments show the length of reach upstream of the existing FSL inundated with progressive weir pool level increases at 0.25 m intervals

Figure 6-23 shows the longest spell for each flow category. Again, for current conditions the longest spell is the same for all elevation increments. Under the future conditions, the pattern is consistent with the changes in total number of days as above, although it is shown that while there are more *wet but not flowing days* than *dry days* in total at the lower elevations, the longest spells are associated with dry rather than wet conditions.

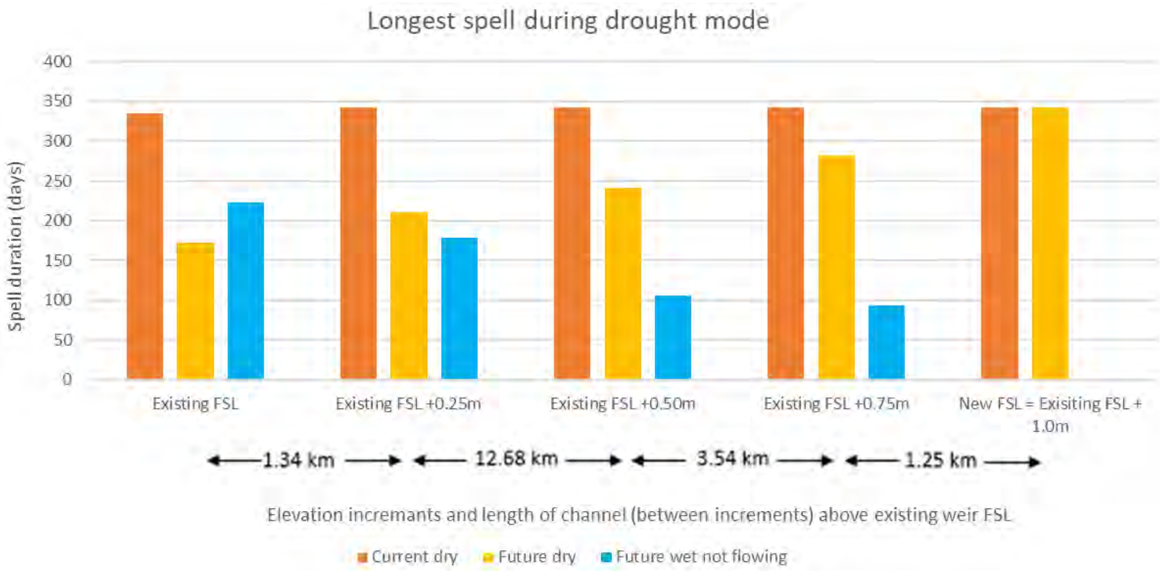


Figure 6-23 Longest spell duration for each flow category at incremental water level heights for the reach from the normal FSL to the new FSL . Left side of graph shows the number of days experiencing each flow condition at the location of the existing weir FSL. Distance increments show the length of reach upstream of the existing FSL inundated with progressive weir pool level increases at 0.25 m intervals

Figure 6-24 shows median spells under current and future conditions. As can be expected, median spells follow the same pattern as above, however importantly, these results indicate that median *dry* spells and median *wet not flowing* spells under future conditions are comparable and both ≤6 weeks.

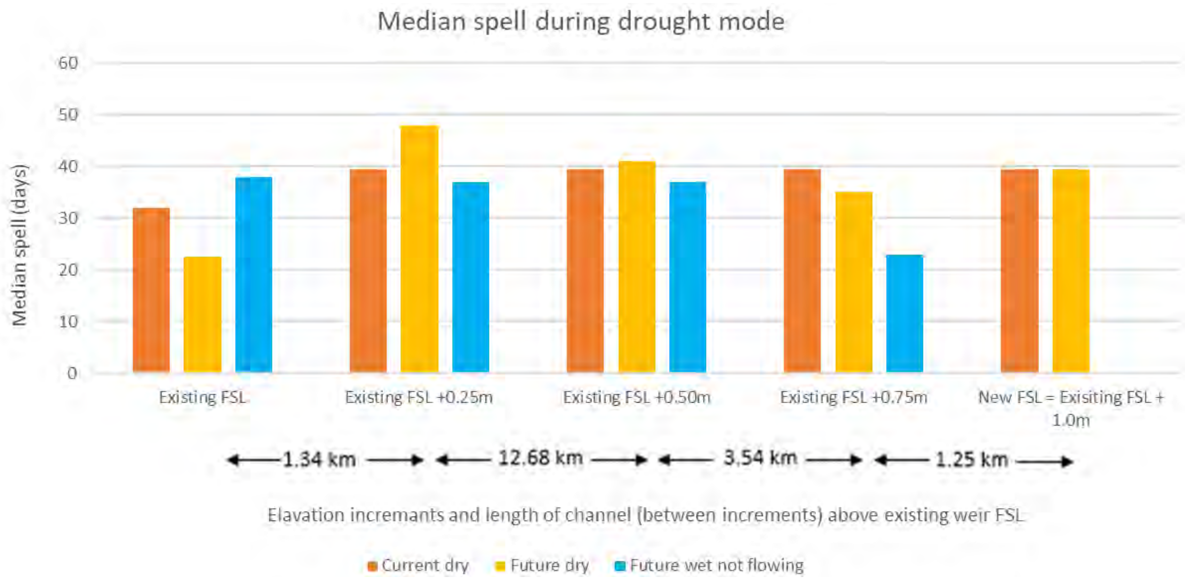


Figure 6-24 Median spell duration for each flow category at incremental water level heights for the reach from the normal FSL to the new FSL. Left side of graph shows the number of days experiencing each flow condition at the location of the existing weir FSL. Distance increments show the length of reach upstream of the existing FSL inundated with progressive weir pool level increases at 0.25 m intervals

During drought security operation mode, the extension of the weir pool up to the drought FSL results in the conversion of 18.1 km of dry river channel and non-flowing refuge pools to a larger single weir pool. At the end of a drought phase and inflows recommence, any residual area that is inundated above the normal FSL is drawn down and channel that was either *dry* or *wet but not flowing* reverts to flowing channel habitat consistent with what occurs under current conditions. This means that the habitat change associated with future drought operations is relatively minor in that the channel that would be dry or contracted to isolated non-flowing refuge pools under existing weir conditions would now be inundated for a longer period, but still non-flowing. The relative periods of *dry* versus *wet but not flowing* vary across the inundation gradient, with longer durations of *wet not flowing* compared to *dry* at the lower elevation and longer periods of *dry* compared to *wet not flowing* at the upper reaches (i.e. similar to current conditions during non-flow periods).

Impact on aquatic biota during drought security operation mode

Any shift in hydraulic conditions (i.e. the slowing of flow velocity during filling and the conversion of flowing to non-flowing habitat) has the potential to impact on aquatic biota. During the filling phase flow velocity would decline as the water level is raised but would not cease until inflows ceased. At this point what would have been dry sections of river bed or isolated refuge pools between the existing FSL and drought security operation mode FSL would become a single large non-flowing pool (i.e. similar to conditions that would be experienced in refuge pools during non-flowing periods). Under this circumstance, there is no loss of flowing habitat because the river would not be flowing anyway.

Importantly, the hydraulic conditions at the most upstream extent of inundation would remain largely unchanged (either dry/isolated pools during drought security operation mode, or flowing during normal operation mode as per Section 6.2.1.1). This upstream habitat (in the top one to two kilometres of the reach) is recognised as the more important flowing habitat in the reach because of the presence of bedrock riffles, the presence of River Mussels (observed during site inspections) and historical evidence of colonisation by Darling River Snails (refer to **Section 4.1.4.1** for more details on the quality of habitat along the upstream reaches).

Although the proposed drought security operation mode would not result in a permanent change from flow to non-flowing hydraulic habitat there are a number of potential effects associated with inundation during drought security operation mode.

The increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods. This could benefit some native species but may also benefit pest species (such as Carp). However, the relative effect compared to current conditions is likely to be small because even under current condition there is already a large length of inundated river reach (about 60 km) that provides similar habitat for native and non-native fish.

With regard to benthic species, River Mussels have been recorded in the reach (refer to **Section 4.1.4** and **Appendix A**). River Mussels prefer flowing channel environments (Ponder, et al, 2020; DPI, 2018) so the conversion of flowing to non-flowing habitat represents a threat to River Mussels as they are sedentary, filter-feeders (Ponder, et al, 2020), meaning they rely on flow for their food source and are also considered to be "oxyconformers", meaning they are dependent on a stable environmental supply of oxygen (Sheldon, 2017). During normal mode the reach upstream of the existing FSL would remain flowing habitat suitable for the persistence of River Mussels (see section 6.2.1.1). During drought mode (as discussed above), it is expected that the proportion of time this section of the river remains *wet but not flowing* would be comparable to the length of time that the channel would have otherwise been *dry* or contracted to isolated refuge pools (i.e. there is no substantial shift in conditions from flowing to non-flowing, the shift is from *dry/small refuge pools* to *wet but not flowing/longer and deeper refuge pools*).

The implications of this shift from *dry* to *wet not flowing* for River Mussels (and Darling River Snails if they were present in this reach) needs to be considered in the context of historical flow conditions and recent flow history. **Figure 6-25** shows the pattern of cease to flows (flow less than 1 ML/day) at Wilcannia from 1972 to 2022 (flow gauge 425008). Prior to the Millennium drought, CtF conditions were rare, typically once every 10 years, for durations shorter than about 50 days and with many years of continuous flow between years with CtF conditions. Since 2002, CtF conditions have become more frequent and last longer. CtF conditions have occurred in 17 of the past 21 years with the longest duration spells often lasting longer than 50 days and with multiple events per year resulting in more than 100 CtF days a year in six of the last 15 years. The median interval between CtF spells since 2002 has been 112 days. This changed pattern of increasing frequency and duration of CtF spells is likely to have profound impacts on biota, such as River Mussels and Darling River Snails, that are restricted to flowing habitats and have limited capacity to 1) move to refuge pool habitat and 2) actually survive in refuge pool habitat given their bio-physical requirements for well oxygenated flowing water.

River Mussels may be able to survive infrequent, short duration CtF spells. However, long duration CtF spells have been shown to result in the death of many River Mussel. Jones (2007) observed that during very-low-flows in the Darling River (Baaka) in 2002 River Mussels did not move into deeper water or burrow into sediments to escape exposure to the sun and as a result suffered high mortality. Mallen-Cooper and Zampatti, 2020 and Sheldon et al. 2020 observed large numbers of dead River Mussels during extended cease to flows in 2018, 2019 and 2020. Of 16 sites along the Darling River (Baaka) from Menindee Weir to Mungindi Weir (on the NSW – QLD border) inspected in March 2019, Mallen-Cooper and Zampatti (2020) observed dead mussel at all but one site (at Tilpa Bridge). Dead Darling River Snails were recorded at four sites upstream of Tilpa but were absent from all other sites including at Wilcannia. Sheldon et al., (2020) surveyed numerous sites along the Darling River and tributaries in February-July 2020. They observed 20 per cent to 100 per cent mortality of River Mussel at an average mortality of 83.5 per cent (65 per cent of sites where River Mussels were observed had 100 per cent estimated mortality). Notably, the site with the largest number of River Mussels and overall lowest mortality (20 per cent) was Tilpa Bridge, the only location that Mallen-Cooper and Zampatti observed live River Mussels in 2019. Sheldon et al. (2020) noted that sites with dead River Mussels were all those with a dry river bed and that survival was likely to be greatest in reaches containing water holes and refugia that did not dry out during the drought.

The above analysis suggests that although River Mussels require flowing water to maintain oxygen and food supply (Jones 2007), during extended cease to flow periods River Mussels located on river channel that dries out are likely to die (Jones, 2007; Mallen-Cooper and Zampatti, 2020; Sheldon et al., 2020) as they appear not to actively seek refuge pools or burry into damp sediments (Jones, 2007), Moreover, survival is likely to be greatest where River Mussels are located in sections of river bed that experience suitable velocity during flowing conditions but that retain water during cease to flows (Sheldon et al., 2020). The implications of this for the proposed weir operation are twofold:

1) During normal operating mode lotic flowing habitat will largely be retained in the reach between the existing FSL and the new FSL (refer to **Section 6.2.1.1**). This will maintain suitable conditions for River Mussels during periods of time when the river is flowing.

2) During drought security operating mode, inundation will extend to the new FSL. At this time habitat will shift first to slower flowing habitat as the pool is filled and then from a combination of dry channel bed and isolated non-flowing refuge pools to a deeper longer pool. This pool will inundate parts of the channel that would have otherwise been dry once inflows cease and provide deeper water depth across areas that would have become isolated shallow refuge pools. Under current conditions River Mussels resident in parts of the channel that would become dry during cease to flows are vulnerable to mortality, especially as the frequency and duration of cease to flows has increased over the past 10-20 years. While River Mussels require flowing habitat and are generally absent from permanent weir pools, evidence from Sheldon et al. (2020) suggest that survival during cease to flow periods is higher where River Mussels are located in habitats that become refuge pools in cease to flow conditions. On this basis the enlargement of the weir pool during drought security operating mode may help River Mussels to survive cease to flow periods that would otherwise result in high mortality if the river bed was to dry out (refer to **Figure 6-26** for a conceptual model of River Mussel vulnerability).

It is important to note that while there is potential for impacts in this upstream section of the study area, changes would only occur during drought conditions. At other times the new weir would be operated as close to possible at the existing FSL and lotic conditions would be retained to as close as possible to existing conditions. The proposed dual mode weir operation represents a much lower risk outcome than that of a fixed crest weir where the additional weir height would have permanently inundated the upstream extent, resulted in the total loss of lotic habitat and resulted in the death of all River Mussels (and Darling River Snails if present).

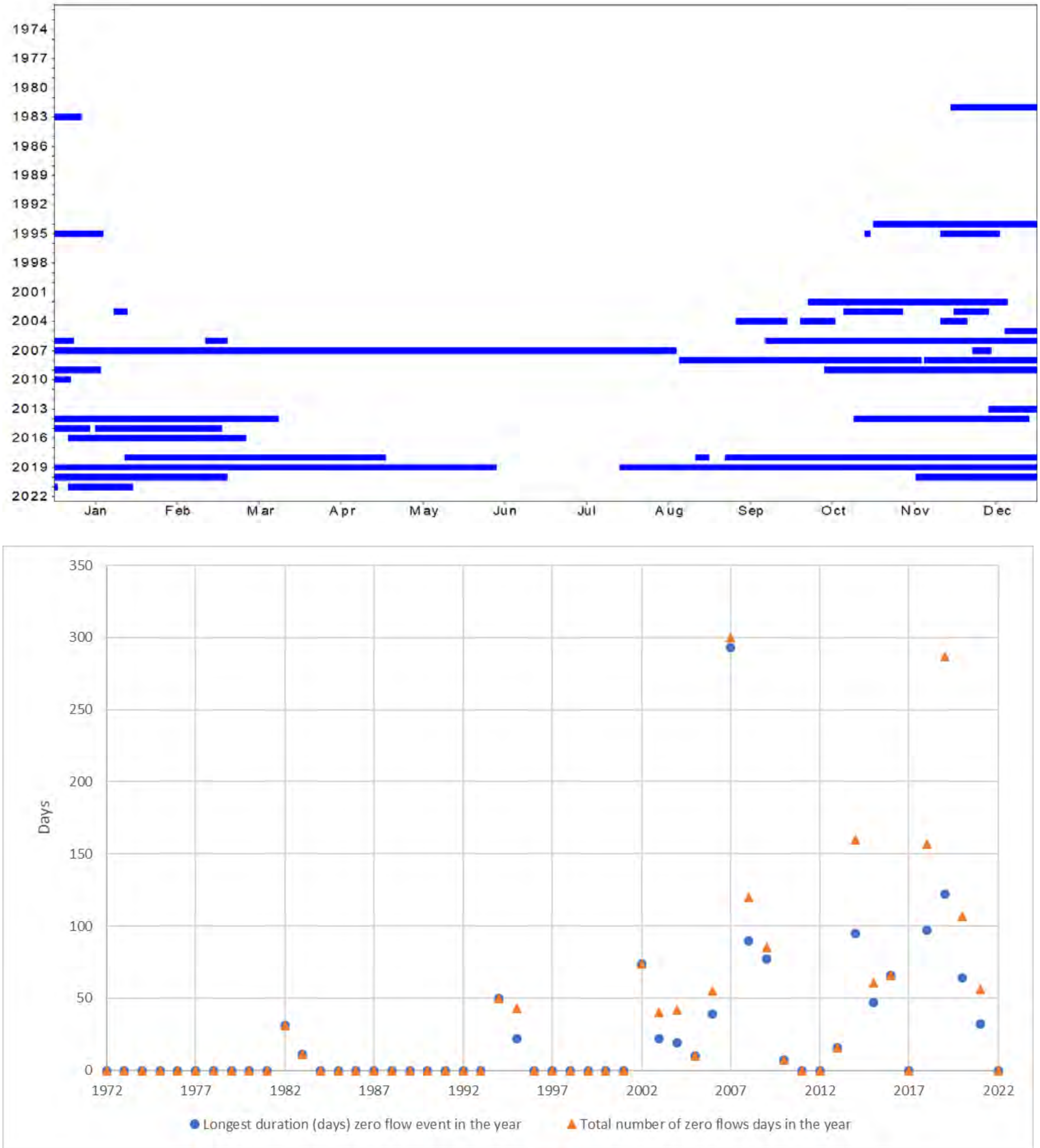


Figure 6-25 Upper panel - pattern of cease to flows (flow less than 1 ML/day) at Wilcannia flow gauge (1972-2022) (flow gauge 425008). Lower panel - total number of cease to flow days per year (triangles) and longest duration ease to flow event per year (circles) (1972-2022)

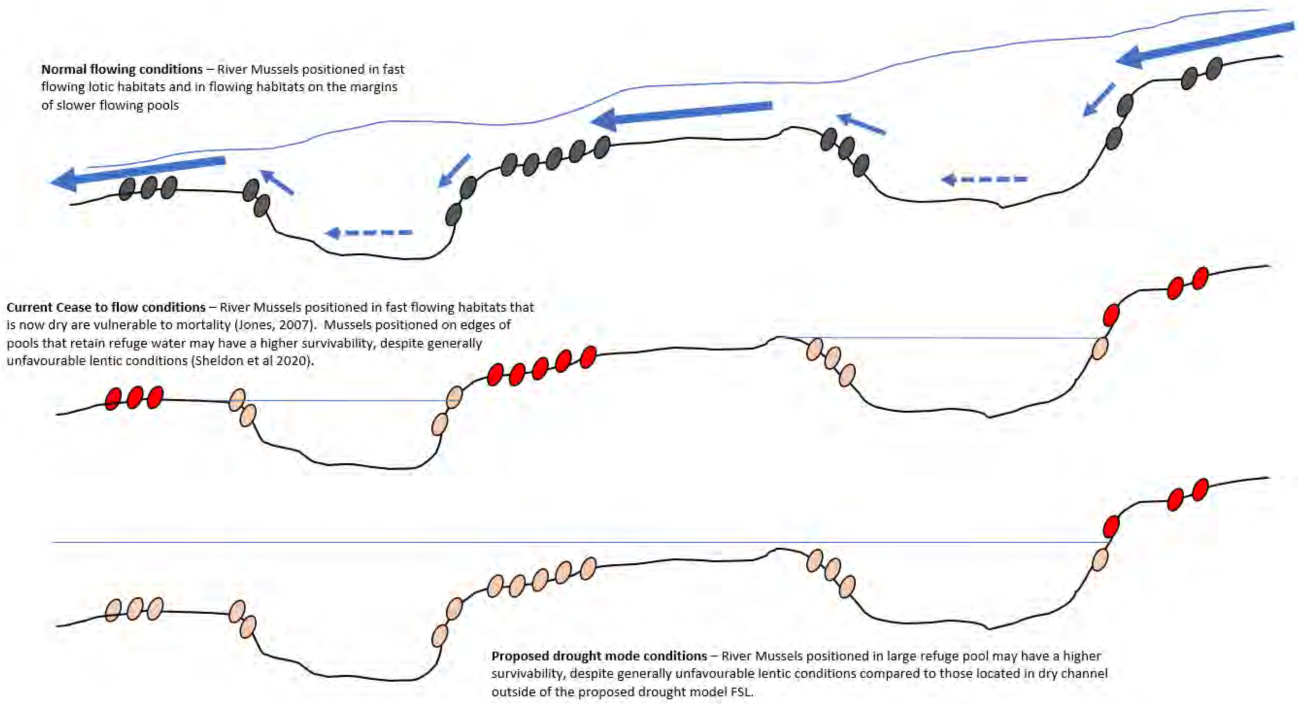


Figure 6-26 Conceptual model for River Mussel vulnerability under current and increased frequency and duration of cease to flow conditions relative to proposed drought mode operation

6.2.2 New town pool

The new weir would permanently inundate about 4.92 kilometres of existing river between the new and existing weirs (the 'new town pool'), and when the new weir is in drought security operation mode, the FSL within the weir pool would be one metre higher than the normal FSL. Changes in water level and velocity during normal operation mode were assessed for the new town pool (from the new weir to the existing weir) in the same way as for the existing weir (refer to **Section 6.2.1.1**). The proposal would significantly reduce flowing water habitat conditions in the new town pool (refer to **Figure 6-28**). This reach of the river currently provides flowing water habitat / hydraulic complexity at flow rates across the range analysed (200-5,000 ML/day). Under the proposal, the new town pool would only provide flowing habitat at higher flows; minimum flowing habitat would be present across about 50 per cent of cross sections at a flow of 3,500 ML/day and higher. While at a flow of 5,000 ML/day and above minimum flowing habitat would be present across all cross sections. At median flows (800 ML/day) and lower, velocity would be less than 0.1 m/s, indicating flowing conditions would be replaced with non-flowing conditions are these flow rates representing a loss of Type 1 Key Fish habitat. The new town pool (about 4.92 river kilometres) represents about five per cent of the flowing reach between the existing weir and the upstream extent of Lake Wetherell (about180 river kilometres).

The river channel in this reach includes some large wood habitat on the lower banks (some of which is partly submerged in the low flow channel and refuge pools) and sandbars (which at the time of inspection were sparsely vegetated with a range of exotic and native grasses and non-woody vegetation). Although the native Freshwater Fish Community Status in this section of river has been classified as fair (DPI, 2015), it retains hydraulic complexity / characteristics that could support native fish and benthic fauna during flowing periods: live River Mussels were observed during site inspections. Permanently changing the hydraulic characteristics of the river in this section of the channel from a "*flowing*" environment to a "*no to low flow*" environment has the potential to impact the abundance and diversity of species reliant on flowing conditions as it can disrupt life-cycles of species and degrade habitat conditions (Sheldon, 2017). In particular, the following impacts would occur due to permanently inundating the river channel:

- Reduced habitat diversity and decreased habitat suitability for native species that prefer flowing habitat (habitat specialists)

- Reduced opportunities for native fish spawning and juvenile recruitment due to impediment of egg and larval drift
- Increased water depth, potentially leading to stratification and subsequent water quality issues such as hypoxic or anoxic (low or no oxygen) environments, or leaching contaminants from bottom sediments. Hypoxic or anoxic conditions can lead to fish kills if there are no easily accessible refuges with suitable oxygen conditions. The potential for the development of stratification and mitigation measures are discussed in Section 3.5.3 of the EIS. The assessment indicates that under current conditions stratification develops about two to three months after the onset of drought conditions with no inflow to the weir. However, under proposed conditions with a deeper weir pool, stratification would take between six and eight months to develop. **Figure 6-27** shows that under current conditions about 30 per cent of cease-to-flow spells last for longer than 60 days whereas under proposed conditions less than five per cent of spells last longer than 180 days. This suggests that the larger weir pool may provide a buffering effect to the onset of stratification and result in less stratification events than currently occur.

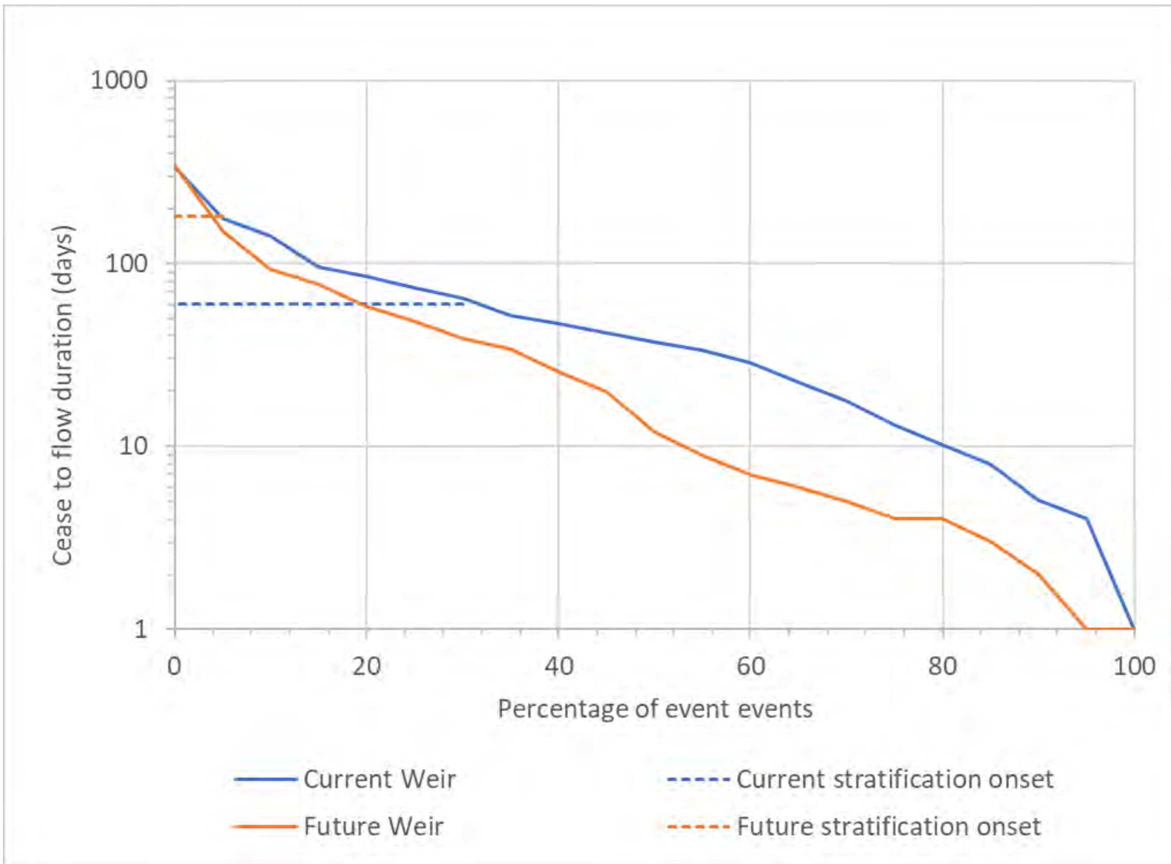
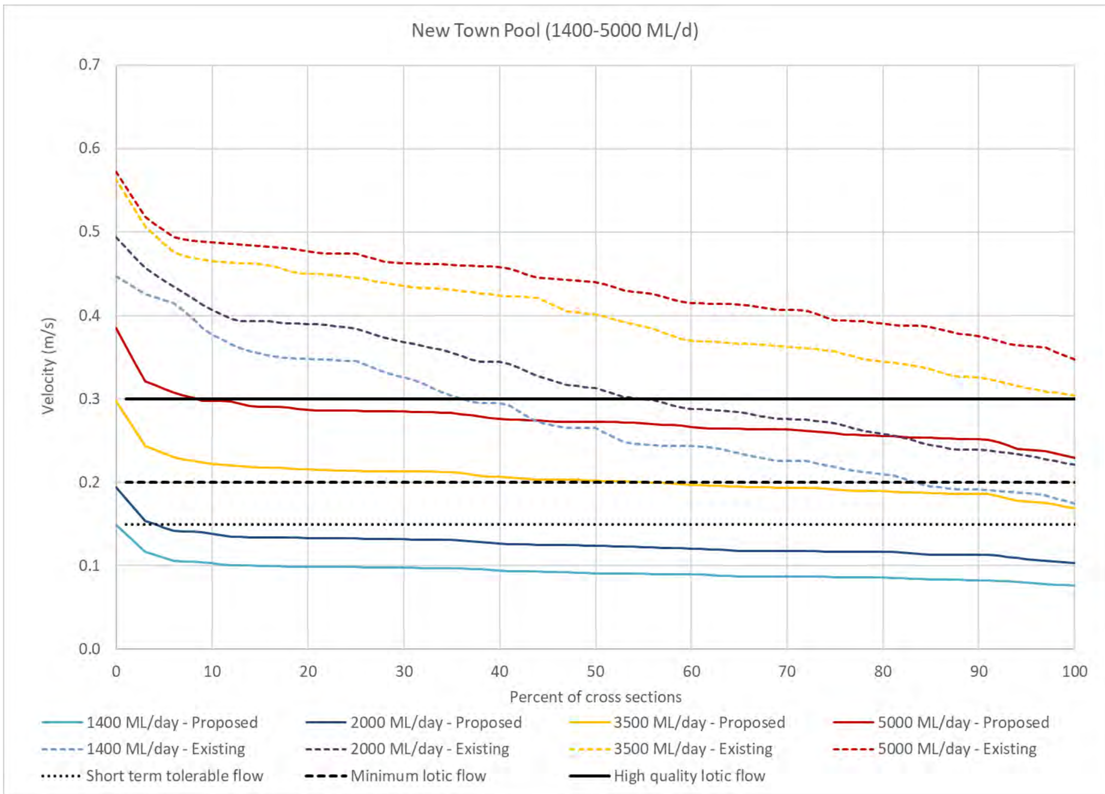


Figure 6-27 Duration of cease to flow events under current and future weir conditions showing percentage of events subject to potential stratification risks

- Alteration of temperature regimes within the impoundment which can impact behavioural cues for spawning
- The new permanently inundated reach would no longer be suitable habitat for the River Mussel or the Darling River Snail
- Sedimentation within the weir pool, which can lead to infilling habitat features, smothering aquatic plants, and clogging fish gills. Highly turbid conditions can additionally decrease light penetration through the water column which can limit photosynthesis of aquatic plants thereby reducing the overall productivity of the system
- Creation of deeper pool habitat may also result in reduced productivity in bottom waters.

Under current conditions, during periods of no flow, this reach contracts to several isolated refuge pools. The new weir would create a larger refuge pool during periods of no flow and enable mobile aquatic biota to access habitat across the entire weir pool rather than be restricted to isolated refuge pools.



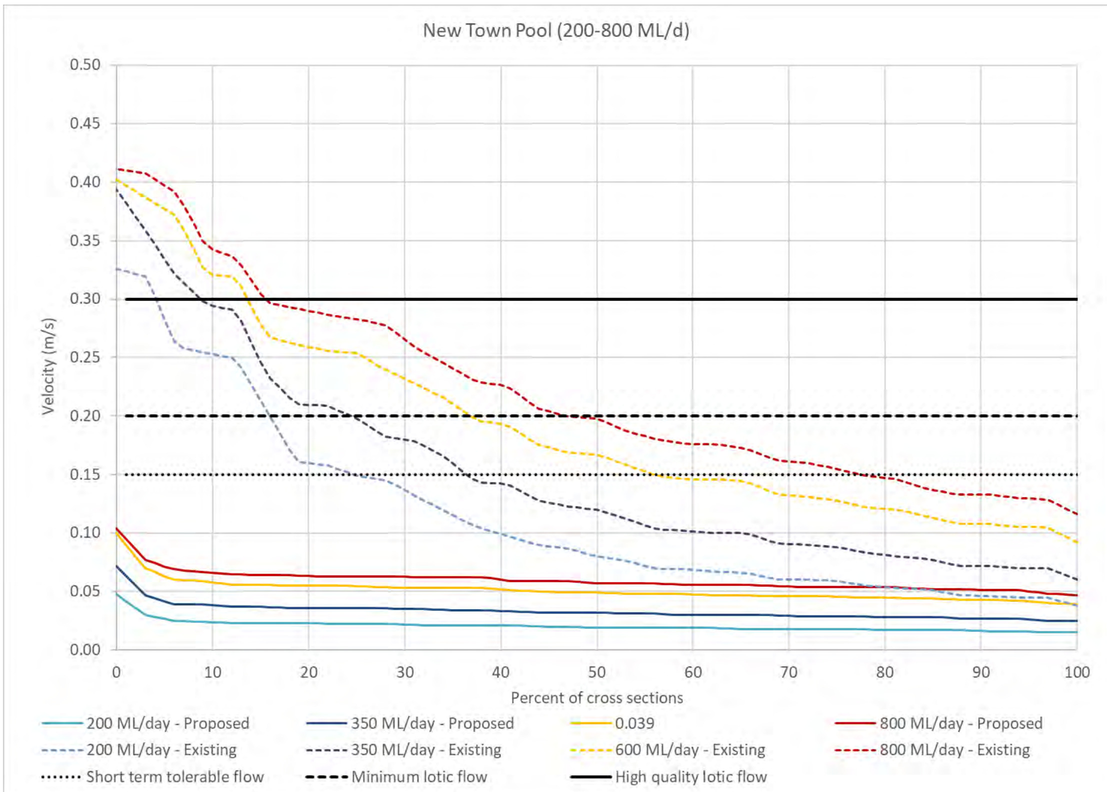


Figure 6-28 Comparison of water velocities to the flowing water habitat criteria in the new town pool (chainage -4920 to 0)

6.2.3 Downstream new weir

The following sections describe the effects of the proposed operation of the new weir on downstream flows. Critical flow components are those defined in the *Barwon-Darling Long Term Water Plan* (refer to **Figure 4-4** for the list of flow components). The assessment considers the change in frequency/number and duration of events as a result of proposed operations, notably the impacts associated with the filling and drought security operation modes, which have the potential to mostly impact on cease-to-flows and low flows. About 180 river kilometres of flowing habitat exists downstream of the Wilcannia Weir to the next downstream weir at Menindee (Lake Wetherell). This habitat is acknowledged as critical Type 1 flowing habitat. Any change in flow to this reach represents a potential risk to aquatic fauna reliant on flowing conditions and hydraulic complexity.

6.2.3.1 Cease-to-flow

During normal operation mode river flows would pass downstream as current. However, once upstream flow triggers indicate the potential for dry conditions the weir filling phase commences to raise the pool level for drought security operation mode. The filling phase requires the downstream flow to be reduced relative to upstream inflow so that the weir pool can be filled. Depending on the inflow rates there is potential for discharge to cease downstream of the new weir for short periods of time. The process for filling includes progressive gate closure to avoid a rapid cease-to-flow downstream, which could otherwise strand aquatic fauna. Progressive closure would involve a gradual decline in downstream flows that would allow fauna to retreat to refuge pools (the daily flow decline is currently modelled at 50 per cent of the previous days flow, but could be varied during actual operations based on event specific characteristics, monitoring and adaptive management). Once the pool is filled, if inflows are continuing upstream then the pool would spill and flows would continue downstream for a period of time until inflows cease. The transition to downstream cease-to-flow would closely match the rate at which inflows cease and hence would be similar to current conditions in terms of the transition to cease-to-flow, although current gate closure rules in the modelling can result in cease to flows during drought security operating mode commencing a few days earlier than they would have under current conditions. Under current modelling rules filling phases have been removed from the modelled flows where the drought mode period would be less than 14 days. This avoids a large number of unnecessary filling cease-to-flow (CtF) spells where the drought period is short and hence water security would not be at risk.

The *Barwon-Darling Long Term Water Plan Part B* (DPIE, 2020a) includes requirements for CtF to not persist for more than 20 days in most years, in very dry years to not persist for more than 160 days, and should occur in no more than 50 per cent of years. **Table 6-3** show summary statistics for the modelled existing and new weir operation with regard to resultant CtF spells over the river system model record (1900 to 2019) for CtF spells shorter and longer than 20 days, and longer than 160 days. The results show a large increase in the number of CtF spells that are shorter than 20 days duration, including an increase in the percentage of years that experience a short duration CtF spell. However, the mean duration of these short spells decreases. The vast majority of new CtF spells are events less than 10 days duration, and mostly less than five days duration (refer to **Figure 6-29** lower panel). The increase in the number of short duration CtF spells occurs during the filling phase – when a filling phase is triggered there is a short period when discharge downstream of the weir reduces or ceases while the pool fills. Once the pool is filled discharge recommences until inflows cease. There is a small increase in the number of CtF spells longer than 20 days but a decrease in duration – some longer duration events become 2 shorter duration events. These events are generally driven by longer duration upstream CtF spells rather than new weir operations. There is one extra CtF spell longer than 160 days, but this a160-day spell under existing conditions that become a 164-day spell under future conditions.

Table 6-3 Cease-to-flow statistics under existing and new weir operations (modelled current and future operations 1900-2019)

	CtF spells <20 days duration			CtF spells >20 days duration			CtF spells >160 days duration		
Scenario	Total number in record	% of years with at least one event	Mean duration of event (days)	Total number in record	% of years with at least one event	Mean duration of event (days	Total number in record	% of years with at least one event	Mean duration of event (days
Existing weir	36	23	8.8	85	72	78	10	8	192
New weir	85	72	5.7	97	82	73	11	9	192

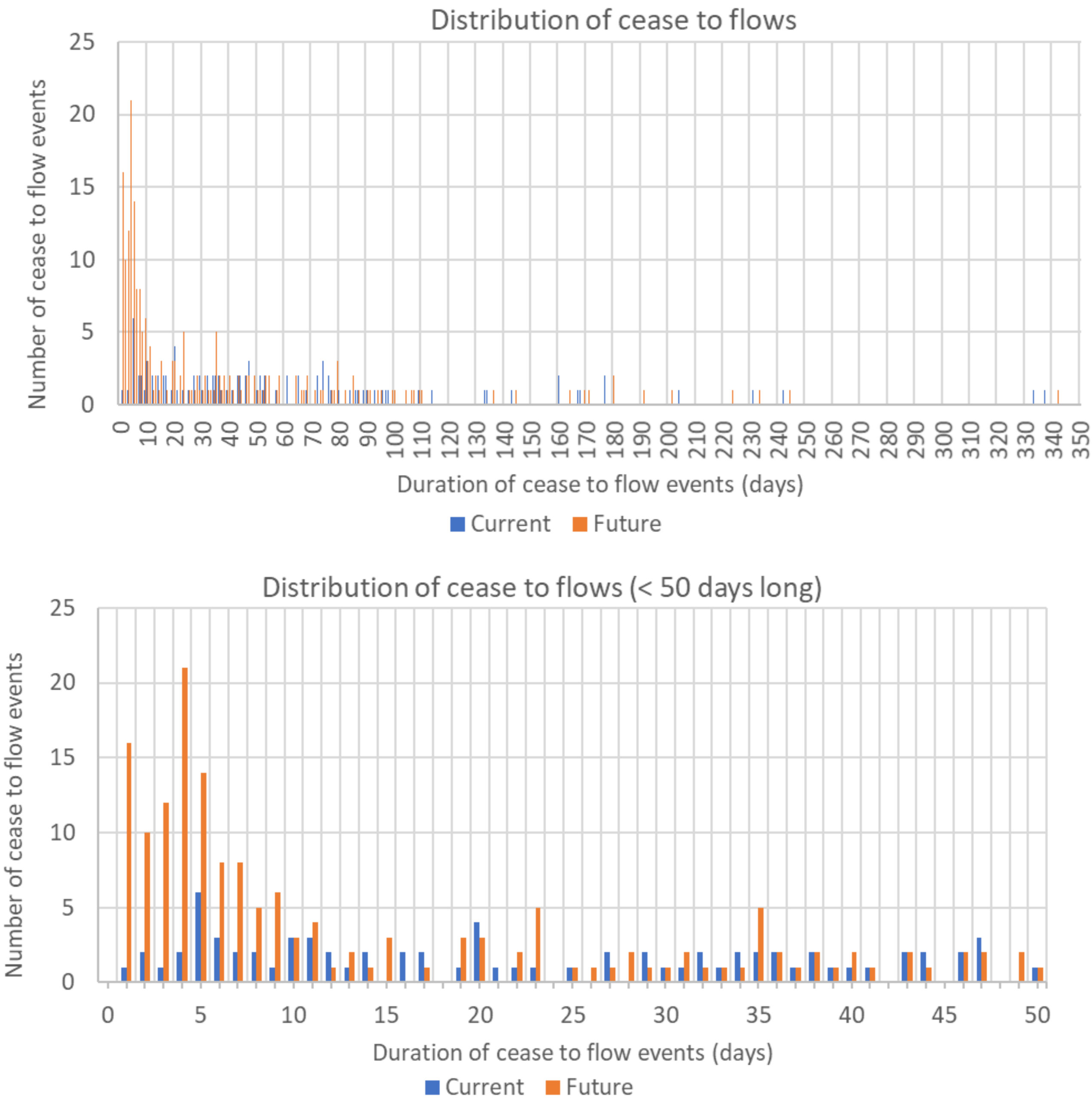
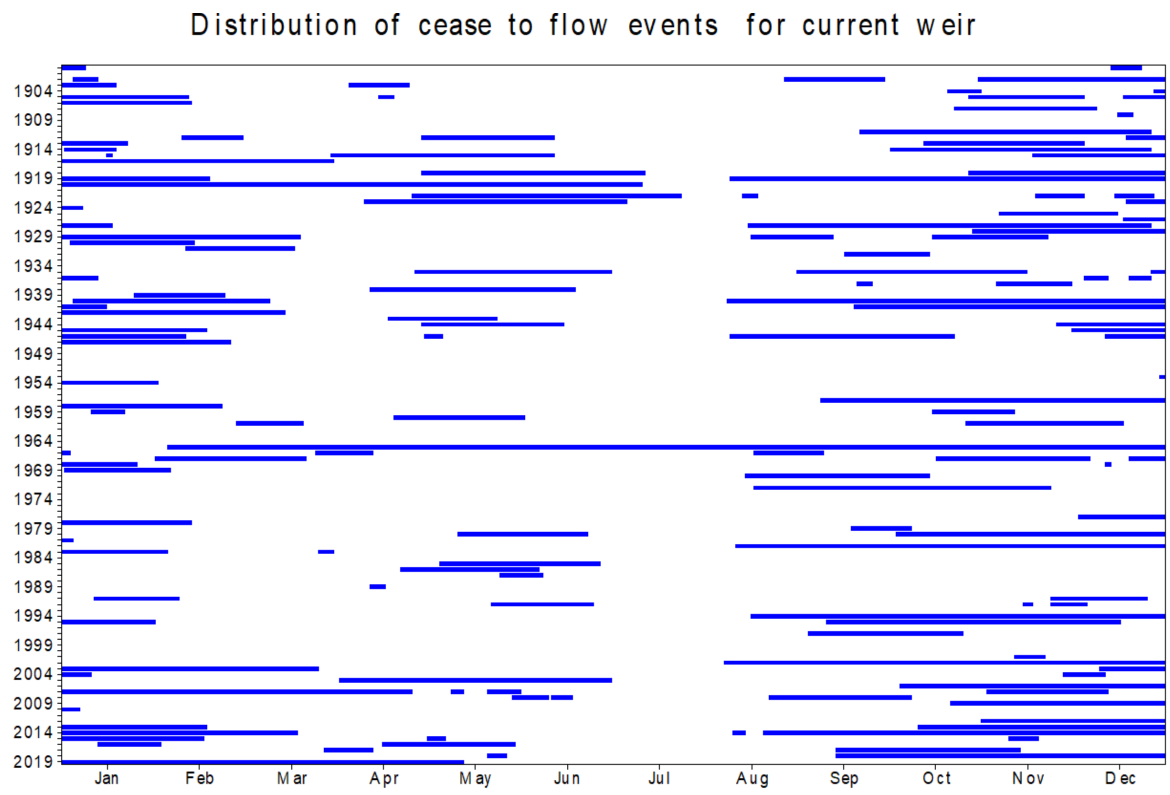


Figure 6-29 Duration frequency of cease to flow spells for the whole data set (upper panel) and cease to flow spells less than 50 days duration (lower panel)

Figure 6-30 shows the pattern of CtF spells across all years. The overall pattern of long duration cease-to-flows is similar between existing and new weir operations, but filling phase results in the addition of short-duration cease to flows (purple bars) and also the extension of existing cease to flows during drought security operation mode (red bars). The later occur as a result of modelled gate closure rules which under modelled rules result in the commencement of cease to flow occurring a day or so earlier than it otherwise would have occurred. Most of these additional cease to flow spells associated with the filling phase occur in the period April to July (refer to **Figure 6-31**), which also highlights little change in longer duration cease-to-flows across each month. Furthermore, there is no difference in the number or duration of CtF spells in very dry years (refer to **Figure** 6-32).



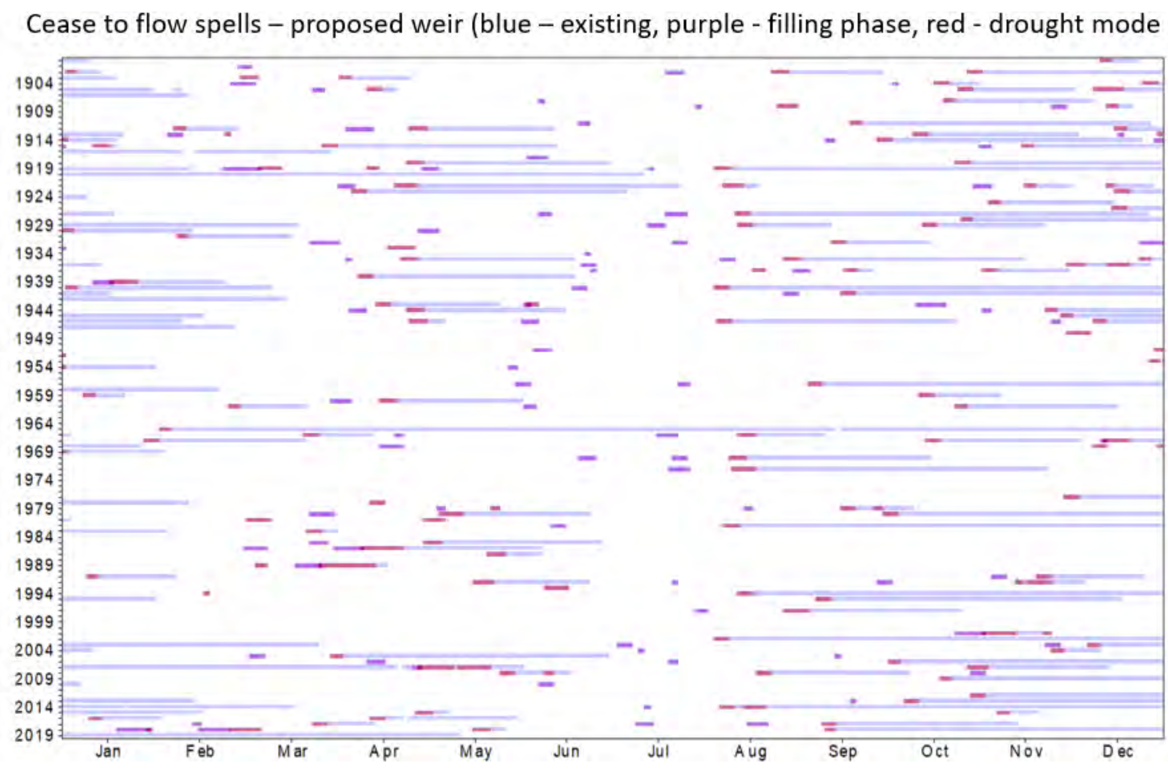


Figure 6-30 Pattern of cease-to-flow (less than 1ML/day) spells for the existing weir (upper), and modelled cease-to-flow spells for the proposed weir (lower). Proposed conditions based on modelled operating rules show the existing cease to flows (light blue) that would continue to occur plus the additional cease to flows associated with filling phase (purple) and drought security operating mode (red)

Figure 6-31 Monthly patterns in number (upper row) and average duration (lower row) of CtFs for events shorter than 20 days (left column) and greater than 20 days (right column)

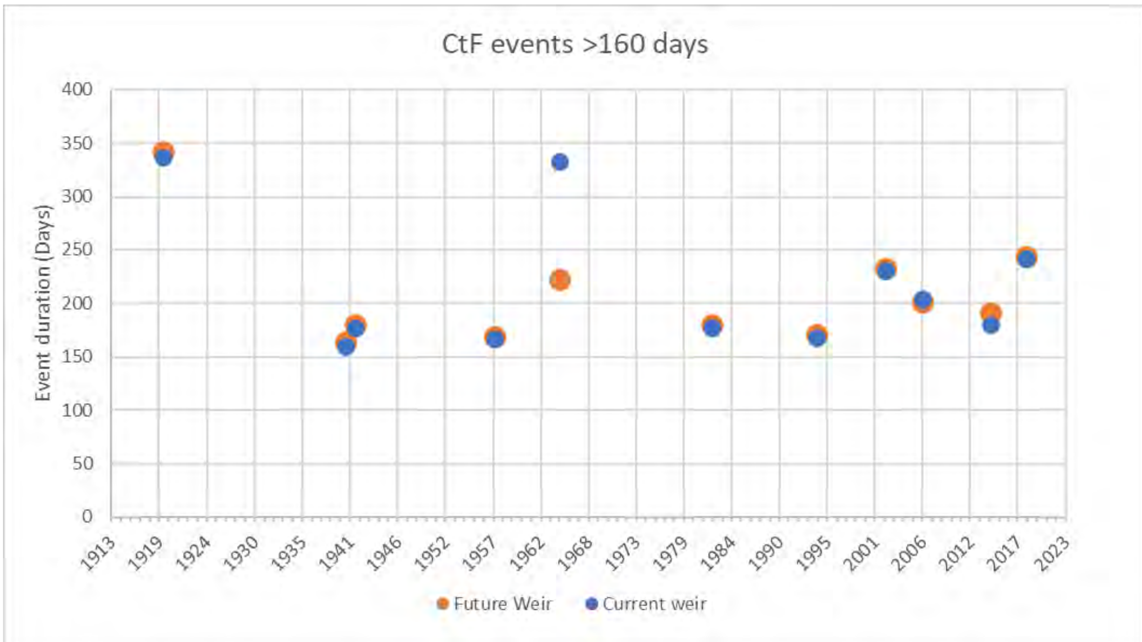


Figure 6-32 Number and duration of very long (greater than160 day) CTF spells

Associated with the increase in the number of short duration cease to flow events during the filling stage, there is a decrease in the interval between cease to flow events (refer to **Figure 6-33**); the median interval between events is halved from around 190 days to75 days.

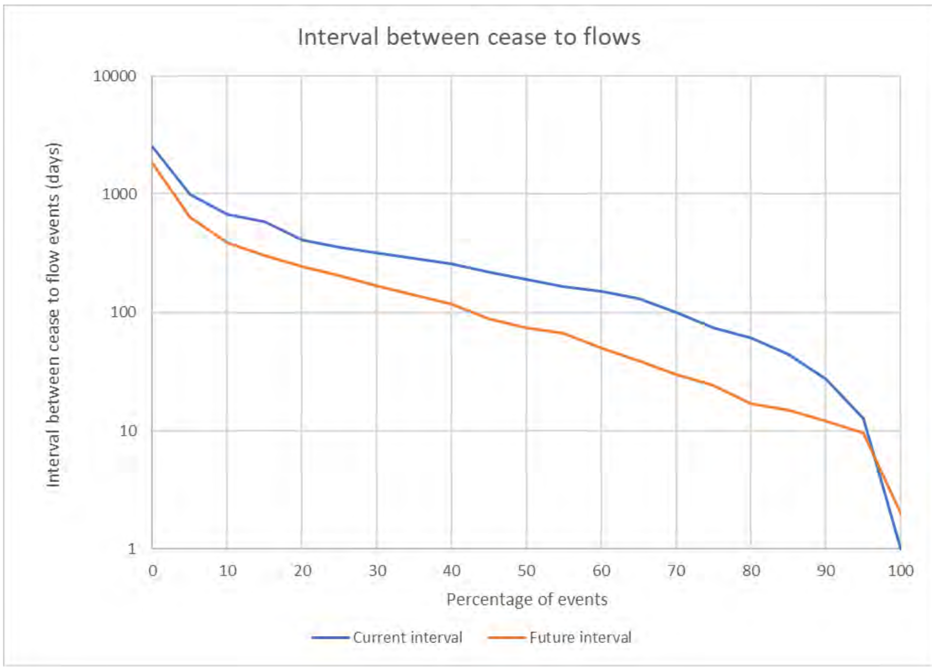


Figure 6-33 Interval between cease to flow spells

Overall, the results indicate that there is a small increase in the number and duration of CtF spells greater than 20 days in duration and there is no change in the number or duration of very long CtF spells (greater than160 days) in very dry years. However, there is the potential for an increase in number of short (less than 20 day) CtF spells during the filling phase and a decrease in the interval between CtF spells.

While CtF spells have the potential to result in adverse effects, operations would not result in a change in the already occurring long duration CtF conditions associated with dry climate periods and zero upstream inflows, so proposed weir operations would not increase the risk to downstream values beyond the already high risks associated with long duration and more frequent CtF conditions observed in the past 20 years.

However, the increase in short duration CtF spells has the potential to result in local scale impacts immediately downstream of the new weir. There is the potential for aquatic fauna (e.g. River Mussels) to be stranded on channel margins if the transition to cease to discharge occurs too quickly and water level drops rapidly.

There is also the potential for benthic fauna restricted to shallow riffle, bar and run habitat (e.g. River Mussels, Darling River Snail and other invertebrates) to be more frequently exposed to desiccation as a result of an increase in the frequency of cease to discharge conditions.

The extent of any impact associated with short duration filling phase cease to discharge events is likely to be greatest immediately downstream of the new weir because the downstream progression of short duration cease to discharge through the weir would be short. During the cease to discharge period downstream flows would continue as pools drawdown and would then refill once discharge recommences. The short duration of the cease to discharge means pools further downstream are unlikely to draw down to levels that would result in flow ceasing before refilling occurs. However, there is some uncertainty regarding how far downstream effects would occur depending on flow lag and attenuation at the time of the event. These would vary based on climate conditions and antecedent flow conditions at the time and could be more pronounced or effect a longer downstream reach if conditions are dry and antecedent flow is decreasing.

The patterns in CtF documented above are based on rules-based operations with the initiation of the filling phase based on upstream flow triggers without the benefit of climate and catchment context. To overcome the potential for false filling the modelling assessed to date incudes a rule that avoids the initiation of filling phase if the flow at Bourke Town Weir falls below the filling trigger for less than 14 days before increasing again. This rule aims to avoid false filling phases (i.e. where upstream flow did not ultimately cease) and hence reduces the number of short-duration CtF spells.

Despite the inclusion of the 14-day rule, the analysis shows there are still likely to be many short-duration filling induced cease to flows that could be avoided with the benefit of flow and climate forecasting. For example, if flows fall below filling trigger levels but climate forecasts or flow monitoring further upstream shows that good inflows are likely to occur then a decision may be made to not initiate a filling phase because forecast flows would be expected to increase without the need to enter drought security operation mode. Such an adaptive approach to decision making should avoid false filling phases and reduce the occurrences of short duration CtF to just those periods when flows are progressing towards a longer duration cease-to-flow period. Moreover, gate closure rates could be adjusted according to inflows so as to avoid additional CtF conditions that would extend an existing CtF spell and more closely match the downstream decline in flow that would have occurred under current conditions (i.e. a fixed crest weir with no operational ability). In this scenario, the downstream effects would more closely match the existing transition to CtF conditions.

The modelled future weir flows were re-analysed with all cease to flow spells five days or shorter removed based on a potential real-time adaptive operational approach using forecasting that would 1) avoid false filling phases or 2) manage gate closure more adaptively to taper downstream flow decline at the commencement of drought security operation mode. **Table 6-4** shows that with the 14-day rule in place (as modelled) there is a reduction in the number of short-duration CtF spells from 120 to 86. If forecasting and adaptive gate closure was successful at further reducing false filling (refer to **Figure 6-34** shows the reduction in filling induced downstream cease to flows that could be achieved under the 14 day rule (middle panel) and real-time adaptive operations (lower panel)), and achieving a smoother transition to downstream CtF conditions the number of short duration CtF spells could decrease even further, and the duration would more closely match current (refer to **Figure 6-35**).

In addition to reducing the number of unnecessary cease to flows, avoiding false fillings would have benefits to upstream reaches by minimising unnecessary increases in weir pool level and changes in hydraulic conditions in the reach between the current and drought security operation mode FSL.

Table 6-4 Cease to flows statistics under existing and new weir operations with CtF spells shorter than five days removed from the future weir scenario to model operational adaptive management of false filling phases (modelled existing and new operations 1900-2019)

	CtF spells <20 days duration		**CtF spells >20 days duration**		**CtF spells >160 days duration**	
Scenario	**Total number in record**	**Mean duration of spell (days)**	**Total number in record**	**Mean duration of spell (days)**	**Total number in record**	**Mean duration of spell (days)**
Existing weir	36	8.8	85	78	10	192
New weir (no 14 day rule)	120	4	97	73	11	192
New weir (with 14-day rule)	86	4	97	73	11	192
New weir (with short duration CtF removed based on real time optimised operation)	45	10	97	73	11	192

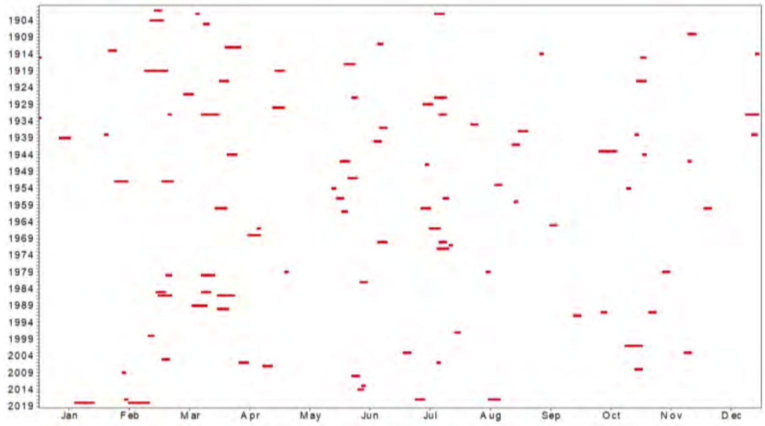
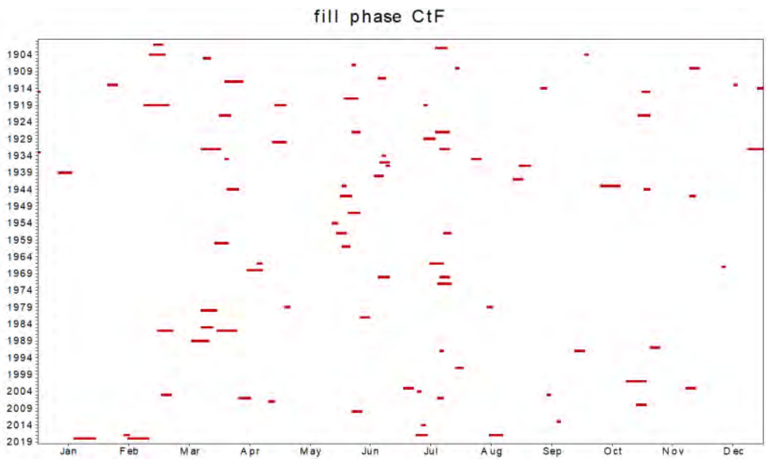
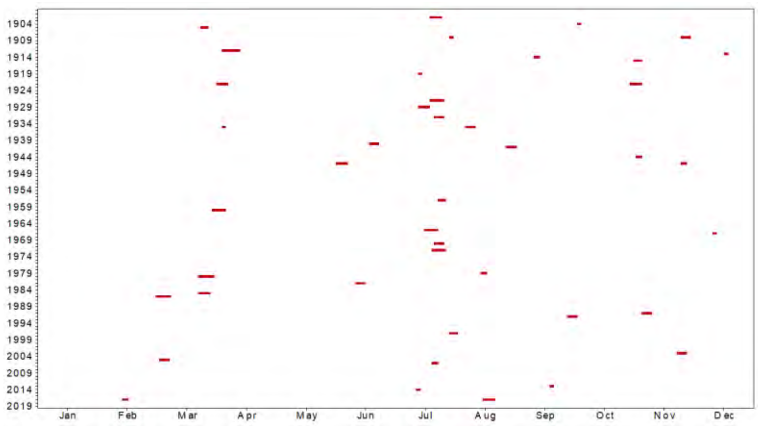
Filling cease-to-flows with all drought triggers included (no 14-day rule)

Filling cease-to-flows with drought periods shorter than 14-days excluded

Filling cease-to-flows with real-time adaptive optimisation to avoid false fillings


Figure 6-34 Duration of cease to flow spells under current, modelled operation and a proposed adaptive operation to minimise short duration (false filling) 'cease to discharge' events

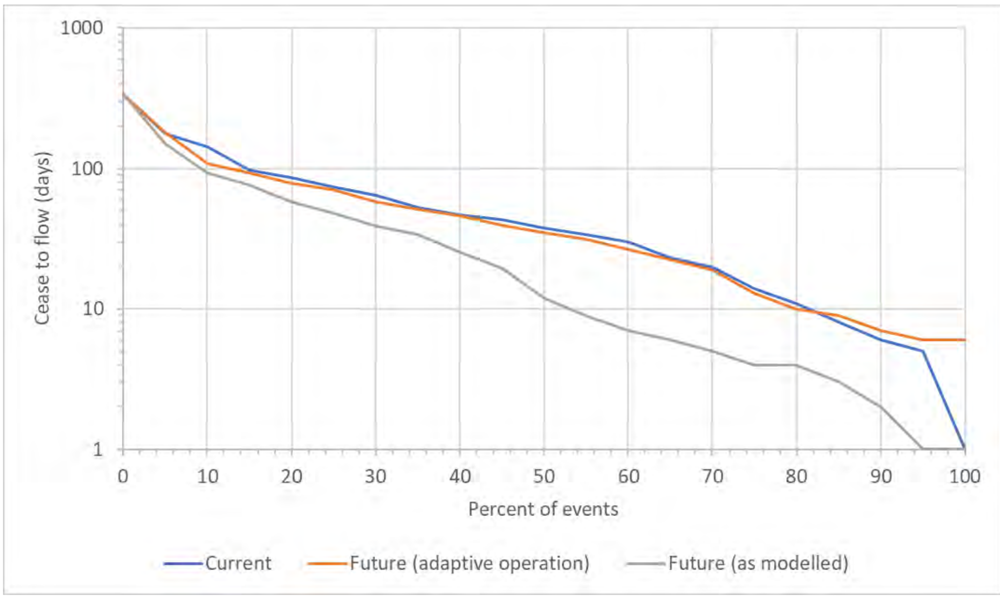


Figure 6-35 Duration of cease to flow spells under current, modelled operation and a proposed adaptive operation to minimise short duration (false filling) 'cease to discharge' events

An operations plan for the new weir is being prepared in consultation with DPE Water, Fisheries NSW, DPE Environment and Heritage, MDBA and WaterNSW. A draft operations plan is provided in Appendix I of the EIS. The operations plan will continue to be developed with the stakeholder agencies, and will identify how real-time adaptive operations will be applied to decision making to further minimise impacts when operating the new weir, notably to avoid false filling and minimise short duration CtF events.

6.2.3.2 Very-low-flows

In the Barwon-Darling system at Wilcannia, very-low-flows assist to maintain aquatic habitat by replenishing water levels within refuge pools, however they do not provide sufficient water depth for fish passage between pools, can still result in water quality issues within these aquatic systems such as low oxygen environments and algal blooms, and are not suitable for native fish spawning and juvenile recruitment (DPI, 2020a; Sheldon, 2017).

The *Barwon-Darling Long Term Water Plan Part B* (DPIE, 2020a) defines very-low-flows as flows greater than 30 ML/day (i.e. in the range 30-350 ML/day - with 350 ML/day becoming the next low flow threshold). The plan requires very-low-flows to occur on at least 340 days in typical years and on at least 165 days in very dry years. **Table 6-5** shows there is a slight decrease in the mean number of days per years that very-low-flows would occur. There is no change in the percentage of years that very-low-flows would occur for more than 165 days, but a slight decrease in the per cent of years that very-low-flows would occur for more than 340 days. The slight decrease in the mean duration of very-low-flows and the reduction in the percentage of years with flows lasting longer that 340 days is because some flows that are currently greater than30 ML/day may reduce slightly and fall below the 30 ML/day threshold. This would occur during the filling phase when downstream discharge declines or ceases as the pool is filled.

Table 6-5 Very-low-flow statistics under existing and new weir operations (modelled existing and new operations 1900-2019)

	Average number of days per year with flow>30 ML/d	% of years with spells >165 days	% of years with spells >340 days
Existing weir	299	96.6	34
New weir	296	96.6	31

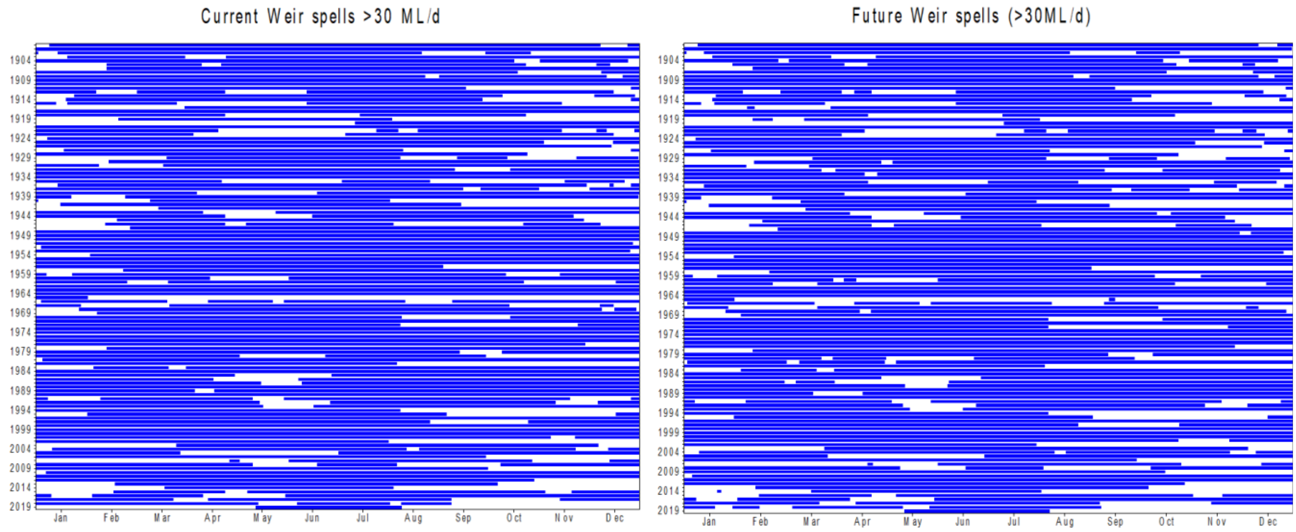


Figure 6-36 Distribution of very-low-flow spells for the existing weir (left) and proposed new weir (right)

Although there are no specific recommendations for flows in the range 0-30 ML/day, an additional analysis indicates the number of days per year across the modelled flow record with flow in the range 1-30 ML/day decreased slightly under future conditions compared to current (refer to **Figure 6-37**). The analysis also shows the increase in the number of cease to flow days under future conditions, a decrease in the number of days in the range 30-350 ML/day and an increase in the number of days with flow greater than 350 ML/day.

Overall the number of days per year in the flow range 1-30 ML/day is small (median five days under current and two days under modelled future). This flow range represents a transition flow between very-low-flow (30 ML/day) and CtF. The decrease in the number of days in the range 1-30 ML/day reflects the increase in the number of CtF days (i.e. some days in the range 1-20 ML/day become zero flow days).

As with CtF spells, adaptive decision making taking into account climate and catchment conditions is likely to reduce the number of false filling phases and hence reduce the potential for flows that are currently greater than 30 ML/day to fall below 30 ML/day of flows in the range 1-30 ML/day to become zero flow days.

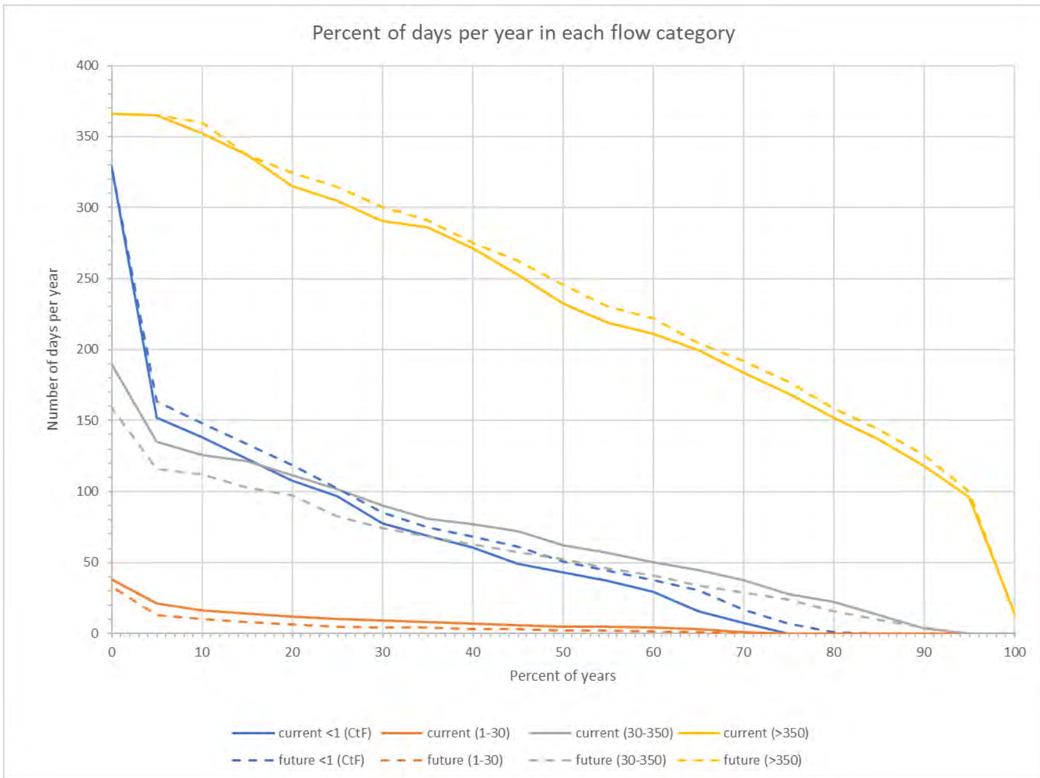


Figure 6-37 Number of days per year with downstream flow in different flow categories for the existing weir and proposed new weir

6.2.3.3 Base flows

The long term water plan specifies two types of base flow. Base flow 1 (BF1) is for flows greater than 350 ML/day at any time of the year for at least 290 days in typical years and 120 days in very dry years. Base flow 2 (BF2) is for flows greater than 350ML/day in September to March for at least 185 days in typical years and 60 days in very dry years within the timing window. These flows assist to maintain water quality, prevent stratification in refuge pools, reduce the risk of algal blooms and provide for fish passage for native species during critical migration periods (DPI, 2020a).

Table 6-6 shows that there is slight reduction in the mean number of days that meet the BF1 criteria but an increase in the number of days that meet the BF2 criteria. There is also a slight decrease in the percentage of years than meet the BF1 criteria but an increase in the percentage of years that meet the BF2 criteria. The shift occurs where flows might be around the flow threshold and fall slightly above or below the flow threshold as a result of operations. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system (refer to **Figure 6-38**). Notably, there is no reduction in the number of days or percentage of years that meet native fish movement requirements associated with BF2.

Table 6-6 Base flow statistics under existing and new weir operations (modelled current and future operations 1900-2019)

	Base flow 1 (anytime)			Base flow 2 (September-March)		
	Average number of days per year with flow>350 ML/d	% of years with spells >120 days	% of years with spells >290 days	Average number of days per timing window with flow>350 ML/d	% of years with spells >60 days	% of years with spells >185 days
Existing weir	240	92	36	153	94	29
New weir	233	90	33	157	94	33

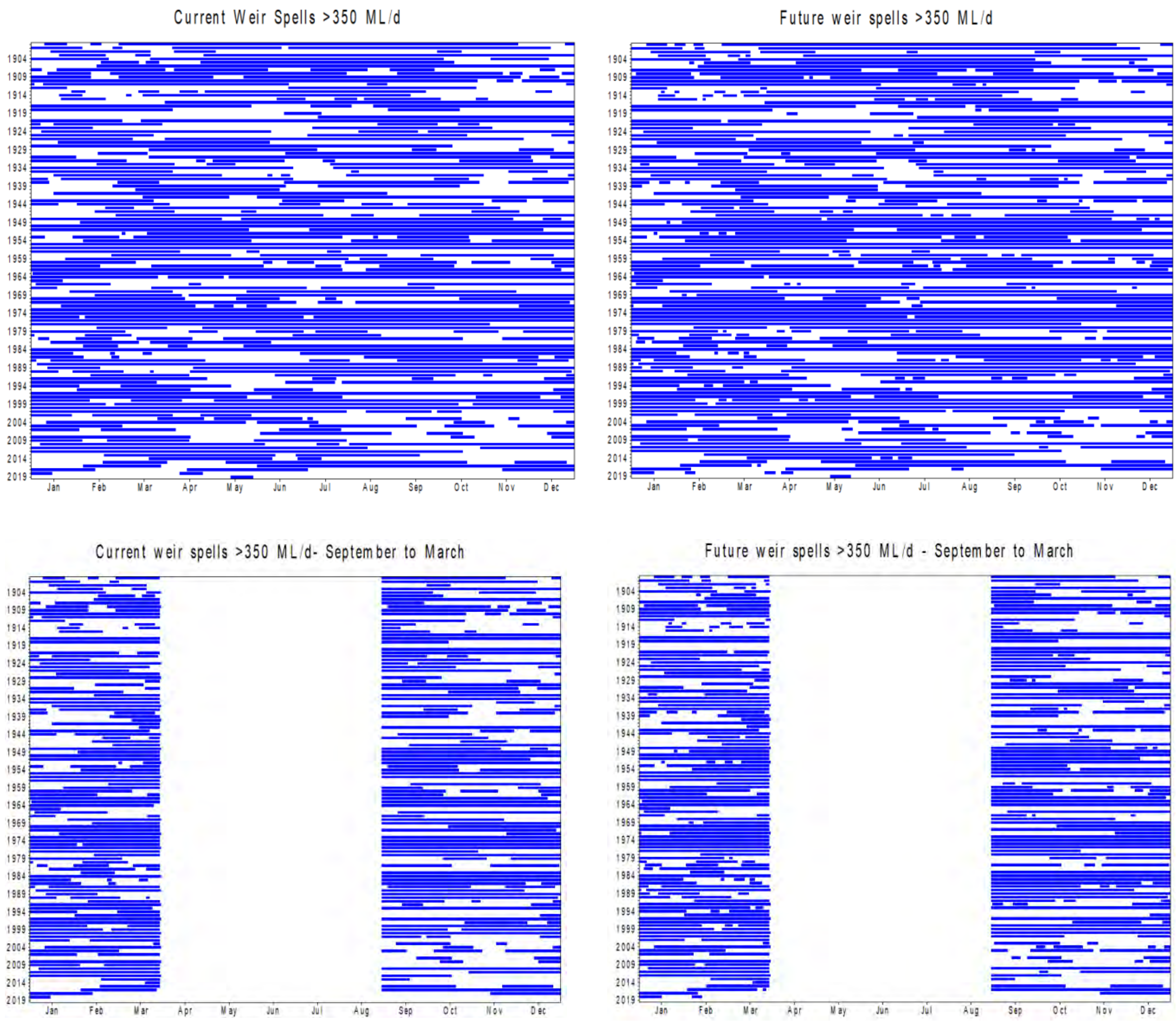


Figure 6-38 Distribution of base flows (greater than 350ML/day); BF1 (upper row) and BF2 (lower row) for current (left column) and future (right column) conditions

6.2.3.4 Small fresh flow 1

The long term water plan specifies two types of small fresh flows. Small Fresh 1 (SF1) is for flows greater than 1,400 ML/day at any time of the year for a minimum of 10 consecutive days in 100 per cent of years. Small fresh 2 (SF2) is for flows greater than 1,400 ML/day in September to April for at least 14 consecutive days in 75 per cent of years. These flows are important as they are needed for native fish spawning and larvae dispersal for some native species, including the threatened Silver Perch (DPI, 2020a; DPI, 2017). These flows are not only needed for movement but also to ensure water remains within the preferred temperature range so as to not disrupt spawning cues for native species. In addition to facilitating spawning, these flows maintain water quality, prevent stratification in refuge pools, reduce the risk of algal blooms and provide flows for feeding River Mussels.

Table 6-7 and **Figure 6-39** show there is no change in the occurrence of small freshes under the new weir conditions. Flows of this magnitude are not affected by the proposed operations. As such, impacts to water quality, habitat condition, or native fish spawning activities downstream of the weir reliant on flows greater than 1,400 ML/day are not anticipated under the new weir operations.

Table 6-7 Small fresh flow statistics under existing and new weir operations (modelled current and future operations 1900-2019)

	Small fresh 1 (anytime preferably Oct-Apr))			Small fresh 2 (September-April)	
	Average number of days per year with flow >1,400 ML/d	% of years with spell >10 days (Oct-Apr)	% of years with at least 1 spell >10 consecutive days	Average number of days per timing window with flow >1,400 ML/d	% of years with at least 1 spell >14 consecutive days
Existing weir	54	92	96	61	92
New weir	54	92	96	61	92

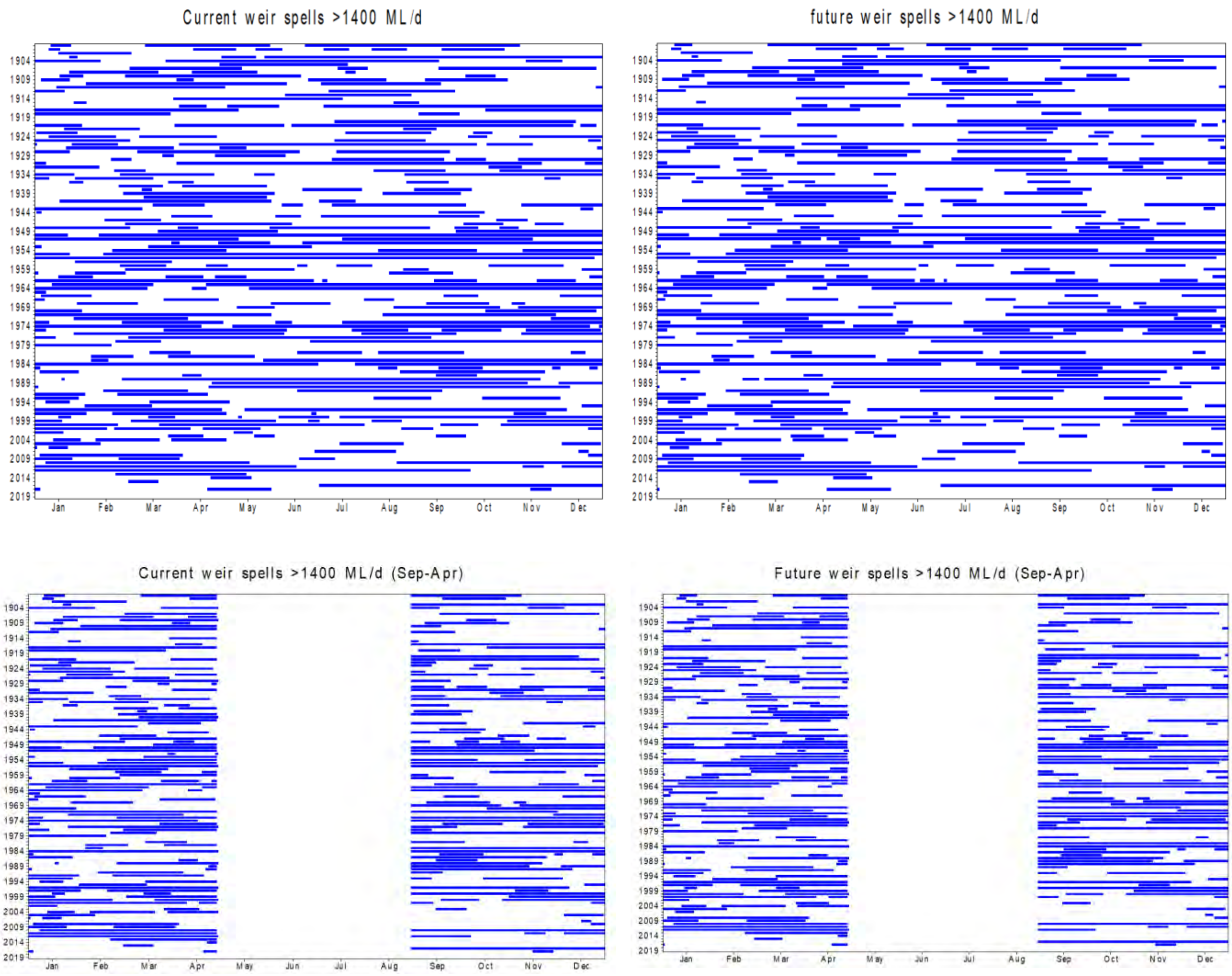


Figure 6-39 Distribution of Small Fresh flows (greater than 1,400 ML/day); SF1 (upper row) and SF2 (lower row) for current (left column) and future (right column) conditions

6.2.3.5 Fish passage

Currently the Wilcannia Weir prevents upstream fish passage unless the existing weir is drowned out such that downstream water levels are close to upstream water levels. This occurs at river flows of about 5,000 ML/day (Heath Robinson, PWA, Pers. com.). In accordance with legislation under section 218 of the FM Act the new weir is required to provide fish passage. The new weir is designed to provide fish passage for large-bodied fish when flow is greater than 60 ML/day (although flow would pass through the fishway at lower flows and passage for smaller bodied fish may be available at these lower flows). **Figure 6-40** shows the distribution of time when fish passage is available for the existing weir compared to the new weir. The inclusion of the fishway substantially increases the number of day that fish passage is possible from a mean 46 days per event under current conditions to 162 days per event under future conditions. Not only is this a marked increase in fish passage overall, but the number of days that fish passage is available during the spawning season (September to December) would on average nearly double from 37.5 days to 66 days.

During flowing conditions biota would benefit from increase fish passage at the new weir. Increased fish passage would provide species with improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which would in turn boost biodiversity, long-term population resilience and contribute to food webs. The fishway together with the partial removal of the existing weir would make about 240 kilometres of the river between the existing Wilcannia Weir and Tilpa Weir more accessible for aquatic species.

Further discussion regarding fishway design is provided in **Section 8**.

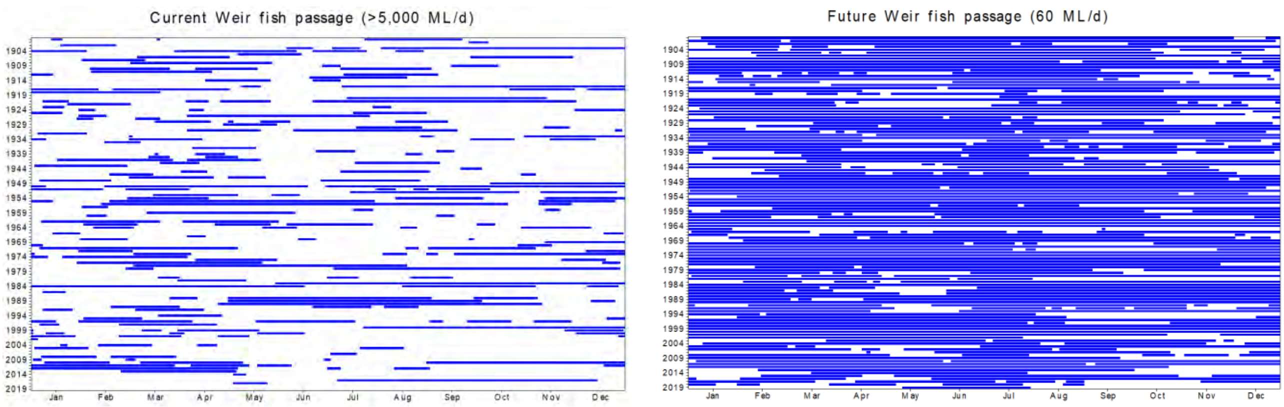


Figure 6-40 Distribution of events where fish passage is available for the existing weir (left), and modelled new weir operations (right)

6.2.4 Protected Environmental Water events

Under the proposed weir operations there is the ability to pass small flows and freshes to downstream reaches during drought security operation mode. These flows could be the result of Protected Environmental Water delivered from upstream or small unregulated inflows that are not sufficient to trigger transition from drought security operation mode to normal operation mode but could none the less be passed downstream. This provides significant advantage over the existing weir during drought conditions where there is no ability to manipulate release downstream of the existing weir. During drought periods the existing pool draws down below the FSL and if small flows do occur the pool needs to fill first before those events pass downstream. On some occasions these small flows may be entirely captured in the weir pool and no flows would progress downstream. The new weir includes gates that can be used to enable any inflows to the weir to be passed downstream while in drought security operation mode (i.e. translucency of flows). This enables small unregulated flows and manged environmental flows that may be delivered during dry periods to be passed through the weir pool and on to downstream reaches.

The implementation of the translucency rule will be detailed in the operations plan for the new weir that is being prepared in consultation with DPE Water, Fisheries NSW, DPE Environment and Heritage, MDBA and WaterNSW. A draft operations plan is provided in Appendix I of the EIS. The operations plan will continue to be developed with the stakeholder agencies.

As noted in **Section 6.1.6**, a translucency rule would be implemented when the new weir is in drought security operation mode and this would allow for any inflows to Pool 1 to be passed downstream. This would provide a benefit to flowing water habitat downstream of the new weir compared to the existing weir which has no ability to prioritise downstream flows ahead of water storage. When the new weir is in drought security operation mode the river downstream of the new weir would typically not be flowing and would likely comprise isolated pools. Translucency flows downstream of the new weir would provide moisture to dry channel beds, and connect and replenish isolated pools.

Additionally, at the end of the filling phase any flows in excess of those required to fill the new weir to the drought full supply level would be discharged either over the weir crest or through the weir gates by the immediate implementation of the translucency rule once the drought full supply level is reached. There is flexibility to operate the weir gates after initial filling to minimise any increases in upstream weir pool levels to ensure upstream velocities are maintained.

The translucency rule would provide several benefits to aquatic habitats and species downstream of the new weir including:

- Providing flowing water at times when the existing pool may have otherwise captured small inflows
- Replenishing isolated pools, which may sustain some species throughout the drought
- Enabling fish species to move between pools.

However, any decision to pass flows to downstream reaches during drought security operation mode would still need to consider the climatic conditions at the time and the potential for small passing flows to result in poor quality water entering downstream refuge pools. For example, small flows over hot, dry river bed could increase temperatures that threaten biota in refuge pools, or water low in dissolved oxygen could mix with refuge pools and create hypoxic conditions. The decision making process for make passing flow releases during drought security operation mode would be documented in the operations plan and decisions would include consultation with relevant agencies, including Fisheries NSW.

6.2.5 Mobilisation of sediment deposited behind the existing weir wall

Sedimentation occurs upstream of weirs because they reduce the velocity of flowing water, which causes sediment in the flow to settle and deposit on the riverbed. The proposed partial removal of the existing weir would remove the physical barrier that currently prevents sediment deposited on the riverbed from moving downstream. Following the partial removal of the existing weir it is likely that some of the sediment deposited behind the existing weir would remobilise and be transported downstream. This would be most likely to occur during high flow events.

The mobilisation of sediment for behind the existing weir would create a risk of poor water quality, particularly within the new town pool located immediately downstream of the existing weir. Remobilised sediment could also be transported downstream of the new weir, although this risk is diminished by the physical barrier created by the new weir.

There is potential for remobilised sediment from behind the existing weir to contain contaminants, however, this risk is considered to be small.

6.3 Cumulative impacts

The operation of the proposed Wilcannia Weir has the potential to be influenced / interact with the Western Weirs Program. The Western Weirs Program is a study by Water Infrastructure NSW to investigate a whole-of-river system approach to the management of the Barwon-Darling and Lower Darling systems and their river infrastructure.

Water Infrastructure NSW has developed a strategic business case for the program. The program seeks to improve water security for towns in the Far West Region, including Aboriginal communities supplied by those towns, by evaluating infrastructure options to improve water security for towns and improve river flows along the

Barwon-Darling and Lower Darling rivers (Baaka). The strategic business case also assesses alternative non-weir options that could have similar benefits for improving town water security.

A key driver of the study is to improve system flows, so any future improvements to the volume or quality of inflows to Wilcannia that are identified would be beneficial.

The strategic business case for the Western Weirs Program is being considered by Infrastructure NSW. Infrastructure NSW will determine if the program receives further funding to proceed to a more detailed analysis in a final business case.

Implementation of the Western Weirs Program may include all or some of the following:

- Construction of either new or upgraded weirs at towns incorporating gates and fishways
- Possible removal or lowering of some weirs that do not supply water for towns
- Alternative options to weirs to improve town water security.

Within Water Infrastructure NSW, the Wilcannia Weir Replacement project team has consulted regularly with the Western Weirs Program team to ensure that it is informed of the proposal's construction and operation, so that there is overarching consistency between the proposal and the various hydraulic modelling studies being undertaken for the Western Weirs Program.

6.4 Risk assessment

For identified impacts described in **Section 6.2**, a risk assessment has been carried out to consider the consequence and likelihood of impacts in accordance with criteria specified in Section 3.6. The risk assessment has considered the risk of operational impacts:

1. without the implementation of environmental management and mitigation measures (risk)
2. with the implementation of proposed operational management (residual risk).

With implementation of the dual mode operational regime, use of adaptive management techniques and instream management measures, the risk of impacts to the Darling River (Baaka) aquatic environment and aquatic species varies depending on location.

In the upstream portion of the project (above the normal FSL), potential impacts would be variable depending on the level of inundation of the weir pool, and therefore the amount of river channel that would be converted from a flowing to non-flowing environment. The risk in this reach has been determined to be medium during drought mode due to temporary disruption to habitat for species of local and regional significance. However it is expected that there would not be a permanent loss of flowing habitat or of aquatic biota that require flowing habitat, from this reach. The proposed dual mode operation reduces the risk from severe to medium in this reach.

The permanent inundation of the new town pool is rated a high risk as it results in a permanent change from "*flowing*" to "*no to low flow*" habitat and represents a loss of Type 1 Key Fish Habitat. The length of reach impacted represents an about eight per cent additional pool length to the existing Wilcannia Weir pool and about five per cent of the existing flowing habitat downstream of the Wilcannia Weir pool to Menindee. While this is a relatively small proportion of the flowing habitat in the total reach it still represents a loss of flowing habitat. However, the loss of this habitat is unlikely to result in impacts to threatened species or ecological communities at the landscape scale. The inclusion of a fishway at the new weir, will significantly increase connectivity between the new town pool upstream of the new weir wall and the river downstream of the weir wall compared to its current state where two completely disconnected upstream and downstream habitats exist for the majority of the time. While the new fishway cannot count as an offset against the loss of Type 1 habitat it represents a benefit over current conditions.

Downstream of the new weir, modelling indicates the potential for the new weir operation to result in an increase in the number of short-duration cease to flow events during the weir fill stages and progressive gate closure at the start of drought security operation mode. This has the potential to impact biota sensitive to cease to flow, especially benthic species such as River Mussels, Darling River Snail and other benthic macroinvertebrates located on shallow riffles, banks and bars, and represents a potential medium risk – adaptive operations would be required during filling phases to avoid false filling phases and reduce unnecessary short duration cease-to-flow spells. Base flows and fresh flows are largely unaffected by the proposed operations. Furthermore, the proposed operations, and in particular the translucency operations enables small unregulated flows and Protected Environmental Water to be passed downstream of the new weir during drought mode. This would help to mitigate long duration cease to flow events that currently occur and reduce the risks to aquatic biota associated with those long duration events.

Table 6-8 Risk assessment of identified impacts – Operation

Activity	Potential threat of new weir without operational management (fixed crest weir)	Consequence	Likelihood	Risk	Operational management measures (dual operation mode)	Consequence	Likelihood	Risk
Upstream								
18.81 river kilometres of intermittent inundation upstream of the existing weir pool	▪ Conversion of flowing habitat to permanent non-flowing habitat ▪ Loss of habitat suitable for species that require flowing habitat (e.g. some native fish, River Mussels) ▪ Creation of conditions that favour Common Carp.	**Major** ▪ A fixed crest weir would result in permanent inundation upstream of the existing weir pool, meaning flow regime of the upstream area would be permanently changed during operation ▪ Habitat suitability for native species which prefer flowing habitat would be permanently reduced representing a loss of around 10% of the available flowing habitat between the existing Wilcannia Weir and the next upstream weir at Tilpa ▪ River mussels and Darling River Snails would not be able to survive permanently inundated as they require flow for oxygen and food supply, representing a loss of local populations. ▪ Loss of habitat suitable for native fish spawning, may meaning spawning may be interrupted in some years. During flowing conditions the extended weir pool could represent a sink for downstream drifting eggs and larvae due to its longer length compared to current.	**Almost certain** ▪ The permanent extension of the weir pool up to the drought FSL would result in the permanent conversion of flowing habitat to non-flowing weir pool habitat and represent a loss of 18.81 km of Type 1 Key Fish Habitat.	**Severe**	▪ Variable pool level operation ▪ Inundation only occurs during drought security operation mode and results in conversion of dry and non-flowing refuge pools to a larger area of non-flowing inundation ▪ Restoration of as close as possible to existing pool level during normal operation mode, results in maintenance of existing upstream flowing habitat ▪ During flowing periods flowing habitat would be retained at key habitat locations (bars and the reach between the existing FSL and the new drought mode FSL ▪ Proposed operation minimises the reduction in flowing habitat during normal operation mode compared to fixed crest structure that would result in permanent inundation and loss of flowing habitat.	**Minor** ▪ A shift in the hydraulic conditions of the upstream extent would be intermittent and would only occur during drought conditions, when the new weir is operating in drought security operation mode. From the drought FSL, the storage would be incrementally drawn down. During normal operating mode the new weir would operate close to the same FSL as the existing weir. Analysis shows during, meaning the flow regime of the upstream area would remain unchanged ▪ At the end of a drought phase when inflows recommence, any residual area that is inundated above the normal FSL would be drawn down and channel that was either *dry* or *wet but not flowing* would revert to flowing channel habitat consistent with what occurs under current conditions. This means that the habitat change associated with drought security operation mode is relatively minor in that channel that would currently be dry or contracted to isolated non-flowing refuge pools would instead be inundated for a longer period, but still non-flowing ▪ It is expected that the proportion of time this section of the river remains *wet but not flowing* would be comparable to the length of time that the channel would have otherwise been *dry* (i.e. there is no substantial shift in conditions from flowing to non-flowing, the shift is from *dry* to *wet but not flowing*). River Mussels are present in this reach, however they suffered high mortality during recent long duration cease to flows where they were located on channel bed and bars that dried out (Mallen-Cooper and Zampatti 2020). Survivability is likely to be enhanced where refuge pools persist through the cease to flow phase, despite such pools not being preferred long term habitat (Sheldon et al., 2002). Ongoing long duration cease to flows mean existing populations in the Darling (Baarka) River are increasingly vulnerable. The extension of the weir pool during periods of cease to flow may help to increase River Mussel survivability in this reach provided high quality flowing habitat can be maintained during the times when the river is flowing. The proposed dual mode operation will create a larger refuge pool during drought periods and retain flowing habitat during	**Likely** ▪ Under drought security operation mode, up to 18.81 kilometres of river upstream of the normal FSL would be temporarily inundated. The extension of the weir pool up to the drought FSL would result in the conversion of dry river channel and non-flowing refuge pools to a larger single weir pool. The lower the elevation level from the drought FSL, the greater the total number of wet days and fewer dry days at each decreasing elevation such that at the equivalent of the normal FSL there would be very few dry days in the future – the pool would nearly always be inundated at or above this level.	**Medium** ▪ Temporary change in habitat characteristics but flowing habitat retained for the majority of time when river is flowing ▪ Possible impact on species of local or regional conservation significance at the site scale during drought mode, although dual operation mode may assist in survivability during long duration cease to flows. ▪ No consequence for these species at the regional scale.

Activity	Potential threat of new weir without operational management (fixed crest weir)	Consequence	Likelihood	Risk	Operational management measures (dual operation mode)	Consequence	Likelihood	Risk
						normal operations. Hence the proposed operation may assist in the survival of River Snails.		
4.92 kilometres of permanent inundation area (new town pool)	▪ Conversion of Type 1 Key Fish "*flowing*" habitat to "*no to low flow*" habitat ▪ Loss of habitat suitable for species that require flowing habitat (e.g. some native fish, River Mussels) ▪ Creation of conditions that favour Common Carp ▪ Reduced opportunities for native fish spawning and juvenile recruitment due to impediment of egg and larval drift ▪ Increased water depth, potentially leading to stratification and subsequent water quality issues.	**Major** ▪ The 4.92-kilometre reach of river proposed to be inundated supports about 5% of the flowing habitat in the reach from Wilcannia to Menindee. ▪ Conversion from flowing to non-flowing habitat in this reach would result in loss of flowing habitat and would impact on local populations of flow dependant species present in the reach (e.g. River Mussels). ▪ A fixed crest weir would result in a permanent reduction in connectivity for species which require flowing habitat for spawning in the weir pool up to the drought FSL ▪ Reduced water quality may degrade aquatic habitat conditions within the weir pool.	**Almost certain** ▪ The new weir would permanently inundate about 4.92 kilometres of existing river between the new and existing weirs (the 'new town pool')	**Severe**	▪ Proposed operation minimises the reduction in flowing habitat during normal operation mode compared to a fixed crest structure that would result in permanent inundation and loss of flowing habitat in the new weir pool and upstream up to the drought FSL ▪ Gate operation has the potential to help manage poor water quality should it occur ▪ The proposed fishway would assist fish to reach upstream and downstream flowing habitat ▪ If needed, it would be possible to implement carp management practices within the weir pool to reduce the numbers of pest species.	**Moderate** The about 4.92-kilometre reach of river provides flowing habitat with variable hydraulic complexity (pools, shallow runs and bars). It provide habitat for River Mussels and may be used by native fish during certain flow conditions and for some life history needs. However: ▪ Existing habitat is not considered critical to the survival of threatened species. However, conversion from "*flowing*" habitat to "*no to low flow*" habitat represents an impact on local habitat and loss of local populations of flow dependant species if they occur within the effected reach but not more broadly (e.g. River Mussels). ▪ Connectivity would be reduced during drought security operation mode, but not during periods when movement is required for spawning. Movement opportunities across a longer length of river would be facilitated by the proposed fishway compared to current conditions ▪ Permanent inundation may enhance conditions for invasive species (carp), however additional non-flowing habitat is small relative to non-flowing habitat already present in the existing pool (about 7.5% increase in non-flowing habitat), so the additional impact would be minor ▪ Only minor impacts on water quality relative to existing conditions, which can still experience algal blooms and poor quality from time to time, especially during drought conditions. ▪ Analysis indicates that stratification would take longer to develop in a larger weir pool, hence potentially reducing the number of events where biota would be subject to potential low dissolved oxygen conditions. Gate operation has the potential to help manage poor water quality should it occur – this is not possible under current conditions.	**Almost certain** ▪ The new weir would permanently inundate about 4.92 kilometres of the river channel between the new and existing weirs (the 'new town pool'), and when it is in drought security operation mode, the FSL within the weir pool would be one metre higher than that of the existing weir pool.	**High** ▪ Possible impact on species of local or regional conservation significance at the site scale but with no consequence for these species at the regional scale
Downstream								
Additional cease-to-flow conditions	▪ Increased likelihood of isolation of refuge pools / fragmentation of the river channel ▪ Reduced habitat diversity and availability ▪ Reduced opportunities for native fish migration,	**Moderate** ▪ A fixed crest weir would result in an increase in number of CtFs ▪ No ability to pass unregulated flows or Protected Environmental Water during drought mode – drawndown weir would need to fill first before	**Almost certain** ▪ CtF spells downstream would increase during weir filling phase.	**High**	▪ Dual mode operation ensures additional CtFs are short duration (<20 days) ▪ Progressive gate closure to minimise rapid drop in downstream water level – transition to cease-to-flow is matched to natural flow rate decline	**Minor** ▪ The new weir would be operated in either drought security operation mode or normal operation mode. CtF conditions would not increase from the current regime under normal operation mode. Implementation of the proposed translucency rule during drought security operation mode would pass small inflows and reduce long duration CtF spells	**Almost certain** ▪ Number of short duration CtF spells would increase – although real-time adaptive decision making would avoid false filling and hence limit the actual number of additional small duration CtF spells.	**Medium**

Activity	Potential threat of new weir without operational management (fixed crest weir)	Consequence	Likelihood	Risk	Operational management measures (dual operation mode)	Consequence	Likelihood	Risk
	spawning and juvenile recruitment ▪ Increased likelihood of fish mortality ▪ Increased likelihood of stratification in large refuge pools ▪ Increased likelihood of poor water quality, leading to variable dissolved oxygen levels, algal blooms or high salinity ▪ Reduced capacity for dispersal of freshwater mussel larvae ▪ Increased likelihood of mortality in large river mussels due to hypoxic (low oxygen) stress ▪ Sudden CtF may result in fish becoming stranded on exposed bars between refuge pools.	unregulated flows could pass downstream. ▪ No ability to control rate of flow decline - a sudden drop in flow may result in the stranding of biota downstream of the weir.			▪ Translucency rules enables small unregulated flows and protected environmental flows (baseflows and freshes) to pass downstream, minimising likelihood of extended CtF ▪ Adaptive decision making on transition to drought security operation mode, taking into account upstream river flows and climate forecasts to avoid false filling would reduce the number of CtF days further (compared to that modelled in the assessment)	▪ Modelling suggests that additional CtF conditions would be short duration (<20 days), and followed by resumed flow conditions. ▪ Long duration CtF patterns, which are more ecologically disturbing, would be unchanged compared to current conditions ▪ Modelled CtF conditions indicate that the majority of these events would occur during the late autumn and winter period, outside of critical spawning periods for threatened species and hence would not alter opportunities for movement compared to current conditions.		
Additional very-low-flow conditions	▪ Reduced habitat diversity and availability, consisting of refuge pools only ▪ Reduced opportunities for native fish migration, spawning and juvenile recruitment ▪ Increased likelihood of stratification in large refuge pools, potentially leading to poor water quality with variable dissolved oxygen levels, algal blooms or high salinity ▪ Reduced capacity for dispersal of freshwater mussel larvae ▪ Increased likelihood of mortality in large river mussels due to hypoxic (low oxygen) stress.	**Moderate** ▪ A fixed crest weir would result in a decrease in the duration and occurrence of very-low-flow events compared with existing. ▪ No ability to pass unregulated flows or Protected Environmental Water during drought mode – drawndown weir would need to fill first before unregulated flows could pass downstream. ▪	**Almost Certain** ▪ Disruption to very-low-flows would occur during weir filling phase.	**High**	▪ Proposed operation in dual mode minimises the increase in very-low-flows and reduction of large flows as conditions would be similar to existing during normal operation mode compared to fixed crest structure that would have resulted in permanent changes to that of drought security operation mode ▪ As with cease-to-flow events, adaptive decision making, taking into account climate and catchment conditions, is likely to reduce the number of false filling phases and hence reduce the potential for flows that are currently >30 ML/day to fall below 30 ML/day ▪ Translucency rules enables small baseflows and freshes to pass downstream, minimising likelihood of extended very-low-flows.	**Insignificant** ▪ The new weir would be operated in either drought security operation mode or normal operation mode. Very-low-flow conditions would not increase from current regime under normal operation mode ▪ Modelling of the dual mode operational regime suggests there would be no change in the percentage of years that very-low-flows would occur for more than 165 days and would only be a slight decrease in the mean duration of very-low-flows and a reduction in the percentage of years with flows lasting longer that 340 days ▪ The short duration small flow events would assist to provide fish passage and a system flush which would otherwise not have occurred under the current operating scenario ▪ Potential impacts would only pose a risk during drought periods when the drought security operation mode is in operation, and with long-term very-low-flow spells truncated into smaller events, it is expected that aquatic ecosystems within refuge pools would be sustained at a suitable quality.	**Almost certain** ▪ There would a be slight decrease in the mean number of days per years that very-low-flows would occur ▪ There is no change in the percentage of years that very-low-flows would occur for more than 165 days, but a slight decrease in the percentage of years that very-low-flows would occur for more than 340 days.	**Low**

Activity	Potential threat of new weir without operational management (fixed crest weir)	Consequence	Likelihood	Risk	Operational management measures (dual operation mode)	Consequence	Likelihood	Risk
Reduction in base flows 1 & 2	▪ Reduced opportunities for native fish migration, spawning and juvenile recruitment during critical migration periods ▪ Reduced capacity for dispersal of freshwater mussel larvae ▪ Reduced ability to maintain water quality, leading to more frequent algal blooms ▪ Reduced ability to prevent stratification in refuge pools, leading to more frequent hypoxic conditions.	**Moderate** ▪ A fixed crest weir would result in a decrease in the duration and occurrence of base flow events compared with existing. Posing a higher risk for potential impact to occur. ▪ No ability to pass unregulated flows or Protected Environmental Water during drought mode – drawdown weir would need to fill first before unregulated flows could pass downstream.	**Almost Certain** ▪ Disruption of base flows would occur during the weir filling phase.	**High**	▪ Proposed operation in dual mode minimises the reduction in base flows as conditions would be similar to existing during normal operation mode compared to fixed crest structure that would have resulted in permanent changes to that of drought security operation mode ▪ The proposed fishway would assist fish to reach upstream and downstream refuge habitat ▪ Translucency rules enables small baseflows and freshes to pass downstream during drought security operation mode.	**Insignificant** ▪ Proposal would be operated in either drought security operation mode or normal operation mode. Base flow conditions would not increase from current regime under normal operation mode ▪ Modelling of the dual mode operational regime suggests there would be a slight decrease in the percentage of years that meet the base flow 1 criteria but an increase in the percentage of years that meet the base flow 2 criteria. The shift occurs where flows might be around the flow threshold and fall slightly above or below the flow threshold as a result of operations. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system ▪ Notably, there is no reduction in the number of days or percentage of years that meet native fish movement requirements associated with base flow 2.	**Almost certain** ▪ Disruption of base flows would occur during the weir filling phase.	**Low**
Reduction in Small Fresh Flows 1 & 2	▪ Reduced opportunities for native fish spawning and juvenile recruitment during critical migration periods ▪ Reduce ability to regulate water temperature, potentially leading to the disruption of spawning cues for some native species ▪ Reduced capacity for dispersal of freshwater mussel larvae ▪ Reduced ability to maintain water quality, leading to more frequent algal blooms ▪ Reduced ability to prevent stratification in refuge pools, leading to more frequent hypoxic conditions.	**Minor** ▪ A fixed crest weir would result in a slight decrease in small fresh flow 1 & 2 spells compared with existing. Posing a higher risk for potential impact to occur.	**Unlikely** ▪ Disruption of small fresh flows 1 & 2 may occur during weir filling phase.	**Low**	▪ Proposed operation in dual mode minimises the reduction in base flows as conditions would be similar to existing during normal operation mode compared to fixed crest structure that would have resulted in permanent changes to that of drought security operation mode ▪ The proposed fishway would assist fish to reach upstream and downstream flowing habitat.	**Insignificant** ▪ The new weir would be operated in either drought security operation mode or normal operation mode. Small fresh flow 1 & 2 conditions would not decrease from current regime under normal operation mode ▪ Modelling of the dual mode operational regime suggests that small fresh flow 1 & 2 spells would remain mostly unchanged from existing.	**Unlikely** ▪ Disruption of small fresh flows 1 and 2 is not expected to occur under the dual mode operating regime.	**Very low**

Activity	Potential threat of new weir without operational management (fixed crest weir)	Consequence	Likelihood	Risk	Operational management measures (dual operation mode)	Consequence	Likelihood	Risk
Fish passage	▪ Reduced ability for species migration.	**Insignificant** ▪ The existing weir does not have a fishway structure therefore aquatic communities upstream and downstream of the weir wall are largely separate for the majority of the time ▪ A fishway would significantly improve fish passage compared with existing.	**Rare** ▪ The proposal is not expected to result in disruption of fish passage more than existing.	**Very low**	▪ The proposed fishway would significantly improve fish passage.	**Insignificant** ▪ The proposal includes a fishway which would increase the mean annual duration of fish passage at Wilcannia from 54 days under current conditions to 255 days under future conditions ▪ Increased fish passage would provide species with improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which would in turn boost biodiversity, long-term population resilience and contribute to food webs.	**Rare** ▪ The new weir is not expected to result in disruption of fish passage.	**Very low**

7. Impact assessment – sensitive receivers

7.1 Key threatening processes

Schedule 6 of the FM Act outlines the key threatening processes related to aquatic species and ecological communities.

The proposal is expected to involve the key threatening processes outlined in **Table 7-1**.

Table 7-1 Key threatening processes related to the proposal

Key threatening process	Proposal impact
Installation and operation of instream structure and other mechanisms that alter natural flow regimes of rivers and streams	**Construction** The construction of the proposal would require instream works for the installation of the new weir and partial removal of the existing weir. The temporary instream structures required for the construction works include cofferdams and silt curtains. Without appropriate management measures, the instream structures could result in barriers to fish passage and alteration of natural flow regime. Barriers to fish passage may lead to decreased trophic interactions, obstruction of species migration, disruption of spawning processes and potentially mortality of free-flowing eggs. Alteration of flow regime may result in behavioural barriers to fish passage where conditions elicit an avoidance response that detects or slows fish movement, for instance, faster than usual flow velocities during a high flow event which may deter species from moving upstream or downstream. Increased flow regime may additionally result in geomorphic changes to a waterway due to increased bank erosion and scour. Erosion may result in downstream sedimentation which can clog fish gills or limit growth of aquatic flora due to blocking sunlight. Mobilised sediments may also contain elevated concentrations of nutrients which can cause algal blooms and subsequently result in the creation of anoxic environments where aquatic life cannot survive. Barriers to fish passage are considered unlikely at the new weir construction site because the floating silt curtains would only be located around instream activities (outside the cofferdams) and cofferdams have been designed to only span about half the width of the waterway at any one time so that no damming or weir effect is created that would obstruct the waterway completely. More specifically, a cofferdam will be built from the eastern bank to about half the width of the waterway during the first stage of works when the new fishway is being constructed. During the second stage when the fishway is operational, silt curtains would be placed outside the upstream and downstream cofferdams but not across the newly constructed fishway. As such, about half of the channel would be unobstructed at all times and fish would be able to move upstream and downstream. In addition, the use of instream structures would be temporary and would be installed/removed from the waterway as each construction stage is completed. Therefore any barriers to fish passage due to use of temporary instream structures would be short term. At the existing weir location, a cofferdam would be built around part of the existing weir to create a dry work site to enable partial removal of the weir wall. River flows would be diverted to the right side of the weir, where there is an existing breach of the weir wall. A floating silt curtain would be placed around the outside of the cofferdam. The instream work site at the existing weir is not considered to be a risk to fish passage because the existing weir already completely obstructs fish passage. Therefore there would be no change in existing conditions until the proposed partial removal of the existing weir structure is complete. At completion, fish passage would be improved as the new

Key threatening process	Proposal impact
	fishway at the new weir site would allow fish passage and the existing weir would no longer block fish passage. Potential increases in flow velocity when temporary instream structures are in place is limited to any high flow events which may occur during the construction phase. These events are expected to be infrequent and temporary if they occur, therefore any potential impacts are expected to be minor, temporary and unlikely to impact any native aquatic species in the long term. Overall, the construction of the proposal would have a minor impact on aquatic species with the implementation of the mitigation and management measures proposed in **Table 10-1**. **Operation** *Upstream* - The new weir would result in a new permanent inundation area (new town pool) which would span a further 4.92 kilometres of river downstream of the existing Wilcannia Weir. There would be a permanent change from "*flowing*" habitat to "*no to low flow*" water habitat in the new town pool. Inundation of this area would result in impacts to species that require flowing habitat but would not impact species more broadly at the landscape scale. In addition, the weir pool would be up to one metre higher than the existing weir pool when the new weir is in drought security operation mode. This would temporarily inundate about 18.81 kilometres of the river channel upstream of the existing weir pool, converting dry river channel and non-flowing refuge pools into a larger single inundated pool, which would be gradually drawn down. The increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods which could benefit some native species but may also benefit pest species (such as Carp). Further, conversion to non-flowing habitat is not suitable for River Mussels which rely on flows to feed and require a stable supply of oxygen to survive. While there is potential for these impacts to occur, the relative effect compared to current conditions is likely to be small because even under current conditions there is a large length of inundated river reach that provides similar habitat for native and non-native fish. Additionally, it is expected that the hydraulic conditions at the most upstream extent of inundation (in the top one to two kilometres of the study reach) would remain largely unchanged (either dry/isolated pools during drought security operation mode, or flowing during normal operation mode) which is the portion of upstream habitat that has been recognised as the more important flowing habitat in the reach because of the presence of bedrock riffles, the presence of River Mussels (observed during site inspections) and historical evidence of colonisation by Darling River Snails. It is also important to note that the upstream areas would only be subject to change from its current state during drought conditions, when the proposal is operating in drought security operation mode (expected to represent about 30 per cent of the time). For the remaining 70 per cent of the time, the new weir would operate at close to the normal FSL, meaning the hydrological regime of the upstream area would remain similar to current. The periodic inundation of about 18.81 river kilometres of flowing habitat upstream of the existing weir extent represents about 10 per cent of the current flowing habitat between the Wilcannia Weir pool and the next upstream weir at Tilpa. The new town weir pool (4.92 river kilometres) represents about five per cent of the current flowing habitat between the existing Wilcannia Weir and Menindee. A change in flow within these areas is not expected to significantly impact the overall function of the aquatic ecosystem at a landscape scale.

Key threatening process	Proposal impact
	Downstream – The proposal under drought security operation mode would result in an increase in cease-to-flow events downstream of the weir, however these additional CtF spells are mostly short duration (less than 20 days). Very-low-flows and base flows are expected to decrease slightly as flow would be obstructed when the new weir is in the filling phase. Overall however, any change does not result in a substantial change in the distribution of very-low-flows and base flows to the extent that certain flow components are lost from the system. Implementation of the proposed translucency rule would result in the new weir passing small unregulated inflows during drought security operation mode, resulting in some long-period very-low-flows being punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during these extended periods. The short duration of flow disruptions are not expected to have a major impact on fish migration and the gate closure system will be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. Furthermore, adaptive operations would take into consideration flow forecast to avoid false filling and further reduce the number of unnecessary short duration cease to flow events.
Degradation of native riparian vegetation along New South Wales water courses	The construction of the proposal is anticipated to require removal of about 0.35 hectares of riparian vegetation at the new weir site and a small amount of riparian vegetation at the existing weir site to allow for construction plant and equipment to access the site. This could result in indirect impacts on the aquatic ecosystem as it can affect water quality and result in sedimentation of the waterway if construction runoff mobilises exposed soils downstream. Sedimentation may cause increased turbidity which can clog fish gills or limit growth of aquatic flora due to blocking sunlight. Mobilised sediments may contain elevated concentrations of nutrients which can cause algal blooms and subsequently result in the creation of areas with little to no oxygen where aquatic life cannot survive. Sediments may also contain tannins which can reduce water quality and result in fish kills. Sediments may settle into refuge pools that are used by species during times of low flow. Removal of riparian vegetation can result in destabilisation of the riverbanks and subsequent erosion. Sedimentation and bank erosion can also result in changes to stream geomorphology which may impact flow velocities or changes to aquatic habitat features downstream. Clearance of riparian vegetation would be avoided as much as practicable and following completion of construction at a site, riparian vegetation would be re-established in areas not used during operation. Furthermore, riparian vegetation clearing on the slopes of the banks at the new weir site would be undertaken within the enclosed dry site areas therefore loose sediment would be captured prior to mobilisation. Any other vegetation clearing that is required would be set back from the riverbank (in the contractor's temporary works areas) and sediment fences would be erected around sites prior to clearance. The proposed partial removal of the existing weir will be undertaken during low flow conditions and floating silt fences will be installed 40 metres upstream and downstream from the demolition site, therefore mobilisation of poor water quality from this site is considered unlikely. Mitigation measures are further detailed in **Section 10**.

Key threatening process	Proposal impact
Removal of large woody debris from NSW rivers and streams.	Removal of instream aquatic vegetation and habitat features including large woody debris, rocks and instream aquatic vegetation, have the potential to impact aquatic species that depend on these habitat features for food supply, shelter and spawning. Removal of habitat features has the potential to result in habitat loss, reduced reproductivity or direct mortality. Any instream habitat features such as large woody debris that are situated within the instream dry site areas would be removed as required, as a final step following fauna salvage and dewatering. Habitat features would be relocated upstream or downstream in consultation with an appropriately qualified ecologist. Further, it is anticipated that aquatic habitat features would then be reinstated, to the extent possible, once construction is completed. Reinstatement of aquatic habitat features such as woody debris would occur in consultation with WaterNSW to ensure that they do not pose a risk to the operation of the new weir. The existing weir would remain mostly intact and some features of this structure such as the fish traps on the downstream embankment would provide new instream habitat.

7.2 Threatened species and ecological communities

As discussed in **Sections 5** and **6**, aquatic species, populations and ecological communities including those that are listed as threatened under the FM Act and EPBC Act (refer to **Table 4-1**) have potential to be directly or indirectly impacted by the proposal because of the following activities:

- riparian vegetation removal
- instream construction works
- accidental spills and pollution
- erosion and sedimentation due to construction activities.
- removal or degradation of aquatic habitat features (large woody debris, aquatic vegetation and rocks)
- permanent instream structures altering flow regime.

Significance tests in accordance with the Commonwealth and state legislation have been carried out for all threatened species, populations and endangered ecological communities listed in **Table 4-1**. **Table 7-2** provides a summary of the key considerations and the outcome of the significance tests. The Murray Cod, which is a nationally listed species, was assessed against the significant impact criteria for species listed as vulnerable under the EPBC Act (DoE, 2013). All other species have been assessed against the '7-part test' of significance in accordance with the FM Act. The Silver Perch is listed as critically endangered under the EPBC Act and vulnerable under the FM Act so has been assessed against both tests of significance. **Appendix B** presents the significance tests in further detail.

Table 7-2 Summary of significance impact assessment for threatened aquatic species

Scientific name	Common name	FM Act	EPBC Act	Key considerations	Determination of significance
Lowland Darling River Aquatic Ecological Community	Darling River EEC	EEC	-	▪ The proposal during construction would require disturbance of the streambed and removal of habitat features such as instream vegetation and large woody debris. These risks would be mitigated through standard erosion and sediment controls and habitat features will be re-instated upstream and downstream of the proposal footprint. ▪ The new weir would result in a new permanent inundation area (new town pool) which would span a further 4.92 kilometres of river downstream of the existing Wilcannia Weir. There would be a permanent change from highly variable flowing habitat to mostly no-low flow habitat in the new town pool. Inundation of this area would result in only minor impacts to species that require flowing habitat but would not impact species more broadly. The inundation may even assist to improve aquatic habitat in the area as it would provide additional refuge habitat and result in submerging aquatic features such as exposed roots, large woody debris and overhanging branches. ▪ The weir pool would be up to one metre higher than the existing weir pool when the new weir is in drought security operation mode, which is predicted to occur about 30 per cent of the time. This would temporarily inundate about 18.81 river kilometres to the drought FSL, converting dry river channel and non-flowing refuge pools into a larger single inundated pool in the upstream extent of the new weir pool, which would be gradually drawn down. The increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods which could benefit some native species but may also benefit pest species (such as Carp). The proposed operation avoids the permanent conversion of flowing to non-flowing habitat, so flow dependent species, such as River Mussel, should persist within the reach. ▪ While there is potential for these impacts to occur, the relative effect compared to current conditions is likely to be small because even under current conditions there is large lengths of inundated river reach that provides similar habitat for native and non-native fish. Additionally, it is expected that the hydraulic conditions at the most upstream extent of inundation (in the top one to two kilometres of the study reach) would remain largely unchanged (either dry/isolated pools during drought security operation mode, or flowing during normal operation mode) which is the portion of upstream habitat that has been recognised as the more important flowing habitat in the reach because of the presence of bedrock riffles, the presence of River Mussels (observed during site inspections) and historical evidence of colonisation by Darling River Snails.	Proposal is not likely to significantly impact on Darling River EEC.

Scientific name	Common name	FM Act	EPBC Act	Key considerations	Determination of significance
				▪ It is also important to note that the upstream areas would only be subject to change from its current state during drought conditions, when the new weir is in drought security operation mode (expected to represent about 30 per cent of the time). For the remaining 70 per cent of the time, the weir would operate at the normal FSL, meaning the hydrological regime of the upstream area would remain unchanged by the proposal in operation. Moreover, the periodic inundation of about 18.81 river kilometres of flowing habitat upstream of the existing weir extent and about 4.92 river kilometres of flowing habitat in the new town pool is considered to be a minor portion of the flowing habitat that is available within the entire Barwon-Darling River (Baaka), therefore a change in flow within these areas is not expected to significantly impact the overall function of the aquatic ecosystem as a whole. ▪ When the new weir is in drought security operation mode there would be an increase in downstream cease-to-flow events, however these additional cease-to-flow spells are mostly short duration (less than 20 days), therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also predicted to increase, however implementation of the proposed translucency rule would result in the new weir passing small inflows during drought security operation mode, resulting in some long-period very-low-flows being punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during these extended periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in weir filling phase. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system. The short duration of flow disruption is not expected to have a major impact on fish migration and the gate closure system will be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat.	
Ambassis agassizii	Western population of the Olive Perchlet	EP	-	▪ The proposal during construction would require disturbance of the streambed and removal of habitat features such as instream vegetation and large woody debris. These risks would be mitigated through standard erosion and sediment controls and habitat features will be re-instated upstream and downstream of the proposal footprint. ▪ The new weir under the drought security operation mode would result in a permanent change from flowing habitat to no-low flow habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. For Olive Perchlet, permanent or temporary inundation areas are not expected to impact on the survival of individuals. In fact, the new inundation areas could assist to submerge new structural features such as large woody debris, exposed roots and over hanging vegetation which Olive Perchlet	Proposal is not likely to significantly impact on Olive Perchlet.

Scientific name	Common name	FM Act	EPBC Act	Key considerations	Determination of significance
				utilise for habitat and spawning. In addition, the new fishway will provide them with improved ability to complete migration, as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. ▪ Changes to flow downstream of the new weir structure are not expected to impact on the survival of Oliver Perchlet populations downstream of the proposal.	
Bidyanus bidyanus	Silver Perch	V	CE	▪ The proposal during construction would require disturbance of the streambed and removal of habitat features such as instream vegetation and large woody debris. These risks would be mitigated through standard erosion and sediment controls and habitat features will be re-instated upstream and downstream of the proposal footprint. ▪ The new weir under the drought security operation mode would result in a permanent change from flowing habitat to no-low flow habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. For Silver Perch, permanent or temporary inundation areas are not expected to impact on the survival of adult individuals directly, however loss of flowing habitat and an increase in no-low flow conditions may impact breeding success as this species requires flowing habitat for egg and larvae dispersal. This does not present a major change from current conditions however because the current weir pool already experiences no-low flow, therefore larvae dispersal in this region would be limited. On the contrary however, the new fishway will provide individuals with improved ability to complete migration, spawning and larvae dispersal (when flow is generated during normal operation when environmental flows are released), as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. ▪ Changes to flow downstream of the new weir structure are not expected to impact on the survival of Silver Perch populations downstream of the proposal.	Proposal is not likely to significantly impact on Silver Perch.

Scientific name	Common name	FM Act	EPBC Act	Key considerations	Determination of significance
Macculochella peelii	Murray Cod	-	V	▪ The proposal during construction would require disturbance of the streambed and removal of habitat features such as instream vegetation and large woody debris. These risks would be mitigated through standard erosion and sediment controls and habitat features will be re-instated upstream and downstream of the proposal footprint. ▪ The new weir under the drought security operation mode would result in a permanent change from flowing habitat to no-low flow habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. For Murray Cod, permanent and temporary inundation areas are not expected to impact on the survival of individuals. There is, however, potential for no-low flow habitat to result in reduced recruitment success. The impact on recruitment success is expected to be minor as the study area is subject to similar conditions currently within the existing weir pool. On the contrary, however, the new inundation areas could assist to submerge new structural features such as large woody debris, exposed roots and over hanging vegetation which Murray Cod utilise for laying eggs. In addition, the new fishway will provide them with improved ability to complete migration for spawning, as well as reduce population fragmentation. ▪ Changes to flow downstream of the new weir structure are not expected to impact on the survival of Murray Cod populations downstream of the proposal.	Proposal is not likely to significantly impact on Murray Cod
Notopala sublineata	Darling River Snail	-	CE	▪ The proposal during construction would require disturbance of the streambed and removal of habitat features such as instream vegetation and large woody debris. These risks would be mitigated through standard erosion and sediment controls and habitat features will be re-instated upstream and downstream of the proposal footprint. ▪ The new weir under the drought security operation mode would result in a permanent change from flowing habitat to no-low flow habitat in the new town pool and an intermittent change from flowing habitat to non-flowing habitat in the upstream extent of the new weir pool. A change from a flowing river environment to an inundated environment would no longer be suitable habitat for the Darling River Snail as they are known to prefer flowing channel environments (Ponder, et al, 2020). However there is no evidence of the presence of living populations of Darling River Snail in the reach. The only suitable habitat for them is at the very upstream end of the reach, which would continue to experience a similar regime to current and would not result in the conversion of flowing habitat to non-flowing at time when flow is occurring (i.e. during normal operation mode). Importantly, during drought security operation mode, this upstream habitat would be drawn down first meaning the habitat would remain largely	Proposal is not likely to significantly impact on Darling River Snail

Scientific name	Common name	FM Act	EPBC Act	Key considerations	Determination of significance
				unchanged from current conditions during drought therefore no significant change to current Darling River Snail habitat is anticipated. ▪ While it is possible for the Darling River Snail to currently occupy the areas of new permanent and intermittent inundation, it is expected that these areas are not important or critical habitat for the species as they have not been detected in the area and the only known remnant populations are located in irrigation pipelines in southern NSW. As such, it is considered unlikely that inundation of the new town pool and upstream extent of the weir pool at the drought FSL (in drought security operation mode) would remove important habitat, or fragment/isolate Darling River Snail populations in the area. ▪ Changes to flow downstream of the new weir structure are not expected to impact on the survival of Darling River Snail populations downstream of the proposal.	

8. Fishway design review

A preliminary concept design has been prepared for a fishway to enable the upstream and downstream passage of native fish (and turtles) past the new weir. Overshot type regulator gates and a plunge pool are proposed to enable safe downstream fish and larvae passage. The fishway design was developed by Public Works Advisory, on behalf of Water Infrastructure NSW. Public Works Advisory and Water Infrastructure NSW engaged with Fisheries NSW during the development of the fishway design.

A 'Functionality and Basis of Design' report (November 2021) was prepared by Public Works Advisory to support the fishway preliminary concept design and is provided in **Appendix C**. Water Infrastructure NSW provided a draft of this report to Fisheries NSW and their comments were considered in the final report. Comment on the preliminary concept design is provided here. It should be noted that the review comments in this section do not represent a comprehensive technical review or approval, which should be undertaken by others as the fishway design progresses in final design.

The fishway design proposes the upstream passage of native fish between 50 mm and 1.3 m body length (large Murray Cod). The maximum design differential head at Wilcannia Weir is in the order of 3.01 metres when the headwater level is raised to the drought FSL of RL 66.71 (i.e. normal FSL of RL 65.71 + 1 m) and 60 ML/day is passed through the fishway. The variable 1 m headwater level (RL 65.71 to RL 66.71) appears to add a level of complexity for the design of gravity type fishway channel. The fishway is required to pass fish up to the weir drown-out tailwater level, which is estimated at about RL 67.99, some 1.28 m above the drought FSL.

Options for the provision of fish passage have been assessed by NSW Public Works Advisory in accordance with the preferred fish passage options from the WaterNSW Strategic Fishway Implementation Program (SFIP) – Options to Design Fishways Project, including three short-listed fishway options of (i) cast *in situ* concrete vertical slot fishway, (ii) precast concrete channel fishway with sheet pile outer wall, and (iii) precast concrete / rock fishway with sheet pile outer wall. Benefits and risks are described for each option in the report.

A 'hybrid' rock ramp type fishway arrangement has been proposed. Twenty-eight rows of slotted precast concrete baffles are nominated with a baffle / slot head loss of 110 mm. The fishway pool sizes are considered very large at 10.4 m wide x 4 m long. The channel appears to be widened to 10.4 m to provide suitable flow conditions associated with the 1 m variation in FSL (RL 65.71 to RL 66.71), which creates a very wide fishway channel. The fishway features a driven sheet pile outer wall.

A key requirement for the proposed fishway option is to pass the first 10 per cent of passing flows through the fishway to optimise fish attraction to the entrance, in accordance with the SFIP recommendations, hence the size of the fishway. The 10 per cent flow requirement is balanced in the SFIP study by the preference to provide construction cost savings wherever possible through the use of prefabricated concrete items, instead of cast *in situ* concrete, with an associated reduction in on-site construction time and labour costs. It is noted that the large size of the fishway channel appears to have presented challenges to the designer for fitting in the riverbed and bank, with the potential for construction cost savings potentially reduced. Construction costs have not been sighted.

The fishway preliminary design as presented is considered suitable to meet the biological objectives for the upstream (and downstream) passage of the target native fish species and sizes, and turtles. The fishway design includes small ramps at the base slots of the fishway to enable turtles to move through the fishway during periods of low / no flow, moving past the weir and finding refuge during droughts, which is a benefit.

Moving forward to final design, it is suggested that early in the design process, a cost-benefit analysis be undertaken for the proposed hybrid type rock ramp fishway design arrangement, to confirm that construction cost savings will be achieved for the proposed arrangement, whilst still passing the first 10 per cent of flows for attraction. If cost savings are not achieved, potentially / alternatively in final design, consideration could be given to a smaller (narrower) fishway channel with less flow capacity, but with the first 10 per cent of flow provided through the downstream fishway entrance, perhaps via an additional and separate ancillary regulator gate. This could potentially provide a greatly reduced fishway construction footprint and less construction cost whilst still providing the 10 per cent fishway attraction criteria.

The fishway entrance needs to be located at the ‘limit of upstream fish migration’ for the anticipated range of flow conditions associated with the operation of the weir, from fishway minimum operating flows (about 60 ML/day) up to weir drown-out conditions, so that fish moving upstream can readily find and enter the fishway. This requirement will be tested through during the design process with computational fluid dynamics modelling and scaled physical modelling.

In the final design, it is suggested that the impacts on the 1 m variable headwater level on the fishway design is further investigated and understood, particularly on the requirement for additional fishway channel width and / or the requirement for additional fishway upstream exit gates, as and if required.

In the final design, integration of the fishway channel and adjacent regulator gates should be further investigated, particularly with regards to providing safe operator access to the regulator gates past / over the fishway channel, perhaps via a bridge section.

It is understood that computational fluid dynamics modelling has already been undertaken to understand the fishway performance at the high flow level range. Physical model testing of the fishway will take place in July 2022, with further computational fluid dynamics modelling undertaken post that. The target is to have all physical and computational fluid dynamics modelling completed prior to detailed design. Water Infrastructure NSW will refine the fishway design during the detailed design phase of the proposal based on modelling outcomes, having regard to the need to secure the town’s water supply, optimise downstream flows and optimise fish passage. Any changes between the concept design presented in **Appendix C** and the final design would be developed in consultation with Fisheries NSW and subject to their acceptance.

9. Aquatic biodiversity offset strategy

As per the SEARs, the proposal requires an aquatic biodiversity offset strategy that is consistent with relevant policy and guidelines and is adequately funded to mitigate and manage impacts of the Wilcannia Weir replacement during construction and subsequent operation. The key guidelines are the *NSW Biodiversity Offsets Policy for Major Projects* (State of NSW and Office of Environment and Heritage, 2014) (FBA) which provide a standard method for determining offsets for areas where there is a predicted loss of biodiversity, including aquatic biodiversity. While the FBA broadly outlines the approach, the guidelines refer to the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013a) as the primary document that details the process to be followed with respect to aquatic biodiversity offsets. The FBA states that:

"to meet aquatic biodiversity offset requirements, the NSW policy and guidelines (DPI, 2013) will classify the habitat types being offset. It will then apply a ratio and dollar value to determine the total dollar value of the offset required to be implemented by the proponent via on-ground protection or rehabilitation works, or placed into the aquatic biodiversity offset fund. The proponent will have the opportunity to reduce this cost through direct negotiation with Fisheries NSW, subject to meeting the minimum overall offset ratio requirements".

According to the NSW policy and guidelines (DPI, 2013), aquatic biodiversity offsets relate to waterways that have been identified as KFH by NSW KFH Mapping (DPI, 2021a). In the NSW policy and guidelines (DPI, 2013) this is stated as *"NSW DPI will focus the application of the FM Act, FM Regulations and the NSW Policy and Guidelines for Fish Habitat Conservation and Management on KFH (as defined in the guidelines)"*. The NSW policy and guidelines (DPI, 2013) further clarify that *"NSW DPI enforces a 'no net loss' of KFH habitat policy as a permit condition or condition of consent. This may require proponents to conduct habitat rehabilitation and/or provide environmental compensation. A monetary bond or payment may be required to be lodged with NSW DPI to ensure the works are completed in accordance with the permit conditions"*. The guidelines also indicate that mitigation and compensation "*may include re-establishing habitat that has been removed or otherwise damaged, re-instating fish passage along waterways (removing barriers or building fishways) and improving water quality*".

The general principal which should be applied to the offset strategy is:

"…proponents should, as a first priority, aim to avoid impacts upon key fish habitats. Where avoidance is impossible or impractical, proponents should then aim to minimise impacts. Any remaining impacts should then be offset with compensatory works".

Section 3.3.3.2 of the NSW policy and guidelines (DPI, 2013) provides guidance for calculating monetary offsets, where it is stated that *"NSW DPI calculates habitat compensation on a minimum 2:1 basis for all key fish habitat (TYPE 1-3) to help redress other indirect impacts of development.*

The calculation of aquatic biodiversity offsets is based on a current (June 2022) rate of $56,75 per square metre for marine and freshwater vegetation which equates to $113.50 per square metre to meet the 2:1 habitat offset requirement.

As the proposal is located on the Darling River (Baaka), it is classified as 'Type 1- Highly Sensitive Key Fish Habitat' and therefore requires an aquatic habitat offset strategy including monetary offsets to be proposed in accordance with the N*SW policy and guidelines* (DPI, 2013). The following sections outlines the aquatic biodiversity offset strategy that Water Infrastructure NSW is currently negotiating with Fisheries NSW, taking into consideration the proposal design and operational regime.

9.1 Changes to KFH

9.1.1 Temporary instream footprint

The works associated with the construction of the proposed new weir and partial removal of the existing weir may result in temporary loss of KFH due to direct disturbance of streambeds, clearance of vegetation and removal of woody debris on the streambed and on the banks, as well as partial obstruction of fish passage due to temporary instream structures (cofferdams and silt curtains).

To minimise potential loss of KFH during construction, the construction methodology proposes the following standard practices:

- To minimise downstream impacts to water quality from sedimentation, erosion and sediment controls will be established prior to any works being conducted in proximity or within the Darling River (Baaka).
- Floating silt curtains would be placed upstream and downstream of instream activities. In particular:
  - At the new weir construction site, the floating silt curtains would be located around instream activities and cofferdams have been designed to only span about half the width of the waterway at any one time so that no damming or weir effect is created that would obstruct the waterway completely. This is because construction will be carried out in two stages; the first stage will be construction of the fishway and the second stage will be construction of the weir wall once the fishway becomes operational.
  - A cofferdam and silt curtain area also proposed around a temporary in-stream work site at the existing weir, however, this is not considered to be a risk at this location as the existing weir structure already completely obstructs fish passage and the silt curtains will only obstruct the top portion of the water column. Therefore there would be no change in existing conditions until the proposed partial removal of the existing weir structure is complete. At completion, fish passage would be improved as the new fishway at the new weir site would allow fish passage.
- Prior to construction of instream structures, habitat features that are within the instream construction area which are able to be relocated (i.e. large woody debris) would be moved from the proposal site to areas upstream or downstream, in consultation with a qualified ecologist. It is proposed that habitat features would only be moved from instream dry sites following fauna salvage and dewatering of the area. Aquatic vegetation, woody debris and riparian vegetation would subsequently be reinstated in the construction footprint area after construction. Further, it is anticipated that by partially removing the existing weir and restoring this section of the riverbed, aquatic habitat at this location will be improved from current conditions.

Provided these standard practices are maintained throughout the construction phase, temporary loss of KFH is not expected to result in any long-term degradation of KFH. Accordingly, an aquatic biodiversity offset is not proposed for temporary loss of KFH.

9.1.2 Permanent instream footprint

The preliminary concept design for the new weir has been developed with the aim of minimising direct loss of instream habitat as far as practicable, however due to the instream structural component of the design and provision of a 120-metre-long fishway, the proposal would result in a permanent loss of aquatic habitat within the footprint of the new weir, comprising the area shown in **Figure 9-1**, which includes the weir crest and embankment, and fishway.

The permanent instream footprint, which comprises the weir crest and fishway, has been determined to occupy a total area of 2,967 square metres. However, as stated in Section 1.6 of the DPI (2013a) policy and guidelines, "*…mitigation and compensation for key fish habitat loss may include re-instating fish passage along waterways (including building fishways)*" therefore it is considered reasonable to exclude the 1,866 square metre area that encompasses the fishway structure from the calculation.

This loss of KFH due to the footprint of the new weir has been considered in the negotiation of an appropriate aquatic biodiversity offset for the proposal.

Figure 9-1 Permanent instream footprint

9.1.3 Hydrological changes upstream of the existing weir pool

As discussed in **Section 6.2.1**, the proposal would not significantly reduce flowing water habitat conditions upstream of Bar 3 and especially upstream of the existing weir pool, which currently provide good quality aquatic habitat. While there would be a small decrease in high quality flowing water habitat conditions at high flow rates, these habitat conditions would still exist at many locations in this reach of the river.

Additionally, as discussed in **Section 6.2.1.1**, when the new weir is in drought security operation mode the proportion of time the about 18.81 river kilometre temporary extension of the weir pool would be wet but not flowing would be comparable to the length of time that the channel would have otherwise been dry (i.e. there is no substantial shift in conditions from flowing to non-flowing, the shift is from dry to wet but not flowing). This would preserve in-stream habitat including keeping structural features such as exposed roots and large woody debris submerged. It would also enable River Mussels to survive submerged within the expanded weir pool for a period of time equivalent to the existing duration of dry conditions.

The minor impact on flowing water habitat conditions upstream of the existing weir pool together with the benefits to aquatic biodiversity in this reach during droughts are being considered in the negotiation of an appropriate biodiversity offset for the proposal.

9.1.4 Hydrological changes in the new town pool

The new weir structure has been proposed to be constructed about 4.92 kilometres downstream of the existing weir structure, therefore during operation, this would result in permanent inundation of this portion of river reach between the new and existing weirs (the 'new town pool'). The inundation of this reach of the river would result in it changing from 'Type 1- Highly Sensitive Key Fish Habitat' to 'Type 2 – Moderately sensitive key fish habitat'.

These hydrological changes would result in alteration of aquatic habitat in this reach of the river, notably from a "*flowing*" habitat to "*no to low flow*" environment, however aquatic habitat is not considered to be 'lost' as it is expected that these sections of river will remain available for all aquatic species during these times.

As described in **Section 6.2.2**, the 4.92 river kilometre reach of the Darling River (Baaka) proposed to be permanently inundated (new town pool) under current conditions comprises about two kilometres of dry river bed and about three kilometres of shallow isolated pools during non-flow periods. During "*flowing*" conditions the reach would experience a range of hydraulic conditions from slow flowing pools to faster flowing sections over sandbars. At the time of inspection, this section of the river was observed to be in a degraded state, even following significant rainfall and recent flows, as shown in **Figure 9-2** and **Figure 9-3** and in more detail in **Appendix A**.

Figure 9-2 Aquatic environments in the new town pool at site A2

Figure 9-3 Aquatic environments in the new town pool at site A4

The river channel included some large woody habitat on the lower banks (some of which were partly submerged in the low flow channel and refuge pools) and sandbars which were sparsely vegetated with a range of exotic and native grasses and non-woody vegetation. While the native Freshwater Fish Community Status in this section of the Darling River (Baaka) has been classified as fair (DPI, 2015), the habitat conditions observed were overall poor and it is unlikely that the reach represents critical spawning or refuge habitat for threatened species.

Considering the above, it is expected that even though the conversion of this reach from "*flowing*" to "*no to low flow*" would result in a shift in habitat condition, it would not mean a total loss of habitat and is not likely to impact on the availability of critical habitat for threatened species or the ecosystem as a whole. Further to this and similarly to the upstream temporary inundation area, inundating the new town pool may present some benefits to native benthic and turtle species as it would result in increased availability of refuge habitat during dry conditions, as well as submerge structural features such as exposed roots, large woody debris and overhanging branches utilised by aquatic species.

It is important to note that with the partial removal of the existing weir, habitat connectivity between the new town pool and the river upstream of the existing weir would be improved significantly compared to its current state where two completely disconnected upstream and downstream habitats exist for the majority of the time. The improvement in the connectivity of the habitat in the new town pool as a result of the removal of the barrier to fish passage created by the existing weir would offset some of the impact cause to this reach of the river by its inundation.

In recognition of the impact of the proposal on aquatic ecology in the new town pool, Water Infrastructure NSW has selected a design for the new weir that includes weir and fishway gates that provide much greater operational flexibility than a fixed crest weir and thereby provide an offset for the weir's impacts. The operational flexibility provided by the weir and fishway gates includes allowing for planned environmental water to flow downstream and enabling the inclusion of a translucency rule in the proposed operating rules for the new weir. As discussed in **Section 6.1.6**, the translucency rule would be implemented when the new weir is in drought security operation mode and would enable inflows to Pool 1 to be passed downstream to benefit downstream aquatic habitats. The translucency rule is included in the operations plan for the new weir that is being prepared in consultation with DPE Water, Fisheries NSW, DPE Environment and Heritage, MDBA and WaterNSW. A draft operations plan is provided in Appendix I of the EIS. The translucency rule and other opportunities created by the inclusion of the weir and fishway gates will continue to be developed with the stakeholder agencies.

The weir and fishway gates also enable the dual operation modes discussed in **Section 6.1.1,** which allow the new weir to increase its storage capacity temporarily when there are drought indicators, thereby providing Wilcannia with water security while also limiting the additional upstream inundation required to provide this water security to times when there would be minimal flows in the river.

All the factors discussed above are being considered in the negotiation of are being considered in the negotiation of an appropriate biodiversity offset for the new town pool.

9.2 Offset calculation and rehabilitation strategy

Water Infrastructure NSW is discussing the factors discussed in the preceding sections and other considerations in its negotiations with Fisheries NSW to develop an appropriate aquatic biodiversity strategy for the proposal. These negotiations will include the opportunity to use some of the agreed aquatic habitat offset to fund the installation of a fish screen over the town water supply intake owned by Central Darling Shire Council. Installation of a fish screen would prevent fish from swimming or being drawn into the intake.

10. Management and mitigation measures

Impacts to aquatic ecology due to construction activities are largely related to construction machinery from instream works, mobilisation of poor-quality runoff and erosion/sedimentation. The contractor will prepare a construction environmental management plan (CEMP) that describes how activities undertaken during the construction phase of the proposal will be managed to avoid or mitigate environmental impacts, and how those environmental management requirements will be implemented.

A biodiversity management plan would be prepared as a sub-plan to the CEMP and will identify aquatic habitats that need to be protected and include a procedure for salvaging any aquatic fauna species that are at risk from dewatering, the establishment of instream construction work sites or other aspects of the works.

Erosion and sediment control measures such as sediment fences and temporary drainage would be installed in construction areas to prevent the mobilisation of runoff and sediment into the Darling River (Baaka) during rainfall events. Specific erosion and sediment controls would be identified and developed for the new and existing weir sites, which would be detailed in a construction soil and water management plan (CSWMP) as part of the CEMP.

Where impacts cannot be avoided, measures to minimise or manage impacts to aquatic ecology should be implemented. Recommendations for environmental safeguards and mitigation measures are detailed in **Table 10-1**.

Table 10-1 Summary of aquatic ecology management and mitigation measures

Ref.	Aspect	Impact issue	Environmental safeguards	Timing
SW2	Impact of construction activities and mobilising sediment	Increased sedimentation impacts within the Darling River (Baaka) at the new and existing weir sites	Erosion and sediment control measures will be implemented at all works sites in accordance with the principles and requirements in Managing Urban Stormwater – Soils and Construction Volume 1 (Landcom 2004) and Volume 2D (NSW Department of Environment, Climate Change and Water 2008), commonly referred to as the “Blue Book”. Additionally, any water collected from work sites will be treated before being discharged to avoid contaminants from entering the Darling River (Baaka). Erosion and sediment control measures will be identified in the construction soil and water management plan and will likely consist of cofferdams, diversion drains, sediment fencing, coir logs, catch drains, perimeter bunds, silt curtains and sediment basins. Progressive site-specific erosion and sediment control plans will be	▪ Detailed design ▪ Construction

Ref.	Aspect	Impact issue	Environmental safeguards	Timing
			prepared for work sites. These plans will include: ▪ Detailed consideration of staging and management in accordance with the Blue Book ▪ Identification of site conditions for construction activities that could potentially result in erosion and associated sediment runoff ▪ Identification of stockpile and storage locations and provide erosion and sediment controls around these ▪ Methods to minimise potential adverse impacts of construction activities on the water quality within surrounding waterways and floodplains ▪ Proposed types and locations of control measures such as sediment fencing, silt curtains and covering stockpiles ▪ Progressive stabilisation and revegetation of exposed areas following disturbance as soon as is practicable. A suitably qualified erosion and sediment control specialist will be engaged where deemed appropriate to provide advice regarding erosion and sediment control including review of erosion and sediment control plans.	
SW3	Instream works	Downstream flows potentially causing pollution and sedimentation impacts during instream construction works within the Darling River (Baaka) at the new and existing weir sites	To minimise stress on aquatic environments and protect water quality in the Darling River (Baaka) the following measures will be implemented: ▪ Implementing practices to minimise disturbance of banks (such as creating no access zones, minimising vegetation removal and installing rock gabions) ▪ Undertaking bank stability practices as soon as possible	▪ Pre-construction ▪ Construction

Ref.	Aspect	Impact issue	Environmental safeguards	Timing
			after installing instream structures ▪ Maintain minimum flows to assist in maintaining the viability of aquatic communities and preventing barriers to fish passage. Undertake construction and demolition during low or no flow in the watercourse to minimise sediment loads downstream.	
SW4	Dewatering	Changes to water quality	A dewatering management plan will be prepared as a sub-plan of the construction soil and water management plan and it will outline: ▪ The method for dewatering the cofferdams as well as discharges from sediment basins/water quality ponds ▪ Opportunities for using captured water on site, such as for dust suppression ▪ The method for monitoring discharge from temporary construction sediment basins and actions required for treatment or disposal if water quality does not meet Darling River (Baaka) water quality targets ▪ Supervision requirements ▪ Staff responsibilities and training ▪ Discharge to surface water will be carried out in accordance with the POEO Act or the requirements of any environment protection licence issued under the POEO Act for the proposal.	▪ Pre-construction ▪ Construction
SW5	Spills and leakages	Contamination of the Darling River (Baaka) from chemicals or hydrocarbon spills	The construction soil and water management plan will outline site-specific control measures and required procedures to ensure containment of accidental spills and reduce the risk of the release of potentially harmful chemicals	▪ Pre-construction ▪ Construction

Ref.	Aspect	Impact issue	Environmental safeguards	Timing
			from spills entering the Darling River (Baaka). This will include: ▪ All fuels, chemicals and liquids will be stored on level ground at least 50 metres away from waterways (including existing stormwater drainage system, if present) and will be stored in a sealed bunded area within ancillary facilities ▪ An emergency spill kit will be provided at all ancillary facilities and construction work areas at all times. An emergency spill response procedure will be prepared to minimise the impact of accidental spillages of fuels, chemicals and fluids during construction. Regular visual water quality checks (for hydrocarbon spills/slicks, turbid plumes and other water quality issues) will be carried out when working near the Darling River (Baaka).	
SW8	Concrete work	Accidental release of concrete waste	To avoid ingress of concrete waste material into the Darling River (Baaka), the construction environmental management plan will outline procedures to capture, contain and appropriately dispose of any concrete waste. These procedures and the level of management required will be informed by concrete analysis which will be carried out before construction.	▪ Detailed design ▪ Construction
AB1	Interaction with fauna during construction	Fauna salvage	Aquatic fauna salvage will be conducted by a qualified ecologist. A pre-construction survey will be undertaken in areas that would be enclosed by silt curtains and during dewatering of cofferdams. Procedures for undertaking aquatic fauna salvage will be detailed in the biodiversity management sub-plan in the CEMP.	▪ Construction

Ref.	Aspect	Impact issue	Environmental safeguards	Timing
AB2	Riparian and instream vegetation rehabilitation	Removal of riparian and instream vegetation in the construction footprint	Rehabilitation of disturbed areas of riparian and instream vegetation will be undertaken as soon as practical, progressively and in accordance with the rehabilitation strategy. Rehabilitation at both the new and existing weir sites will involve replacing topsoil and re-planting native trees and plants.	▪ Construction
AB3	Fish entrainment in town water supply extraction pumps	Small fish, larvae and eggs could be entrained in the water supply pumps	Consider the installation of fish screens on pump inlets as part of the aquatic biodiversity offset for the proposal.	▪ Detailed design
AB4	River Mussels in the new town pool	The new town pool would create unsuitable habitat for River Mussels	In consultation with Fisheries NSW, investigate practicality and feasibility of translocation of River Mussels from the new town pool prior to its inundation.	▪ Pre-operation
AB5	Ongoing maintenance of the fishway	Sediment build-up in the fishway structure causing a barrier to fish passage	Inspections and maintenance of the fishway will be carried out on a regular basis to ensure that fish passage is not obstructed.	▪ Operation
AB6	Ongoing monitoring of the fishway and waterway in proximity of new weir	Use of fishway during operation and surrounding habitat	Ongoing monitoring of the fishway and the surrounding aquatic habitat will be carried out following completion of construction and for the first two years during operation to document impacts/benefits on the aquatic ecosystem due to the new weir structure.	▪ Operation
HY2	Cease-to-flow spells	Triggers for the filling phase	In consultation with WaterNSW, investigate opportunities to refine the triggers for the filling phases with the aim of reducing the frequency of filling while ensuring that water security is maintained. The investigations should consider: ▪ Flows in tributaries downstream of Bourke Town Weir, including inflows from the Warrego River and Paroo River	▪ Pre-operation ▪ Operation

Ref.	Aspect	Impact issue	Environmental safeguards	Timing
			▪ Anticipated flows from upstream of Bourke Weir ▪ Climatic conditions and prevailing weather.	
HY3	Flows downstream of the new weir	Optimisation of the translucency rule	The initial downstream flows resulting from the implementation of the translucency rule will be monitored to identify opportunities to optimise these flows. Based on the findings of this monitoring, the operations plan may be revised if opportunities are identified to increase downstream flows by modifying how the translucency rule is implemented and/or its effectiveness. Any proposed revisions to the implementation of the translucency rule will be discussed with key stakeholders prior to the operations plan being updated.	▪ Operation

11. Conclusion

The Darling River (Baaka) at Wilcannia is 'Type 1 – Highly Sensitive Key Fish Habitat' (Department of Planning, Industry and Environment, 2021) and it supports a diverse assemblage of native and introduced aquatic species, with three native species that are listed as threatened under both the EPBC Act and FM Act predicted to occur. The proposed new weir would include a fishway that would increase fish passage at Wilcannia from a mean of 54 days per year at the existing weir to 255 days per year at the new weir, with the number of days fish passage is available during the spawning season (October to April) increasing significantly. Increased fish passage would provide species, including threatened species, with an improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which would in turn boost biodiversity, long-term population resilience and contribute to food webs.

The proposed new weir would be located about 4.92 river kilometres downstream of the existing weir and would include weir gates and fishway gates that would enable its operation to be managed to optimise water security for Wilcannia as well as reduce environmental impacts to the river. The new weir would be operated in either a normal or drought security operation mode, with normal and drought FSLs at existingand one metre above the existing FSL respectively. During normal operation mode dynamic storage rules would apply and during drought security operation mode translucency rules would apply. The impacts of the design of the new weir and these operating rules on aquatic ecology include:

- Transformation of about 4.92 kilometres of the river channel between the new and existing weirs from "*flowing*" to "*no to low flow*" habitat. It is important to note, however, that with the inclusion of the fishway and provision of environmental flows during normal operation mode, the new permanent inundation area would not become still-water habitat for the majority of the time. Nevertheless, a reduction in flows in the area has the potential to impact the abundance and diversity of species that are reliant on flowing conditions as it can disrupt life-cycles of species and degrade habitat conditions (Sheldon, 2017).
- Moreover, habitat connectivity between the permanent inundation area upstream of the new weir wall and the river downstream of the weir wall would be improved significantly compared to its current state where two completely disconnected upstream and downstream habitats exist for the majority of the time. As such, it is considered that the benefits which improved habitat connectivity will provide outweigh the impacts that a shift in the type of available habitat from highly variable "*flowing*" habitat to permanently "*no to low flow*" habitat could potentially cause.
- Extension of the upstream extent of the existing weir pool by about 18.81 river kilometres, with this section of the river becoming subject to temporary inundation to a depth of up to one metre. Depending on whether there are inflows to the weir pool, this would result in a change from either flowing or dry conditions to still-water conditions for the section of channel that is temporarily inundated. The increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods. This could benefit some native species but may also benefit pest species (such as Carp). However, the relative effect compared to current conditions is likely to be small because even under current condition there is a large length of inundated river reach that provides similar habitat for native and non-native fish.
- Changes to the frequency and duration of discharges from the new weir compared to the existing weir, most notably an increase in the number of short duration CtF spells but an overall reduction in the mean duration of CtF spells. The predicted increase in short duration cease-to-flow events has the potential to result in local scale impacts immediately downstream of the new weir. There is the potential for aquatic fauna to be stranded on channel margins if the new weir stops discharging suddenly when it transitions to drought security operation mode causing downstream water levels to drop rapidly. The downstream extent of any impact to aquatic ecology is likely to be short for the predicted increase in short duration cease-to-flow events given that discharge from the new weir would recommence relatively quickly (within days). Downstream flows would continue as pools drawdown and these pools would refill once discharge from the weir recommences. The short duration of these additional cease-to-flow events at the weir discharge point means that downstream pools are unlikely to draw down to levels that would result in downstream flows ceasing before refilling occurs.

- There would be a reduction in high quality flowing water habitat conditions in the existing weir pool. While flows of 5,000 ML/day currently create high quality flowing water habitat conditions in several locations in the existing weir pool, the proposal would reduce this to a much smaller number of locations. However, a flow rate of 5,000 ML/day would continue to provide a large number of good flowing water habitat conditions. A similar impact would occur at lower flow rates; flows of 1,400 ML/day currently create some good flowing water habitat conditions, but would generate negligible good flowing water habitat conditions under the proposal. The new weir would not significantly reduce flowing water habitat conditions at the upstream end of the existing weir pool and especially upstream of the existing weir pool, which currently provide good quality aquatic habitat. While there would be a small decrease in high quality flowing water habitat conditions at high flow rates, these habitat conditions would still exist at many locations in this reach of the river.
- A permanent loss of 1,101 square metres of key fish habitat where the new weir crest and associated embankments would occupy the river channel. The proposal would also impact key fish habitat in the new town pool. Water Infrastructure NSW is negotiating with Fisheries NSW to develop an appropriate aquatic biodiversity offset strategy for the proposal in accordance with the *NSW Biodiversity Offsets Policy for Major Projects* (State of NSW and Office of Environment and Heritage, 2014).

The storage behaviour modelling of the proposal that this aquatic ecology assessment has relied upon includes a trigger for the transition of the new weir from normal to drought security operation mode based on flows over Bourke Weir falling below 250 megalitres per day. A consequence of this simple trigger is short duration drought security operation mode events that a more sophisticated trigger might avoid. Investigations are recommended to refine the trigger with the aim of reducing these short duration drought security operation mode events, which would in turn reduce the instances of additional short duration cease-to-flow events.

The construction of the proposal would present several risk to aquatic ecology due to instream works, removal of instream habitat features and riparian vegetation, bank excavation and temporary barriers to fish passage. A range of mitigation and management measures would be implemented to reduce these risks.

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Appendix A. Aquatic Habitat Assessment

Appendix A provides a full assessment of aquatic habitat undertaken at survey sites (shown on **Figure 3-1**). The assessment was undertaken to characterise the aquatic environment of the Darling River (Baaka) within the proposal construction and operational footprints.

Since the Darling River (Baaka) within the study area is known to support threatened species listed under the EPBC Act and FM Act, the entire study reach has been classified 'Type 1 – Highly Sensitive KFH' (DPI, 2013). The purpose of the site assessment was to characterise the aquatic habitat features of the waterway and assess against aquatic habitat criteria outlined the *Policy and Guidelines for Fish Habitat Conservation and Management* (2013) and *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (*Fairfull and Witheridge, 2003). **Table A-1** discusses the findings of the aquatic habitat assessment undertaken at survey sites.

Table A-1 Aquatic habitat assessment findings

Site name	Site photographs	Description
A1-A **~480 metres downstream of proposed new weir**	 Assessment site A1-A facing upstream  Assessment site A1-A facing downstream	At the time of inspection, the Darling River (Baaka) at Site A1-A had moderate water level and little to no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour, was highly turbid and there was some scum present on the surface. The site was located on a meander bend of the river, about 5.5 kilometres downstream of the existing Wilcannia Weir. The channel was about 30 metres wide at this location and the riverbanks were moderately steep. The tops of the banks in the riparian zone was densely vegetated and dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally covered in common *Agrostis avenacea* (blown-grass), with some *Cyperus gymnocaulos* (Spiny flatsedge) and some other riparian weed species including *Rumex crystallinus* (Glistening dock), *Conyza bonariensis* (Flaxleaf fleabane), and *Pseudognaphlium luteoalbum* (Jersey cudweed). Immediately upstream and downstream of the site were two large, deep pools which are likely to be utilised by fish for refuge during dry periods. There were also three vegetated bars present instream and connected to the riverbank. The substrate consisted of a fine silt. There was no evidence of active erosion at this site. Physical aquatic habitat features at the site consisted of some riparian vegetation, woody snags greater than three metres located instream and on the riverbanks, some emergent woody vegetation instream, exposed instream bars and overhanging vegetation. The northern bank had evidence of a River Mussel (*Alathyria jacksoni*) bed including some live *in-situ* mussels and mussel shells. A shell of a Darling River Snail (*Notopala sublineata*) was also found on this bank. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during flow events when water levels are higher. The banks and bars are likely to be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A1 **At proposed new weir site**	 Assessment site A1 facing upstream  Assessment site A1 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A1 had moderate water level and little to no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located about 5 kilometres downstream of the existing Wilcannia Weir. The channel was about 30 metres wide at this location and the riverbank was moderate on the western bank and steep on the eastern bank (near vertical on the eastern bank). The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis (*River Red Gum). The bank slopes were generally bare ground with some native grass *Agrostis avenacea* (common blown-grass) and native riparian vegetation C*yperus gymnocaulos* (spiny flatsedge), as well as other riparian weed species including *Xanthium occidentale* (Noogoora burr), *Perscicaria* (Knotweed) and *Conyza bonariensis* (Flaxleaf fleabane). A large pool spanned the entire eastern side of the reach of the river at the site and connected two large pools immediately upstream and downstream of the site. The deep pool is likely to be utilised by fish for refuge during dry periods. There was a small bar connected to the western riverbank which was mostly bare except for some dead emergent woody vegetation. The substrate consisted of a fine silt which appeared to have been trampled. There was evidence of undercutting at the site. Physical aquatic habitat features at the site consisted of some riparian vegetation, some emergent woody vegetation, exposed instream bars, woody snags located instream and, on the riverbanks, and exposed tree roots. River Mussel (*Alathyria jacksoni*) shells were present on the western bank. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during flow events when water levels are higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A2 **~160 metres upstream of proposed new weir**	 Assessment site A2 facing upstream  Assessment site A2 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A2 had moderate water level and little to no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located about 4.8 kilometres downstream of the existing Wilcannia Weir. The channel was about 20 metres wide at this location and the riverbank was moderate on the western bank and steep on the eastern bank (near vertical on the eastern bank). The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally bare ground with some native grass including common *Agrostis avenacea* (blown-grass), native riparian vegetation C*yperus gymnocaulos* (spiny flatsedge), as well as other riparian weed species including *Rumex crystallinus* (Glistening dock) and *Conyza bonariensis* (Flaxleaf fleabane). A large pool was present on the eastern side of the river which connected two large pools immediately upstream, downstream of the site which are likely to be utilised by fish for refuge during dry periods. A small instream bar and another large bar that was connected to the riverbank were present on the western side of the river. Both bars appeared to be mostly bare, apart from some dead woody vegetation present on the edges of the bars. The substrate consisted of a fine silt which appeared to have been trampled. There was evidence of active erosion at the site, including undercutting, exposed tree roots and gully erosion. Physical aquatic habitat features at the site consisted of some riparian vegetation, some emergent woody vegetation instream, exposed instream bars, woody snags greater than 3 metres located instream and on the riverbanks, overhanging vegetation, bank overhang and exposed tree roots. A native aquatic floating plant *Ludwigia peploides* (Floating primrose-willow) was also present. River Mussel shells and a Darling River Snail shell was found on the western bank. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during flow events when water levels are higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A3 **~450 metres upstream of proposed new weir**	 Assessment site A3 facing upstream  Assessment site A3 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A3 had moderate water level and little to no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located approximately 4.5 kilometres downstream of the existing Wilcannia Weir. The channel was approximately 30 metres wide at this location and the riverbanks were moderate on the western bank and steep on the eastern bank. The tops of the banks in the riparian zone were dominated by large *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally bare ground with some native grass *Agrostis avenacea* (common blown-grass), as well as some riparian weed species including *Xanthium occidentale* (Noogoora burr), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). A large pool was present on the eastern side of the river which connected two large pools immediately upstream, downstream of the site. On the western side of the river was a small bar connected to the riverbank. The bar appeared to be mostly bare, apart from some woody snags, dead woody vegetation and *Xanthium occidentale* (Noogoora burr) present. The substrate consisted of a fine silt. There was evidence of undercutting at the site. Physical aquatic habitat features at the site consisted of some riparian vegetation, some emergent woody vegetation instream, exposed instream bars, woody snags greater than 3 metres located instream, on the bars and on the riverbanks, bank over hang and exposed tree roots. A Darling River Snail (*Notopala sublineata*) shell was identified on the bar on the western side of the river. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during flow events when water levels are higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A4 **~1.1 kilometres upstream of proposed new weir**	 Assessment site A4 facing upstream  Assessment site A4 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A4 had low water level and low, shallow flow through some sections of the bar (small riffle between bars). Water appeared to be a green/brown colour and was highly turbid. The site is located approximately 4 kilometres downstream of the existing Wilcannia Weir. The channel was approximately 50 metres wide at this location and the riverbanks were moderately steep on both sides of the river. The tops of the banks in the riparian zone were dominated by large *Eucalyptus camaldulensis* (River Red Gums). On the eastern bank, the slopes were generally bare ground with some native grass *Agrostis avenacea* (common blown-grass) and *Eucalyptus camaldulensis* (River Red Gums) with exposed roots. The western bank was dominated by weed species including *Lactuca cerriola* (Prickly lettuce) and *Conyza bonariensis* (Flaxleaf fleabane). Two large instream bars which were connected to the banks extended about 260 metres and were each approximately 20 metres wide, encompassing most of the river channel except for a 2-metre-wide flowing channel in the centre. The bars were vegetated with C*yperus gymnocaulos* (spiny flatsedge) beds and riparian weeds including *Conyza bonariensis* (Flaxleaf fleabane) and *Xanthium occidentale* (Noogoora burr). There was also dead woody vegetation present on the bars. The substrate consisted of a fine silt. There was evidence of bank erosion where rain had eroded small channels on the bare bank slope on the southern side. Physical aquatic habitat features at the site consisted of some riparian vegetation, some emergent woody vegetation instream, exposed instream bars, woody snags greater than 3 metres located instream, on the bars and on the riverbanks, and exposed tree roots. A River Mussel (*Alathyria jacksoni*) shell was identified on the bar on the southern side of the river. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during flow events when water levels are higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A5-A **~1.75 kilometres upstream of proposed new weir**	 Assessment site A5-A facing upstream  Assessment site A5-A facing downstream	At the time of inspection, the Darling River (Baaka) at Site A5-A had moderate water level and little to no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located approximately 3.25 kilometres downstream of the existing Wilcannia Weir. The channel was approximately 30 metres wide at this location and both riverbanks were steep. The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally bare ground with some native grass *Agrostis avenacea* (common blown-grass), as well as some riparian weed species including *Xanthium occidentale* (Noogoora burr), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). Two large pools were present at the upstream and downstream extent which are likely to be utilised by fish as refuge pools during dry periods. A small bar was connected to the eastern riverbank and appeared to have no vegetation growing. Another small bar was located on the western bank and has some native (C*yperus gymnocaulos*) and weed (*Xanthium occidentale*) growing. The substrate consisted of a fine silt. There was evidence of past bank failure and gully erosion on the western bank. Physical aquatic habitat features at the site consisted of some large overhanging riparian vegetation, a large fallen tree that was located instream, and exposed tree roots. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during flow events. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A5 **~2.45 kilometres upstream of proposed new weir**	 Assessment site A5 facing upstream  Assessment site A5 facing downstream	The Darling River (Baaka) at Site A5 at the time of inspection had low water level and no flow (apart from some wind-blown surface ripples). The water exhibited a green/brown colour and was highly turbid. The site is located approximately 1.75 kilometres downstream of the existing Wilcannia Weir. The river channel at this location was approximately 50 metres wide however there were two large, vegetated bars connected to riverbanks on either side of the channel that span the length of the reach. The channel that had water was about 3 metres wide. Both banks of the river were moderately steep and the tops of the banks were vegetated with large, mature *Eucalyptus camaldulensis* (River Red Gum). The vegetated bars had a mixture of native riparian vegetation (C*yperus gymnocaulos*) and riparian weed species including *Xanthium occidentale* (Noogoora burr), *Conyza bonariensis* (Flaxleaf fleabane), *Pseudognaphlium luteoalbum* (Jersey cudweed) and *Lactuca cerriola* (Prickly lettuce). The bank slopes exhibited some native grasses (*Agrostis avenacea*) and *Pseudognaphlium luteoalbum* (Jersey cudweed). A minor depression was present between the western bank slope and the channel which is likely to become a backwater in times of higher flow. There was also three small mud bars within the channel, the substrate consisted of a fine silt. There was evidence of past bank failure and exposed tree roots on the eastern bank slope. Physical aquatic habitat features at the site consisted of large woody snags that were located instream, and exposed tree roots. A River Mussel (*Alathyria jacksoni*) shell was identified on the bar on the western side of the river. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during high flow events when the water level is higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A6 **~3.45 kilometres upstream of proposed new weir**	 Assessment site A6 facing upstream  Assessment site A6 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A6 had low water level and no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located approximately 1.55 kilometres downstream of the existing Wilcannia Weir. The channel was approximately 40 metres wide at this location and both riverbanks were moderately steep. The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally covered with native grass *Agrostis avenacea* (common blown-grass), as well as some riparian weed species including *Xanthium occidentale* (Noogoora burr), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). A large pool was present at the upstream extent of the reach which is likely to be utilised by fish as a refuge pool during dry periods. A bar that was connected to the eastern riverbank appeared to have some riparian native (C*yperus gymnocaulos*) and weed (*Xanthium occidentale*) species growing. Another bar was connected to the western bank and had some native (C*yperus gymnocaulos*) and weed (*Xanthium occidentale*) species growing. A small instream bar was present at the downstream extent of the site but had no vegetation. There was also some dead woody vegetation instream. The substrate consisted of a fine silt. There was no evidence of active erosion at this site. Physical aquatic habitat features at the site consisted of some large woody debris instream and on the bank slopes, some emergent woody vegetation instream, exposed instream bars and exposed tree roots. A rocky gravel bed was also identified downstream of the site. A River Mussel (*Alathyria jacksoni*) shell was identified downstream on a bar on the western side of the river. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during high flow events when the water level is higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A7 **~4.25 kilometres upstream of proposed new weir**	 Assessment site A7 facing upstream  Assessment site A7 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A7 had low water level and no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/brown colour, was highly turbid and there was lots of litter within the channel and on the banks. The site is located approximately 750 metres downstream of the existing Wilcannia Weir and a large road bridge with instream pylons is approximately 100 metres upstream. The channel was approximately 40 metres wide at this location and both riverbanks were moderately steep. The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally covered with native grass *Agrostis avenacea* (common blown-grass), as well as some riparian weed species including *Xanthium occidentale* (Noogoora burr), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). A dry mud-bar that was connected to the northern riverbank appeared to have some riparian native (C*yperus gymnocaulos*) and weed (*Xanthium occidentale*) species growing. Another large bar was connected to the southern bank also had some native (C*yperus gymnocaulos*) and weed (*Xanthium occidentale*) species growing. The water channel was approximately 3 metres wide and flowed between the two bars. There was also some dead woody vegetation instream. The substrate consisted of a fine silt. There was evidence of past bank failure and undercutting on the western bank. Physical aquatic habitat features at the site consisted of some large woody debris instream and on the bank slopes, some emergent woody vegetation instream, exposed instream bars and exposed tree roots. A rocky gravel bed was also located in the instream reach near the northern bar. Several River Mussel (*Alathyria jacksoni*) shells were identified on the northern bar. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel and a Carp carcass on the northern bank. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during high flow events when the water level is higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A8 **At existing weir site**	 Assessment site A8 facing upstream  Assessment site A8 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A8 had moderate water level and low flow which was being generated by a small amount of water flowing down the northern side of the weir structure due to a breach in the weir wall. Water appeared to be a green/blue colour, appeared mostly clear and there was lots of litter within the channel and on the banks. The site is located immediately downstream of the existing Wilcannia Weir. There was rock armouring at the downstream side of the weir structure and there was an extraction pipe about 50 metres upstream of the weir wall on the northern side. The channel was approximately 40 metres wide at this location and both riverbanks were moderately steep. The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slopes were generally covered with riparian weed species including *Ploypogon monspeliensis* (Annual beard-grass), *Rumex crystallinus* (Glistening dock), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). An instream bar that was connected to southern riverbank had some riparian native (C*yperus gymnocaulos*) and weed (*Xanthium occidentale*) species growing. Another bar was connected to the northern bank and was mostly bare ground with gravel beds but also had some native (C*yperus gymnocaulos*) growing. The channel which had water was about 10 metres wide. There was also some dead woody vegetation instream near the edges of the northern bar. The substrate consisted of a fine silt. There was evidence of past bank failure and undercutting on the western bank. Physical aquatic habitat features at the site consisted of some large woody debris instream and on the bank slopes, some emergent woody vegetation instream, exposed instream bars and exposed tree roots. A rocky gravel bed was also located in the instream reach near the western bar. Several River Mussel (*Alathyria jacksoni*) shells were identified on the western bar. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel and a Carp carcass on the western bank. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat and potential spawning habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet during high flow events when the water level is higher. The banks and bars may be suitable for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A9 **~1.8 kilometres upstream of existing weir**	 Assessment site A9 facing upstream  Assessment site A9 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A9 had high water level (weir pool at FSL) and no flow (except for some small ripples on the surface of the water that were being generated by wind). Water appeared to be a green/blue colour and was mostly clear. The site is located on a meander bend of the river, and approximately 1.8 kilometres upstream of the existing Wilcannia Weir. The Warrawong camping ground and a large farm property were situated on the southern bank of the river. The channel was approximately 60 metres wide at this location and both riverbanks were moderately steep. The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The northern bank slope was generally covered with native grass *Agrostis avenacea* (common blown-grass), *Eucalyptus camaldulensis* (River Red Gum) with exposed roots, and some native riparian vegetation (C*yperus gymnocaulos*). The southern slope was dominated by riparian weed species including *Lactuca cerriola* (Prickly lettuce), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). The site consisted of a large, deep pool (part of the weir pool). The substrate consisted of a fine silt. There was evidence of undercutting, exposed tree roots and gully erosion on the bank slopes. Physical aquatic habitat features at the site consisted of some large woody debris instream and on the bank slopes, some emergent woody vegetation instream, overhanging vegetation, bank over hang and exposed tree roots. A native aquatic floating plant *Ludwigia peploides* (Floating primrose-willow) was also present. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel, as well as three extraction pipes and a pumping shed with a generator on the southern bank. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. Unlikely to be suitable habitat for the Darling River Snail (*Notopala sublineata*) or River Mussel (*Alathyria jacksoni*).

Site name	Site photographs	Description
A10 **~4.6 kilometres upstream of existing weir**	 Assessment site A10 facing upstream  Assessment site A10 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A10 had high water level (weir pool at FSL) and no flow. Water appeared to be a green/brown colour and was highly turbid. Scum and a small amount of green filamentous algae were present on the surface of the water. The site is located on a meander bend of the river, and approximately 4.6 kilometres upstream of the existing Wilcannia Weir. The channel was approximately 35 metres wide at this location. The eastern bank slope was moderately steep and the top of the bank in the riparian zone was dominated by *Eucalyptus camaldulensis* (River Red Gum). The bank slope was mostly covered with native grass *Agrostis avenacea* (common blown-grass) or was bare ground and there were several *Eucalyptus camaldulensis* (River Red Gum) with exposed roots protruding from the slope. The western bank slope at the site was gently sloped (access track to the riverbank) and mostly bare ground or covered with native grass *Agrostis avenacea* (common blown-grass). A large vegetated bar that was connected to the western bank was dominated by C*yperus gymnocaulos* (spiny flatsedge) and there were rocks/gravel at the edge of the bar. Most of the site consisted of a large, deep pool (part of the weir pool). The substrate consisted of a fine silt. There was evidence of undercutting, exposed tree roots and gully erosion on the bank slopes. Physical aquatic habitat features at the site consisted of some large woody debris instream and on the bank slopes, some emergent woody vegetation instream, overhanging vegetation, and exposed tree roots. A native aquatic floating plant *Ludwigia peploides* (Floating primrose-willow) was also present. Other observations at the site included presence of dragonflies and butterflies, small River Mussel (*Alathyria jacksoni*) shells (approximately 2 cm wide), Yabby (*Cherax destructor*) skeleton and Yabby holes. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The western bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A24 **~5.1 kilometres upstream of existing weir**	 Assessment site A24 facing upstream  Assessment site A24 facing upstream	At the time of inspection, the Darling River (Baaka) at Site A24 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. Scum and some green filamentous algae were present on the surface of the water. The site is located approximately 5.1 kilometres upstream of the existing Wilcannia Weir and approximately 40 metres downstream of the confluence with Kallyanka Creek (which is ephemeral and dry most of the time). The channel was approximately 32 metres wide at this location. The northern bank slope was very steep (near vertical) and the southern bank slope was moderately steep. The tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some native grass *Agrostis avenacea* (common blown-grass), riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed) and there were several *Eucalyptus camaldulensis* (River Red Gum) with exposed roots protruding from the slopes. The entire reach of the river at the site consisted of a large, deep pool (part of the weir pool). The substrate consisted of a fine silt. There was evidence of minor undercutting, exposed tree roots, large fallen trees on the banks and instream, and gully erosion on the bank slopes. Physical aquatic habitat features at the site consisted of some large woody debris/fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod, and Olive Perchlet. The site is unlikely to be suitable habitat for the Darling River Snail (*Notopala sublineata*) or River Mussel (*Alathyria jacksoni*).

Site name	Site photographs	Description
A11 **~10.3 kilometres upstream of existing weir**	 Assessment site A11 facing upstream  Assessment site A11 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A11 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a dark green colour and was slightly turbid. A slight oil sheen and patches of green filamentous algae was present on the surface of the water. The site is located on a meander bend and approximately 10.3 kilometres upstream of the existing Wilcannia Weir. A rural residential property was situated about 150 metres to the west on the northern bank of the river. The channel was approximately 80 metres wide at this location. The southern bank slope was moderately steep and the northern bank at the site was gently sloped (forming an access track to the water's edge). The top of the bank on the southern side in the riparian zone was dominated by *Eucalyptus camaldulensis* (River Red Gum). The southern bank slope was mostly bare ground with some native grass *Agrostis avenacea* (common blown-grass), riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed) and there were several *Eucalyptus camaldulensis* (River Red Gum) with exposed roots protruding from the slopes. The northern bank was mostly covered with native grass *Agrostis avenacea* (common blown-grass) and *Eucalyptus camaldulensis* (River Red Gum), however there were also several riparian weed species including *Lactuca cerriola* (Prickly lettuce), *Conyza bonariensis* (Flaxleaf fleabane) and *Pseudognaphlium luteoalbum* (Jersey cudweed). The entire reach of the river at the site consisted of a large, deep pool (part of the weir pool). The substrate consisted of a fine silt. There was evidence of active erosion on the southern bank including minor undercutting, exposed tree roots, large fallen trees on the banks and submerged instream, and gully erosion on the bank slopes. Physical aquatic habitat features at the site consisted of some large woody debris/fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel, as well as an extraction pipe located near the residential property. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The site is unlikely to be suitable habitat for the Darling River Snail (*Notopala sublineata*) or River Mussel (*Alathyria jacksoni*).

Site name	Site photographs	Description
A12 **~26 kilometres upstream of existing weir**	 Assessment site A12 facing upstream  Assessment site A12 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A12 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located on a meander bend and approximately 26 kilometres upstream of the existing Wilcannia Weir. The channel was approximately 35 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The southern bank slope was mostly bare ground with several *Eucalyptus camaldulensis* (River Red Gum) with exposed roots protruding from the slopes. The northern bank slope was mostly covered with native grass *Agrostis avenacea* (common blown-grass) and *Eucalyptus camaldulensis* (River Red Gum), with some C*yperus gymnocaulos* (spiny flatsedge) near the water's edge. A large pool spanned the entire northern side of the reach of the river at the site and there was a large mud-bar connected to the southern bank which was mostly bare except for some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The substrate consisted of a fine silt. There was evidence of active erosion on the bank slopes including exposed tree roots, large fallen trees on the banks and submerged instream, and gully erosion on the southern bank slope. Physical aquatic habitat features at the site consisted of some large woody debris/fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The southern bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

<table>
<tr><th>Site name</th><th>Site photographs</th><th>Description</th></tr>
<tr><td>A13

~30.1 kilometres upstream of existing weir</td><td>
Assessment site A13 facing upstream

Assessment site A13 facing downstream</td><td>At the time of inspection, the Darling River (Baaka) at Site A13 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. Patches of green filamentous algae were present on the surface of the water.

The site is located on a meander bend and approximately 30.1 kilometres upstream of the existing Wilcannia Weir. The channel was approximately 50 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by Eucalyptus camaldulensis (River Red Gum). The western bank slope was mostly bare ground with some native grass Agrostis avenacea (common blown-grass) and some riparian weed species Pseudognaphlium luteoalbum (Jersey cudweed). A large pool spanned the entire western side of the reach of the river at the site (part of the weir pool) and there was a large mud-bar connected to the eastern bank which was mostly bare ground except for some riparian weed species Pseudognaphlium luteoalbum (Jersey cudweed). The substrate consisted of a fine silt. There was evidence of minor undercutting on the western bank slope and gully erosion on the eastern bank slope.

Physical aquatic habitat features at the site consisted of some large woody debris/fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (Cyprinus carpio) swimming in the channel, dragonflies, and Yabby (Cherax destructor) skeleton.

Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The eastern bar may be suitable habitat for the Darling River Snail (Notopala sublineata) and River Mussel (Alathyria jacksoni) during moderate and high flows.</td></tr>
</table>

Site name	Site photographs	Description
A14 **~32 kilometres upstream of existing weir**	 Assessment site A14 facing upstream  Assessment site A14 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A14 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. The site is located on a meander bend and approximately 32 kilometres upstream of the existing Wilcannia Weir. The channel was approximately 45 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The majority of the reach of the river at the site consisted of a large, deep pool (part of the weir pool), except for a small vegetated bar that was connected to the northern bank. The substrate consisted of a fine silt. There was evidence of active erosion including minor undercutting, past bank failure on the southern bank slope, large fallen trees on the banks and submerged instream, and exposed tree roots on the bank slopes. Physical aquatic habitat features at the site consisted of some large woody debris/fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A15 **~38.5 kilometres upstream of existing weir**	 Assessment site A15 facing upstream  Assessment site A15 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A14 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. Small patches of green filamentous algae were present on the surface of the water. The site is located approximately 38.5 kilometres upstream of the existing Wilcannia Weir. The channel was approximately 45 metres wide at this location and there was a disconnected, dry oxbow channel situated on the western side of the river. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The entire reach of the river at the site consisted of a large, deep pool (part of the weir pool), The substrate consisted of a fine silt. There was evidence of active erosion including minor gully erosion on the eastern bank slope where rain has eroded small channels. Physical aquatic habitat features at the site consisted of some large woody debris/fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A25 **~47.5 kilometres upstream of existing weir**	 Assessment site A25 facing upstream  Assessment site A25 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A25 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was highly turbid. Some scum was present on the surface of the water. The site is located at a meander bend and approximately 47.5 kilometres upstream of the existing Wilcannia Weir. The channel was approximately 30 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). A large pool spanned the entire western side of the reach of the river at the site (part of the weir pool) and there was a large mud-bar connected to the eastern bank which was also mostly bare ground with some *Pseudognaphlium luteoalbum* (Jersey cudweed) growing on it. The substrate consisted of a fine silt. There was evidence of active erosion including minor undercutting and past bank failure on the western bank, exposed tree roots, as well as large fallen trees instream and on the banks. Physical aquatic habitat features at the site consisted of some large woody debris and large fallen trees submerged instream and on the bank slopes, overhanging vegetation, and exposed tree roots. A River Mussel (*Alathyria jacksoni*) shell was identified downstream on a bar on the western side of the river. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

<table>
<tr><th>Site name</th><th>Site photographs</th><th>Description</th></tr>
<tr><td>A23

~54.8 kilometres upstream of existing weir</td><td>
Assessment site A23 facing upstream

Assessment site A23 facing downstream</td><td>At the time of inspection, the Darling River (Baaka) at Site A23 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was slightly turbid. Small patches of green filamentous algae were present on the surface of the water.

The site is located about 54.8 kilometres upstream of the existing Wilcannia Weir and about 500 metres downstream of the confluence with Paroo River (although the Paroo River is intermittent and dry most of the time). The channel was approximately 35 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by Eucalyptus camaldulensis (River Red Gum). Both bank slopes were mostly bare ground with some riparian weed species Pseudognaphlium luteoalbum (Jersey cudweed). The majority of the reach of the river at the site consisted of a large, deep pool (part of the weir pool), except for a small bar that was connected to the northern bank. The substrate consisted of a fine silt. There was evidence of active erosion including undercutting, past bank failure and gully erosion produced from rain on the southern bank, as well as exposed tree roots and large fallen trees on both the bank slopes and instream.

Physical aquatic habitat features at the site consisted of some large woody debris and large fallen trees submerged instream, on the bank slopes and on the bar, overhanging vegetation, and exposed tree roots. Other observations at the site included presence of live Common Carp (Cyprinus carpio) swimming in the channel and a Yabby (Cherax destructor) skeleton on the bar.

Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (Notopala sublineata) and River Mussel (Alathyria jacksoni) during moderate and high flows.</td></tr>
</table>

Site name	Site photographs	Description
A16 **~58.6 kilometres upstream of existing weir (and 300 metres downstream of existing weir pool extent)**	 Assessment site A16 facing upstream  Assessment site A16 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A16 had high water level (weir pool at FSL) and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was slightly turbid. The site is located on a meander bend, about 58.6 kilometres upstream of the existing Wilcannia Weir and about 30 metres downstream of the existing weir pool extent. The channel was approximately 35 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The southern side of the river reach consisted of a large, deep pool (part of the weir pool) and the northern side had a large mud-bar that connected to the northern bank. The substrate consisted of a fine silt. There was evidence of undercutting, exposed tree roots and large fallen trees on both the bank slopes and instream. Physical aquatic habitat features at the site consisted of some large woody debris submerged instream, on the bank slopes and on the bar, a large fallen tree on the bar, overhanging vegetation, and exposed tree roots. A live *in-situ* River Mussel (*Alathyria jacksoni*) and mussel shell was found on the northern bar. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel and a Yabby (*Cherax destructor*) skeleton on the bar. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A17 **~1.8 kilometres downstream of existing weir pool extent**	 Assessment site A17 facing upstream  Assessment site A17 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A17 had high water level and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was slightly turbid. Small patches of green filamentous algae were present on the surface of the water. The site is located about 950 metres upstream of the existing weir pool extent. The channel was about 35 metres wide at this location. Both bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The southern side of the river reach consisted of a large, deep pool, and the northern side had a large bar connected to the northern bank. There was also a pooled backwater formation in the centre of the reach. The substrate consisted of a fine silt with some large mud-rock on the bank slope and bars. There was evidence of active erosion including major gully erosion on the northern embankment, as well as exposed tree roots and large fallen trees on both the bank slopes and instream. Physical aquatic habitat features at the site consisted of some large woody debris and large fallen trees submerged instream, on the bank slopes and on the bar, overhanging vegetation, exposed tree roots and gravel beds. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Site name	Site photographs	Description
A18 **~5.8 kilometres upstream of existing weir pool extent**	 Assessment site A18 facing upstream  Assessment site A18 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A18 had high water level and no flow (except for some surface ripples that were being generated by wind). Water appeared to be a green/brown colour and was slightly turbid. Small patches of green filamentous algae and pollen were present on the surface of the water. The site is located on a meander bend, about 8.5 kilometres upstream of the existing weir pool extent. The channel was about 15 metres wide at this location however there was a large pool at the meander bend in the northern extent of the reach, a large dry backwater immediately west of the pool that was about 20 metres wide and a vegetated island with mature *Eucalyptus camaldulensis* (River Red Gum) between the backwater and the channel. The bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). Both bank slopes were mostly bare ground with some native grass *Agrostis avenacea* (common blown-grass), some native riparian species C*yperus gymnocaulos* (spiny flatsedge) and riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The channel on the southern side of the river reach was incised, forming a deep channel with near vertical banks. The eastern corner of the central island exhibited a large, dry mud-rock platform that was adjacent to channel. There was evidence of active erosion including minor undercutting, some gully erosion on the northern embankment, as well as exposed tree roots on the bank slopes. Physical aquatic habitat features at the site consisted of some large woody debris submerged instream, on the bank slopes and on the bar, overhanging vegetation, and exposed tree roots. A River Mussel (*Alathyria jacksoni*) shell was identified on the water's edge at the meander bend on the northern side of the river. More than 20 Darling River Snail (*Notopala sublineata*) shells were identified on the dry backwater area. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern backwater is likely to be suitable habitat for the Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

<table>
<tr><th>Site name</th><th>Site photographs</th><th>Description</th></tr>
<tr><td>A19/20

~1.2 kilometres downstream of proposed weir pool extent</td><td>
Assessment site A19/20 facing upstream

Assessment site A19/20 facing downstream</td><td>At the time of inspection, the Darling River (Baaka) at Site A19/20 had low water level and low, shallow flow. Water appeared to be a mostly clear.

The site is located about 20.3 kilometres upstream of the existing weir pool extent. The water channel was about 10 metres wide at this location however there was a large, dry backwater formation immediately west of the channel that was about 30 metres wide and a vegetated island with mature Eucalyptus camaldulensis (River Red Gum) between the backwater and the channel. The bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by Eucalyptus camaldulensis (River Red Gum). Both bank slopes were mostly bare ground with some native grass Agrostis avenacea (common blown-grass), some native riparian species Cyperus gymnocaulos (spiny flatsedge) and riparian weed species Pseudognaphlium luteoalbum (Jersey cudweed). The backwater formation was at a slightly higher elevation than the river channel and was mostly covered in native grass Agrostis avenacea (common blown-grass) with some riparian weeds Pseudognaphlium luteoalbum (Jersey cudweed) and Rumex crystallinus (Glistening dock). The channel on the southern side of the river reach was shallow and had two large bars connected to both banks. The bars were mostly bare ground and had a fine silt substrate. Evidence of active erosion at the site included a number of large fallen trees on the bank slope and exposed roots.

Physical aquatic habitat features at the site consisted of some large woody debris and large fallen trees submerged instream, on the bank slopes and on the bar, overhanging vegetation, and exposed tree roots. Live in-situ River Mussels (Alathyria jacksoni) and River Mussel shells were present on the northern bank of the channel (north-eastern extent of the large island).

Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern bar may be suitable habitat for the Darling River Snail (Notopala sublineata) and River Mussel (Alathyria jacksoni) during moderate and high flows.</td></tr>
</table>

<table>
<tr><th>Site name</th><th>Site photographs</th><th>Description</th></tr>
<tr><td>A21

~740 metres downstream of proposed weir pool extent</td><td>
Assessment site A21 facing upstream

Assessment site A21 facing downstream</td><td>At the time of inspection, the Darling River (Baaka) at Site A21 had high water level and no flow (except for some surface ripples that were being generated by wind) however there was a small weir structure present at the downstream extent of the reach that was obstructing flow. Water appeared to be a green/brown colour and was slightly turbid. Small patches of green filamentous algae were present on the surface of the water.

The site is located about 20.8 kilometres upstream of the existing weir pool extent. The water channel was about 30 metres wide at this location. The bank slopes were moderately steep and the tops of the banks in the riparian zone were dominated by Eucalyptus camaldulensis (River Red Gum). Both bank slopes were mostly bare ground with some native grass Agrostis avenacea (common blown-grass) and some riparian weed species Pseudognaphlium luteoalbum (Jersey cudweed). A flat, mud-rock platform was connected to the northern bank and was adjacent to the channel on the southern side of the river reach. The channel was incised and formed a deep pool/backwater immediately adjacent to the bar next to the weir. Downstream of the weir structure there was a dry backwater formation that was approximately 30 metres wide and a vegetated island with mature Eucalyptus camaldulensis (River Red Gum) between the backwater and the channel. Evidence of active erosion at the site included some past bank failure on the mud-rock platform, a number of large fallen trees on the bank slope and exposed roots.

Physical aquatic habitat features at the site consisted of some large woody debris and large fallen trees submerged instream, on the bank slopes and on the bar, overhanging vegetation, gravel beds on and at the edge of the mud-rock platform and exposed tree roots on the bank slopes. Live in-situ River Mussels (Alathyria jacksoni) and River Mussel shells were present at the water's edge at the northern side of the channel.

Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The northern mud-rock platform is likely to be suitable habitat for the Darling River Snail (Notopala sublineata) and River Mussel (Alathyria jacksoni) during moderate and high flows.</td></tr>
</table>

Site name	Site photographs	Description
A22 **~130 metres downstream of proposed weir pool extent**	 Assessment site A22 facing upstream  Assessment site A22 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A22 had low water level and low, shallow flow (a small riffle was present within the channel). Water appeared to be a green/brown colour and was slightly turbid. The site is located about 130 metres downstream of the proposed weir pool extent. The water channel was about 45 metres wide at this location. The western bank slope was very steep (near vertical) and the eastern slope was moderately steep. The tops of both banks in the riparian zone were dominated by *Eucalyptus camaldulensis* (River Red Gum). The western bank slope was mostly bare ground with some native grass *Agrostis avenacea* (common blown-grass) and some riparian weed species *Pseudognaphlium luteoalbum* (Jersey cudweed). The eastern slope had some native grass but was dominated by weed species, including *Rumex crystallinus* (Glistening dock), P*seudognaphlium luteoalbum* (Jersey cudweed) and *Lactuca cerriola* (Prickly lettuce). A large mud-rock bar and platform (upstream) was connected to the western bank which was mostly bare ground with some *Pseudognaphlium luteoalbum* (Jersey cudweed). In general, the site had a file silt substrate, however the bar mostly consisted of gravel beds. A small pool/backwater formation was present just upstream of the riffle. Evidence of active erosion at the site included some undercutting and exposed roots on the bank slope. Physical aquatic habitat features at the site consisted of some large woody debris and large fallen trees submerged instream, on the bank slopes and on the bar, overhanging vegetation, gravel beds on and at the edge of the mud-rock bar and exposed tree roots on the bank slopes. Several live *in-situ* River Mussels (*Alathyria jacksoni*) and River Mussel shells were present on the mud-rock bar on the western side of the channel. A Darling River Snail (*Notopala sublineata*) shell was identified at the water's edge on the eastern bank of the channel. Other observations at the site included presence of live Common Carp (*Cyprinus carpio*) swimming in the channel and a Yabby (*Cherax destructor*) skeleton on the bar. Based on features of the waterway at this location, this area is expected to be suitable foraging habitat for threatened species that are predicted to occur within the waterway, including Silver Perch, Murray Cod and Olive Perchlet. The western mud-rock bar is likely to be suitable habitat for the

Site name	Site photographs	Description
		Darling River Snail (*Notopala sublineata*) and River Mussel (*Alathyria jacksoni*) during moderate and high flows.

Appendix B. Threatened Species and Ecological Communities Impact Assessment

The results of this assessment identified three threatened fish species, one endangered fish population and one endangered ecological community listed under the EPBC Act and FM Act. An assessment of significance in accordance with the EPBC Act for relevant Protected Matters is provided in **Section B.1**. A seven-part test of significance in accordance with the FM Act for relevant threatened species is provided in **Section B.2**.

B.1 EPBC Act Assessment of significance

Under the EPBC Act, the approval of the Commonwealth Minister for the Environment is required for any action that may have a significant impact on matters of national environmental significance (MNES). Two aquatic species, listed under the EPBC Act, Silver Perch and Murray Cod, were identified as likely to occur within the proposal area and are assessed against the test of significance in **Table B-1** and **Table B-2**, respectively.

Table B-1 Test of significance for the EPBC listed 'Vulnerable' species – Silver Perch

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will:	
a) lead to a long-term decrease in the size of an important population of the species	Silver Perch is endemic to the waterways of the Murray-darling Basin and was once widespread throughout most of the Basin. In proximity to the study area, the species was relatively common in the Paroo River catchment until the late 1980's (Gehrke, et al, 1995; 1999; NSW DPI, 2006) but has since declined significantly. Currently, the remaining natural, wild and self-sustaining populations of the Silver Perch are known to occur in a region of the mid-Murray River from Yarrawonga Weir as well as several of its anabranches and tributaries including the Edward River – an anabranch of the Murray River that flows through Deniliquin and the Murrumbidgee River. Limited records of the species are present within or in proximity of the study area, however one sighting was recorded in 1975 in the Paroo River near its confluence with the Darling River (Baaka) upstream of Wilcannia. No important populations of Silver Perch have been declared in proximity of the study area. **Construction:** The works associated with the construction of the proposed weir and partial removal of the existing weir may impact on areas of potential habitat through direct disturbance of streambeds, clearance of vegetation and woody debris on the streambed and on the banks, sedimentation caused by construction activities, partial obstruction of fish passage or by cold-water releases during construction dewatering activities. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area and would only be moved from instream dry sites following fauna salvage and dewatering of the area. Aquatic vegetation, woody debris and riparian vegetation would subsequently be reinstated in the area after construction. Provided these standard practices are maintained throughout the construction of the proposal, it is unlikely that a long-term decrease in the size of the population would occur. **Operation:** Operational instream structures have been designed to avoid blockage of fish passage. Importantly, the new weir structure will provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir, therefore proposed instream structures are not expected to negatively impact on the long-term movement and migration of the species and subsequently would not contribute to a reduction in the size of the population. *Upstream* The new weir under the drought security operation mode would result in a permanent change from "*flowing*" habitat to "*no to low flow*" water habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will:	
	larger single inundated pool in the upstream extent of the new weir pool. For Silver Perch, permanent inundation areas are not expected to impact on the survival of adult individuals directly, however loss or reduction of "*flowing*" habitat and an increase in "*no to low flow*" conditions may impact breeding success as this species requires flowing habitat for egg and larvae dispersal. On the contrary, however, the new fishway will provide individuals with improved ability to complete migration, spawning and larvae dispersal (during flows), as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. *Downstream* The new weir under the drought security operation mode is expected to result in an increase in cease-to-flow (CtF) events downstream of the weir, however these additional CtF spells are mostly short duration (less than 20 day) events, therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during extended very-low-flow periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in weir filling phase. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system. The short duration of flow disruptions are not expected to have a major impact on fish migration and the gate closure system will be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. As such, impacts to Silver Perch downstream of the new weir are not expected to be impacted by the proposal.
b) Reduce the area of occupancy of an important population	No important populations of Silver Perch have been declared within or in proximity of the study area. Physical disruption of preferred habitat in the main channel of the Darling River (Baaka) would be limited to the construction footprints at the new and existing weir sites. Appropriate erosion and sediment controls will be adopted at both sites to ensure no significant impacts to downstream environments are caused by disturbance of the banks, streambed or instream habitat features during instream works, mobilisation of construction run-off or dewatering activities. As such, Silver Perch populations are not expected to be negatively impacted by the proposal. Furthermore, physical disruption of preferred habitat is only limited to the construction period as the new weir has been designed to improve fish passage than what is currently existing, therefore would not result in an obstruction of fish migration or reduce the area of occupancy of the population. During construction of the new weir, it is anticipated that about half the width of the Darling River (Baaka) channel would be unobstructed at any one time so that benthic aquatic species are able to migrate upstream and downstream of the site.

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will:	
	Operational instream structures have been designed to avoid blockage of fish passage. The new weir structure would provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir, therefore proposed instream structures are not expected to negatively impact on the long-term movement and migration of the species and subsequently would not contribute to a reduction in the area of occupancy of the species.
c) fragment an existing population into two or more populations	It is considered unlikely that any significant populations of Silver Perch are present within the mid to lower Darling River (Baaka). Nevertheless, the proposed weir is expected to improve connectivity of all aquatic species, including any Silver Perch individuals within the Darling River (Baaka) as the new fish way that has been incorporated into the design of proposal provides upstream migration capabilities which are usually not available at the existing weir. As such, no fragmentation of any existing populations of Silver Perch are anticipated to result from this proposal.
d) adversely affect habitat critical to the survival of a species	While the Darling River (Baaka) within the study area is suggested to support the Silver Perch, no areas have been declared to be 'Critical habitat' for the species. The proposal would require localised disturbance of the Darling River (Baaka) to construct the new weir and demolish the existing Wilcannia Weir. This would include relocation of any instream habitat features within the construction footprints areas, as well as clearance of adjoining riparian vegetation. Disturbance would be limited to the footprint area. Instream works and construction activities carried out on the banks of the river during construction may disturb submerged large woody debris and overhanging riparian vegetation in the relatively small areas affected by construction. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation, rocks and woody debris would subsequently be reinstated in the area after construction. Instream works and temporary instream structures may partially disrupt flow and obstruct fish passage. However, staging construction of the new weir means that at least half the width of the river channel will not be obstructed by instream works at any one time, thereby allowing water flow and benthic aquatic species to migrate upstream and downstream of the works. *Upstream* Operational instream structures have been designed to avoid blockage of fish passage. The new weir structure will provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir. It is expected, however, that the new weir under the drought security operation mode would result in a permanent change from "*flowing*" habitat to "*no to low flow*" habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. In general, the increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods which could benefit Silver Perch but may also benefit pest species (such as Carp), which may indirectly affect Silver Perch as they may be outcompeted by pest species for food and other resources. Carp are also known to exacerbate poor water quality conditions which habitat specialists such as Silver Perch may not be able to tolerate. While there is potential for these impacts may occur, the relative effect compared to current conditions is

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will:	
	likely to be small because even under current condition there is a large length of inundated river reach that provides similar habitat for native and non-native fish. Furthermore, it is important to note that the upstream habitat would only be subject to change from its current state during drought conditions, when the proposal is operating in drought security operation mode (expected to represent about 30 per cent of the time). For the remaining 70 per cent of the time, the weir would operate at the normal FSL, meaning the hydrological regime of the upstream area would remain unchanged by the proposal in operation. Inundation of the about 4.92 river kilometres would result in minor impacts to species that prefer flowing habitat however on the other hand the inundation may assist to improve aquatic habitat in the area as it would provide additional refuge habitat and result in submerging aquatic features such as exposed roots, large woody debris and overhanging branches. *Downstream* The new weir under the drought security operation mode is expected to result in an increase in cease-to-flow events downstream of the weir, however these additional CtF spells are mostly short duration (less than 20 day) events, therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during extended very-low-flow periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in weir filling phase. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system. The short duration of flow disruption is not expected to have a major impact on fish migration and the gate closure system would be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. As such, impacts to Silver Perch downstream of the new weir are not expected to be impacted by the proposal.
e) disrupt the breeding cycle of a population	Silver Perch tend to spawn in spring and summer after migrating long distances upstream. The species spawn naturally in response to a change in conditions; usually a rise in water levels (rainfall) coinciding with warm water temperatures (above 23^{o} Celsius). Each female will lay up to approximately 300,000 eggs that are about 2.7 millimetres in diameter, which hatch within 36 hours. Eggs and larvae passively drift with the river current for a number of days. After about five days the yolk sac is absorbed and the larvae will start to feed on zooplankton. Juveniles disperse over large distances, and are often seen in fishways travelling upstream in large schools (DPI, 2017). The new weir is not expected to result in negative impacts to spawning migrations of adult Silver Perch as the new fishway will improve river connectivity compared to what is currently available at the existing Wilcannia Weir. There is, however, potential for changes from "*flowing*" habitat to "*no to low flow*" conditions in the additional weir pool extent created by the proposed weir to result in free-floating eggs to sink before hatching. In the context of the study area, this additional potential for mortality of eggs

An action is likely to have a significant impact on a critically endangered species if there is a real chance or possibility that it will:	
	compared to current conditions is likely to be small because even under current condition there is a large length of inundated river reach that reduces flowing habitat.
f) introduce disease that may cause the species to decline, or	Little is known about the prevalence or effects of diseases on Silver Perch in the wild (DPI, 2006). Naturally occurring protozoan, fungal and bacterial diseases have been documented as occurring in farmed Silver Perch, and a protozoan parasite is thought to be responsible for at least one recorded mass mortality of Silver Perch in Bethungra Dam in the Murrumbidgee catchment in 1999. The proposal would not introduce any alien species that may act as a source of disease.
g) interfere with the recovery of the species.	The proposal is not expected to interfere with recovery actions for the species as set out in the NSW Silver Perch recovery plan (DPI, 2006) (currently no national recovery plan for the species). In particular, the new weir and management control measures have been designed to improve fish passage and species connectivity. Any large woody debris that is removed from the footprint area would be relocated upstream and downstream.

Table B-2 Test of significance for the EPBC listed 'Vulnerable' species – Murray Cod

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
a) lead to a long-term decrease in the size of an important population of the species	Murray Cod can be found in a range of freshwater habitats including rivers and creeks in the Murray-Darling Basin. Recent records suggest that Murray Cod are present in multiple sections of the mid to lower Darling River, having been frequently sighted upstream of Tilpa and downstream of Menindee (ALA, 2021; DPIE, 2021). An important population of Murray Cod has been declared for the Darling River main channel including minor tributaries and anabranches downstream of Menindee. Two sightings of the Murray Cod have been recorded about 60 kilometres downstream of Wilcannia (ALA, 2021). **Construction:** The works associated with the construction of the proposed weir and partial removal of the existing weir may impact on areas of potential habitat through direct disturbance of streambeds, clearance of vegetation and woody debris on the streambed and on the banks, sedimentation caused by construction activities, partial obstruction of fish passage or by cold-water releases during construction. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area and would only be moved from instream dry sites following fauna salvage and dewatering of the area. Aquatic vegetation and woody debris would subsequently be reinstated in the area after construction.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
	Provided these standard practices are maintained throughout the construction of the proposal, it is unlikely that a long-term decrease in the size of the population would occur. **Operation:** Operational instream structures have been designed to maintain flows and avoid blockage of fish passage. The new weir structure will provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir, therefore proposed instream structures are not expected to negatively impact on the long-term movement and migration of the species and subsequently would not contribute to a reduction in the size of the population. *Upstream* The new weir under the drought security operation mode would result in a permanent change from "*flowing*" habitat to "*no to low flow*" habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. For Murray Cod, permanent inundation areas are not expected to impact on the survival of Murray Cod populations. In fact, the new inundation areas could assist to submerge new structural features such as large woody debris, exposed roots and over hanging vegetation which Murray Cod utilise for shelter and laying eggs. In addition, the new fishway will provide them with improved ability to complete migration for spawning, as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. *Downstream* The new weir under the drought security operation mode is expected to result in an increase in cease-to-flow events downstream of the weir, however these additional CtF spells are mostly short duration (less than 20 day) events, therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which will assist to maintain water quality, habitat condition and fish passage during extended very-low-flow periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in the weir filling phase. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system. The short duration of flow disruption is not expected to have a major impact on fish migration and the gate closure system will be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. As such, Murray Cod populations downstream of the new weir are not expected to be impacted by the proposal.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
b) Reduce the area of occupancy of an important population	Physical disruption of preferred habitat in the main channel of the Darling River (Baaka) would be limited to the construction footprints at the new and existing weir sites. Appropriate erosion and sediment controls will be adopted at both sites to ensure no significant impacts to downstream environments are caused by disturbance of the banks, streambed or instream habitat features during instream works, mobilisation of construction run-off or dewatering activities. As such the important population of Murray Cod downstream of Menindee are not expected to be negatively impacted by the proposal. Furthermore, physical disruption of preferred habitat is only limited to the construction period as the new weir has been designed to improve fish passage than what is currently existing, therefore would not result in an obstruction of fish migration or reduce the area of occupancy of the population. During construction of the new weir, it is anticipated that about half the width of the Darling River (Baaka) channel will be unobstructed at any one time so that benthic aquatic species are able to migrate upstream and downstream of the site. Operational instream structures have been designed to avoid blockage of fish passage. The new weir structure will provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir, therefore proposed instream structures are not expected to negatively impact on the long-term movement and migration of the species and subsequently would not contribute to a reduction in the area of occupancy of the species.
c) fragment an existing population into two or more populations	It is expected that existing populations of Murray Cod within the mid to lower Darling River (Baaka) are already isolated (the majority of the time) due to the existing Wilcannia Weir not allowing fish passage during low flows. The new weir has alternatively been designed to include a fishway which will provide fish passage and therefore would not result in further fragmentation of populations.
d) adversely affect habitat critical to the survival of a species	While the Darling River (Baaka) within the study area is known to support the Murray Cod, no areas have been declared to be 'Critical habitat' for the species. The proposal would require localised disturbance of the Darling River (Baaka) to construct the new weir and demolish the existing Wilcannia Weir. This would include relocation of any instream habitat features within the construction footprints areas, as well as clearance of adjoining riparian vegetation. Disturbance would be limited to the footprint area. Instream works and construction activities carried out on the banks of the river during construction may disturb submerged large woody debris and overhanging vegetation in the relatively small areas affected by construction. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area. Aquatic vegetation, rocks and woody debris would subsequently be reinstated in the area after construction.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
	Instream works and temporary instream structures may partially disrupt flow and obstruct fish passage. However, staging construction of the new weir means that at least half the width of the river channel will not be obstructed by instream works at any one time, thereby allowing water flow and benthic aquatic species to migrate upstream and downstream of the works. *Upstream* Operational instream structures have been designed avoid blockage of fish passage. The new weir structure would provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir. It is expected, however, that the new weir under the drought security operation mode would result in a permanent change from "*flowing*" habitat to "*no to low flow*" habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. In general, the increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods which could benefit some native species but may also benefit pest species (such as Carp), which may indirectly affect Murray Cod as they may be outcompeted by pest species for food and other resources. Carp are also known to exasperate poor water quality conditions which habitat specialists such as Murray Cod may not be able to tolerate. While there is potential for these impacts may occur, the relative effect compared to current conditions is likely to be small because even under current condition there is a large length of inundated river reach that provides similar habitat for native and non-native fish. Furthermore, it is important to note that the upstream habitat would only be subject to change from its current state during drought conditions, when the proposal is operating in drought security operation mode (expected to represent about 30 per cent of the time). For the remaining 70 per cent of the time, the weir would operate at the normal FSL, meaning the hydrological regime of the upstream area would remain unchanged by the proposal in operation. Inundation of the about 4.92 river kilometres would result in minor impacts to species that prefer flowing habitat however on the other hand the inundation may assist to improve aquatic habitat in the area as it would provide additional refuge habitat and result in submerging aquatic features such as exposed roots, large woody debris and overhanging branches. *Downstream* The new weir under the drought security operation mode is expected to result in an increase in cease-to-flow events downstream of the weir, however these additional CtF spells are mostly short duration (less than five day) events, therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during extended very-low-flow periods. As such, Murray Cod preferred habitat downstream of the new weir are not expected to be impacted by the proposal.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
e) disrupt the breeding cycle of a population	Murray Cod have an annual reproductive cycle, with spawning occurring from spring to summer. Eggs are deposited on clay beds, rocks and logs in shallow and warm warmer. Larvae hatch after 5-13 days and drift downstream to find food and mature. High water levels enhance the survival of eggs, larvae and juveniles by providing better water quality and more food (Kalatzis and Baker, 2010). Recruitment success is expected to be linked to higher river flows. The new weir is not expected to result in negative impacts to spawning migrations of Adult Murray Cod as it will improve fish passage availability compared to what is currently available at the existing Wilcannia Weir. There is, however, potential for "*no to low flow*" habitat in the additional weir pool extent created by the proposed weir to result in reduced recruitment success. The impact on recruitment success is expected to be minor as the study area is subject to similar conditions currently within the existing weir pool.
f) introduce disease that may cause the species to decline, or	Little is known of the impact of diseases on Murray Cod (National Murray Cod Recovery Team, 2010). Naturally occurring pathogens may be a problem for injured fish. The proposal would not introduce any alien species that may act as a source of disease.
g) interfere with the recovery of the species.	The proposal is not expected to interfere with recovery actions for the species as set out in the national recovery plan (National Murray Cod Recovery Team, 2010). In particular, the new weir and management control measures have been designed to improve flows up and downstream and avoid obstruction of fish passage. Any large woody debris that is removed from the footprint area would be relocated upstream and downstream.

B.2 FM Act Seven-part test of significance

The results of this assessment identified one critically endangered species (Darling River Snail), one vulnerable species (Silver Perch), one endangered population (Western population of Olive Perchlet) and one endangered ecological community (Darling River EEC) listed under the FM Act. A seven part test in accordance with the FM Act has been carried out for each in **Table B-3**, **Table B-4**, **Table B-5** and **Table B-6**.

Table B-3 Seven part test of significance for Lowland Darling River Aquatic Ecological Community (Darling River EEC)

Seven-part test questions	Assessment
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.	Not applicable
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.	Not applicable
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i. is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or	The proposal lies within the natural drainage system of the lowland catchment of the Darling River (Darling River EEC) which includes the Darling River (Baaka). **Construction:** The new weir has been designed with the aim to improve connectivity for fish within the waterway more than what is currently available at the existing Wilcannia Weir. Additionally, aquatic habitat features such as large woody debris, rocks, and boulders would be reinstated into the Darling River (Baaka) within the construction footprint area.

Seven-part test questions	Assessment
ii. is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction	**Operation:** *Upstream* - The new weir under the drought security operation mode would result in a new permanent inundation area (new town pool) which would span a further 4.92 kilometres of river downstream of the existing weir. The new weir pool would also be up to one metre higher than the existing weir pool when it is in drought security operation mode. This would result in a permanent change from "*flowing*" habitat to "*no to low flow*" habitat in the new town pool. Inundation of this area would result in minor impacts to species that prefer flowing habitat but will not impact species more broadly. The inundation may assist to improve aquatic habitat in the area as it would provide additional refuge habitat and result in submerging aquatic features such as exposed roots, large woody debris and overhanging branches. In addition, the weir pool would be extended by up to 18.81 kilometres to the drought FSL which would result in a conversion of dry river channel and non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool which would be incrementally drawn down during operation. The increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods which could benefit some native species but may also benefit pest species (such as Carp), which may indirectly affect Murray Cod as they may be outcompeted by pest species for food and other resources. Carp are also known to exacerbate poor water quality conditions which habitat specialists such as Murray Cod may not be able to tolerate. Further, conversion to non-flowing habitat is not suitable for River Mussels which rely on flows to feed and require a stable supply of oxygen to survive. While there is potential for these impacts may occur, the relative effect compared to current conditions is likely to be small because even under current condition there is a large length of inundated river reach that provides similar habitat for native and non-native fish. Additionally, it is expected that the hydraulic conditions at the most upstream extent of inundation (in the top one to two kilometres of the study reach) would remain largely unchanged (either dry/isolated pools during drought security operation mode, or flowing during normal operation mode) which is the portion of upstream habitat that has been recognised as the more important flowing habitat in the reach because of the presence of bedrock riffles, the presence of River Mussels (observed during site inspections) and historical evidence of colonisation by Darling River Snails. It is also important to note that the upstream areas would only be subject to change from its current state during drought conditions, when the proposal is operating in drought security operation mode (expected to represent about 30 per cent of the time). For the remaining 70 per cent of the time, the weir would operate at the normal FSL, meaning the hydrological regime of the upstream area would remain unchanged by the proposal in operation.

Seven-part test questions	Assessment
	As such, the dual mode weir is a better alternative than that of a fixed crest weir where the additional weir height would have permanently inundated the upstream extent. Moreover, the periodic inundation of about 18.81 river kilometres of flowing habitat upstream of the existing weir extent and about 4.92 river kilometres of flowing habitat in the new town pool is considered to be a minor portion of the flowing habitat that is available within the entire Barwon-Darling River (Baaka), therefore a change in flow within these areas is not expected to significantly impact the overall function of the aquatic ecosystem as a whole. *Downstream* - An increase in cease-to-flow events downstream of the new weir, however these additional cease-to-flow spells are mostly short duration (less than 20 days), therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows when it is in drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during these extended periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in the weir filling phase. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system. The short duration of flow disruption is not expected to have a major impact on fish migration and the gate closure system would be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. The proposal is therefore unlikely to: ▪ Have an adverse effect on the extent of the ecological community or place the community at risk of extinction ▪ Substantially or adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.
d) in relation to the habitat of a threatened species, population or ecological community: i. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and	The extent of riparian habitat that is likely to be cleared during construction is 0.35 hectares. Riparian vegetation would require localised clearing on both banks of the Darling River (Baaka) within the construction footprint at the new weir site and for access to the existing weir site. Areas that are proposed to be cleared within the construction footprint will be rehabilitated as far as practicable following construction. i. The new weir under the drought security operation mode is expected to result in a new permanent inundation area (new town pool) which will span a further 4.92 kilometres of river downstream of the existing Wilcannia Weir. The new weir pool would also be up to one metre higher than the existing weir pool at FSL. This would result in a permanent change from flowing habitat to still water habitat in the new town pool. Inundation of this area would result in minor impacts to species that require flowing habitat but

Seven-part test questions	Assessment
ii. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality	will not impact species more broadly. In addition, the weir pool would be extended by up to about 18.81 river kilometres to the drought FSL which would result in a conversion of dry river channel and non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool which would be incrementally drawn down during operation. The increase in the area of inundation may provide additional refuge habitat for fish during non-flowing periods which could benefit some native species but may also benefit pest species (such as Carp). Further, conversion to non-flowing habitat is not suitable for River Mussels which rely on flows to feed and require a stable supply of oxygen to survive. The proposal under drought security operation mode would result in an increase in cease-to-flow events downstream of the weir, however these additional CtF spells are mostly short duration (less than 20 days), therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during these extended periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in the weir filling phase. Overall however, any change is considered insignificant and does not result in a substantial change in the distribution of base flows to the extent that certain flow components are lost from the system. The short duration of flow disruptions are not expected to have a major impact on downstream habitat quality or fish migration and the gate closure system will be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. ii. As the Darling River (Baaka) in the proposal area is known to support several threatened fish, populations and the Darling River EEC, the proposal aims to improve connectivity within the ecosystem by designing a fishway at the new weir. Additionally, the construction areas will be rehabilitated to restore major habitat features that may be disturbed during construction. Disturbance would include the temporary removal of vegetation and woody debris during the construction phase of the proposal. However, as they would be reinstated the proposal is unlikely to fragment or isolate the long-term survival of the species, population or ecological community in the locality.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	Not applicable.

Seven-part test questions	Assessment
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	Recovery and conservation actions for the EEC which are associated with project activities would include: ▪ Allocate and manage environmental water flows in regulated rivers to lessen the impacts of unseasonal flow and temperature patterns ▪ Conserving and restoring habitats by protecting aquatic and riparian vegetation and, using effective erosion control measures ▪ Reinstating large woody debris and rocks, where appropriate ▪ Providing fish passage by avoiding barriers or installing fishways in consultation with affected stakeholders. Recovery actions would be made in accordance with relevant guidelines, *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) and *Why do Fish Cross the Road? Fish Passage Requirements for Waterways Crossings* (Fairfull and Witheridge, 2003).
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	Threatening processes which may occur during the construction of the proposal may include: ▪ Temporary removal of large woody debris ▪ Alteration of natural flow regimes through the installation of instream structures ▪ Removal of riparian vegetation and associated erosion of stream banks. By incorporating erosion and sediment control measures, rehabilitating habitat structure, installing an appropriately designed fishway at the new weir, and operating the weir with consideration given to environmental flow requirements, the KTPs as mentioned above would be minimised. This is further detailed in **Section 7.1**.

Table B-4 Seven part test of significance for Darling River Snail (Critically Endangered)

Seven part test questions	Assessment
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local	The Darling River Snail was once abundant in flowing rivers of the Murray-Darling System, along the banks, attached to logs and rocks, or crawling in the mud. They are now virtually extinct throughout their natural range however artificially introduced hard surfaces now provide habitat for the species, with populations being recorded as surviving in irrigation pipelines in southern NSW.

Seven part test questions	Assessment
population of the species is likely to be placed at risk of extinction.	The species gives birth to live young rather than laying eggs. As such, the species has limited dispersal capabilities as dispersal via drifting or by dislodged egg capsule is not possible. Fertilisation is internal, and the young remain with the female until they are large enough to survive independently (DPI, 2018). The species has become threatened due to changes in the nature of their food source as a result of altered flow regimes (principally weir and dam building). Algal blooms that grow in reduced flow environments impact on the species due to the environment becoming nutrient deficient. Further, the decline in the species occurred around the time of the incursion of Common Carp into the Darling River system and may be associated with predation by these fish or habitat degradation caused by them. De-snagging and removal of large-woody debris from rivers has also resulted in direct habitat loss for the species (DPI, 2018). **Construction:** The works associated with the construction of the new weir and partial removal of the existing weir may impact on areas of habitat through direct disturbance of rocky substrate on streambeds, clearance of submerged large woody debris, vegetation within the streambed and on the banks, and potential for increased sedimentation caused by construction activities which may lead to algal blooms. Standard measures during construction would be undertaken to avoid impacts. Important habitat features such as woody debris, rocks and boulders would be relocated upstream and downstream of the works and would only be moved from instream dry sites following fauna salvage and dewatering of the area. Aquatic vegetation, woody debris and riparian vegetation would subsequently be reinstated in the construction footprint area following construction. **Operation:** *Upstream* The new weir under the drought security operation mode would result in a permanent change from flowing habitat to still water habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. A change from a flowing river environment to an inundated environment would no longer be suitable habitat for the Darling River Snail as they are known to prefer flowing channel environments (Ponder, et al, 2020). However, there is no evidence of the presence of living populations of Darling River Snail in the reach. The only suitable habitat for them is at the very upstream end of the reach, which will continue to experience a similar regime to current and will not

Seven part test questions	Assessment
	result in the conversion of flowing habitat to non-flowing at time when flow is occurring (i.e. during normal operation mode). *Downstream* An increase in cease-to-flow events downstream of the weir, however these additional CtF spells are mostly short duration (less than five days), therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality and habitat condition during these extended periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in the weir filling phase. The short duration of flow disruption is not expected to have a major impact on any potential Darling River Snail populations and the progressive gate closure system would deliberately manage discharge decline.
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.	Not Applicable.
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i. is likely to have an adverse effect on the extent of the ecological community such that its local	Not Applicable.

Seven part test questions	Assessment
occurrence is likely to be placed at risk of extinction, or ii. is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction	
d) in relation to the habitat of a threatened species, population or ecological community: i. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality	i. The new weir under the drought security operation mode would result in a permanent change from flowing habitat to still water habitat in the new town pool and an intermittent conversion of dry river channel and/or non-flowing refuge pools to a larger single inundated pool in the upstream extent of the new weir pool. A change from a flowing river environment to an inundated environment would no longer be suitable habitat for the Darling River Snail as they are known to prefer flowing channel environments (Ponder, et al, 2020). ii. While it is possible for the Darling River Snail to currently occupy the areas of new permanent and intermittent inundation. It is expected that these areas are not important or critical habitat for the species as they have not been detected in the area and the only known remnant populations are located in irrigation pipelines in southern NSW. As such, it is considered unlikely that inundation of the new town pool and upstream extent of the weir pool at the drought FSL (in drought security operation mode) would remove important habitat, or fragment/isolate Darling River Snail populations in the area.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	No critical habitat has been identified within or downstream of the proposal area.

Seven part test questions	Assessment
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	Recovery and conservation actions for the Darling River (Baaka) which are associated with project activities would include: ▪ Collate data on the historical distribution of the river snail ▪ Conduct surveys to investigation distribution of the river snail in natural habitats ▪ Continue to collect data on the presence/absence of the river snail during incidental surveys ▪ Advocate appropriate allocation and improvement management of environmental flows particularly in area that could potentially support remnant river snail populations. Recovery actions would be made in accordance with relevant guidelines, *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) and *Why do Fish Cross the Road? Fish Passage Requirements for Waterways Crossings* (Fairfull and Witheridge, 2003).
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	Threatening processes which may occur during the construction of the proposal may include: ▪ Temporary removal of large woody debris ▪ Alteration of natural flow regimes through the installation of instream structures ▪ Removal of riparian vegetation and associated erosion of stream banks. By incorporating erosion and sediment control measures, rehabilitating habitat structure, installing an appropriately designed fishway at the new weir, and operating the weir with consideration given to environmental flow requirements, the KTPs as mentioned above would be minimised. This is further detailed in **Section 7.1**.

Table B-5 Seven part test of significance for Western population of Oliver Perchlet (Endangered)

Seven part test questions	Assessment
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.	Not applicable.

Seven part test questions	Assessment
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.	The Olive Perchlet's preferred habitat is the vegetated edges of lakes, creeks, swamps, wetlands and rivers, where it is often associated with woody habitat and aquatic vegetation in areas with little or no flow, particularly backwaters (Lintermans, 2007). They spawn in spring/summer when water temperatures reach between 22 – 23˚C. The eggs are small, adhesive and attach to aquatic plants and rocks on the streambed. Hatching occurs in 5 – 7 days at 22˚C. The lifecycle is threatened by loss of aquatic habitat and spawning sites through siltation and vegetation removal, reduced spawning success and degradation of preferred habitat through alterations to flow patterns and flooding regimes, and loss of spawning cues due to cold water pollution. It is noted that there are recent recordings of the Olive Perchlet within the study area based on database searches (DAWE, 2021; EESG, 2021; ALA, 2021) and the species has predicted distribution within the study area (DPI, 2016). The works associated with the construction of the new weir and partial removal of the existing Wilcannia Weir may impact on areas of breeding habitat through direct disturbance of rocky substrate on streambeds, clearance of vegetation within the streambed and on the banks, potential for increased sedimentation caused by construction activities, partial obstruction of fish passage or by water pollution from untreated construction runoff, dewatering or construction discharges. Standard measures during construction would be undertaken to avoid impacts. Important habitat features such as woody debris, rocks and boulders would be relocated upstream and downstream of the works and would only be moved from instream dry sites following fauna salvage and dewatering of the area. Aquatic vegetation, woody debris and riparian vegetation would subsequently be reinstated in the construction footprint area following construction. The new weir would be designed to improve connectivity for fish species as it will include an appropriately design fishway. Construction works would be undertaken in accordance with appropriate erosion and sediment controls to manage and minimise further siltation. To minimise impact on spawning success, construction of the new weir and partial removal of the existing Wilcannia Weir should be undertaken outside of the breeding season (spring / summer). These standard practices would minimise adverse effects on the life cycle of the population. *Upstream* The new weir under the drought security operation mode is expected to result in a new permanent inundation area (new town pool) which will span an additional 4.92 kilometres of river downstream of the existing Wilcannia Weir. In addition, the weir pool would be extended by up 18.81 kilometres to the drought FSL under the drought security operating mode. This would result in a permanent change from flowing habitat to still water habitat in the new town pool and an intermittent change from flowing habitat to still water habitat in the upstream extent of the new

Seven part test questions	Assessment
	weir pool. In general, a change from flowing to still water conditions may result in a reduction of habitat diversity and water quality which can lead to reduced native fish fauna diversity and potentially assist to proliferate pest species (such as Carp) that are habitat generalists. For Olive Perchlet, permanent inundation areas are not expected to impact on the survival of individuals. In fact, the new inundation areas could assist to submerge new structural features such as large woody debris, exposed roots and over hanging vegetation which Olive Perchlet utilise for habitat and spawning. In addition, the new fishway will provide them with improved ability to complete migration, as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. *Downstream* The new weir under the drought security operation mode is expected to result in an increase in cease-to-flow (CtF) events downstream of the weir, however these additional CtF spells are mostly short duration (less than five day) events, therefore are unlikely to impact habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during extended very-low-flow periods. Base flows are expected to decrease slightly as flow would be obstructed when the scheme is in the weir filling phase. The short duration of flow disruption is not expected to have a major impact on fish migration and the gate closure system will be deliberately managed to ensure that discharge decline does not cause sudden stranding of fish in edge habitat. As such, Olive Perchlet populations downstream of the new weir are not expected to be impacted by the proposal.
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i. is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or	Not Applicable.

Seven part test questions	Assessment
ii. is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction	
d) in relation to the habitat of a threatened species, population or ecological community: i. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality	i. The proposal is not expected to remove or negatively impact preferred habitat for the Olive Perchlet. ii. The proposal is not expected to result in fragmentation or isolation of Olive Perchlet populations. Conversely, the fishway is likely to improve fish passage for the species.
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	No critical habitat has been identified within or downstream of the proposal area.
f) whether the action proposed is consistent with the objectives or	Applicable priority action statements for the Olive Perch include the following recovery actions: ▪ Allocate environmental water flows in regulated rivers to restore natural season flow patterns, and to reduce the impact of cold water pollution downstream of dams

Seven part test questions	Assessment
actions of a recovery plan or threat abatement plan	▪ Promote appropriate land management practices to improve water quality and river health. Standard management practices including erosion and sediment controls and water treatment prior to discharge will be implemented to improve water quality and preserve the health of the river at and downstream of the construction sites. During operation, the proposal aims to improve connectivity within the area through appropriate design of a fishway at the new weir. These environmental management measures and fishway design option are in keeping with recovery actions.
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process	Threatening processes which may occur during the construction of the proposal may include: ▪ Temporary removal of large woody debris ▪ Alteration of natural flow regimes through the installation of instream structures ▪ Removal of riparian vegetation and associated erosion of stream banks. By incorporating erosion and sediment control measures, rehabilitating habitat structure, installing an appropriately designed fishway at the new weir, and operating the weir with consideration given to environmental flow requirements, the KTPs as mentioned above would be minimised. This is further detailed in **Section 7.1**.

Table B-6 Seven part test of significance for Western population of Silver Perch (Vulnerable)

Seven part test questions	Assessment
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.	Silver Perch can be found in a range of habitats and climates across the Murray-Darling Basin. Limited records of the species are present within or in proximity of the study area, however one sighting was recorded in 1975 in the Paroo River near its confluence with the Darling River upstream of Wilcannia. No local populations of Silver Perch have been declared in proximity of the study area, however the Darling River is predicted habitat for the species according to DPI threatened species distribution mapping (DPI, 2016). The species generally prefers faster-flowing water including rapids and more open sections of river (DPI, 2017). Adult Silver perch can travel large distances, often associated with spawning activity in spring and summer. Juveniles disperse over large distances and are often seen at fishways travelling upstream in large schools. Females can lay up to 300,000 eggs which passively drift with the river current for a number of days before hatching. The lifecycle is threatened by: ▪ Changes in water quality associated with agriculture and forestry, for example siltation (as a result of clearing) can destroy deep rock pools used by adults as well as smothering spawning areas

Seven part test questions	Assessment
	▪ Modification of natural river flows and temperatures as a result of construction of dams and weirs lead to disrupted cues for migration and spawning and reduce opportunities for dispersal and availability of food ▪ Loss of riparian vegetation by deliberate removal result in sedimentation, increased salinity and declines in water quality subsequently degrading instream habitats important to Silver Perch ▪ Loss of submerged macrophytes which are important nursery areas for juvenile Silver Perch and important sites for feeding ▪ Competition from introduced species such as Carp, Redfin Perch and Gambusia (DPI, 2017). **Construction:** The works associated with the construction of the new weir and partial removal of the existing Wilcannia weir may impact on areas of potential habitat through direct disturbance of streambeds, clearance of vegetation and woody debris on the streambed and on the banks, sedimentation caused by construction activities, partial obstruction of fish passage or by cold-water releases during construction. Works would be undertaken in accordance with standard sediment and erosion controls to manage and minimise further siltation. Instream woody debris that is required to be removed from site would be moved upstream and downstream of the proposal area and would only be moved from instream dry sites following fauna salvage and dewatering of the area. Aquatic vegetation and woody debris would subsequently be reinstated in the construction footprint area after construction. Provided these standard practices are maintained throughout the construction of the proposal, it is unlikely that a long-term decrease in the size of the population would occur. **Operation:** Operational instream structures have been designed to avoid blockage of fish passage. Importantly, the new weir structure will provide additional opportunity for fish migration than what is currently available at the existing Wilcannia Weir, therefore proposed instream structures are not expected to negatively impact on the long-term movement and migration of the species and subsequently would not contribute to a reduction in the size of the population.

Seven part test questions	Assessment
	Upstream The new weir under the drought security operation mode would result in a new permanent inundation area (new town pool) which would span an additional 4.92 kilometres of river downstream of the existing weir. In addition, the weir pool would be extended by up 18.81 kilometres to the drought FSL under the drought security operating mode. This would result in a permanent change from flowing habitat to still water habitat in the new town pool and an intermittent change from flowing habitat to still water habitat in the upstream extent of the new weir pool. In general, a change from flowing to still water conditions may result in a reduction of habitat diversity and water quality which can lead to reduced native fish fauna diversity and potentially assist to proliferate pest species (such as Carp) that are habitat generalists. For Silver Perch, permanent inundation areas are not expected to impact on the survival of adult individuals directly, however loss of flowing habitat and an increase in still water conditions may impact breeding success as this species requires flowing habitat for egg and larvae dispersal. On the contrary, however, the new fishway will provide individuals with improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. *Downstream* The new weir under the drought security operation mode is expected to result in an increase in cease-to-flow (CtF) events downstream of the weir, however these additional CtF spells are mostly short duration (less than five day) events, therefore are unlikely to impact flows, habitat condition or water quality downstream. Very-low-flows are also expected to increase, however due to the translucency of the proposed weir structure and its ability to pass small inflows during drought security operation mode, it is expected that long-period very-low-flows would be punctuated by small flows which would assist to maintain water quality, habitat condition and fish passage during extended very-low-flow periods. As such, impacts to Silver Perch downstream of the new weir are not expected to be impacted by the proposal.
b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local	Not Applicable.

Seven part test questions	Assessment
population of the species is likely to be placed at risk of extinction.	
c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: i. is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or ii. is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction	Not Applicable.
d) in relation to the habitat of a threatened species, population or ecological community: i. the extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii. whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and the	i. Permanent inundation areas are not expected to impact on habitat for adult individuals directly, however loss of flowing habitat and an increase in still water conditions may impact breeding success as this species requires flowing habitat for egg and larvae dispersal. On the contrary, however, the new fishway will provide individuals with improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs. ii. The proposal is not expected to result in fragmentation or isolation of Silver Perch populations. In fact, the new fishway will provide individuals with improved ability to complete migration, spawning and larvae dispersal, as well as reduce population fragmentation which will in turn boost biodiversity, long-term population resilience and contribute to food webs.

Seven part test questions	Assessment
importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality	
e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	No critical habitat has been identified within or downstream of the proposal area.
f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan	Priority action statements for the Silver Perch include the following recovery actions: ▪ provide advice to consent and determining authorities and management authorities regarding habitat protection and species distribution ▪ community and stakeholder liaison, awareness and education ▪ implement and enforce relevant fishing regulations in priority Silver Perch areas ▪ implement and enforce relevant fishing regulations including national recovery plan to minimise adverse impact on the species ▪ stocking/translocation ▪ habitat protection and rehabilitation including management of environmental flows and water quality; improved fish passage at major regulating structures; protection and rehabilitation of aquatic habitat and riparian vegetation; and mitigate impacts of cold-water pollution. Potential Silver Perch habitat within the proposal area will be protected throughout the construction phase through implementation of site-specific erosion and sediment controls. The disturbed aquatic environments will also be rehabilitated following construction through re-establishment of aquatic habitat features such as large woody debris, aquatic vegetation instream and riparian vegetation on the banks. During operation, the proposal aims to improve connectivity within the area through appropriate design of a fishway at the new weir. These environmental management measures are in keeping with recovery actions.

Seven part test questions	Assessment
g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process	Threatening processes which may occur during the construction of the proposal may include: ▪ Temporary removal of large woody debris ▪ Alteration of natural flow regimes through the installation of instream structures ▪ Removal of riparian vegetation and associated erosion of stream banks. By incorporating erosion and sediment control measures, rehabilitating habitat structure, installing an appropriately designed fishway at the new weir, and operating the weir with consideration given to environmental flow requirements, the KTPs as mentioned above would be minimised. This is further detailed in **Section 7.1**.

Appendix C. Fishway Design Report

NSW GOVERNMENT | Public Works Advisory

Wilcannia Weir Replacement

Fishway Preliminary Concept

Functionality and Basis for Design

Report Number: ISR21177

November 2021

Prepared for:

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Cover photo: *Existing Wilcannia weir upstream of town during 2019 prolonged drought conditions (view from right-hand side riverbank | flow typically from left to right)).*
(Source: Martin Mallen-Cooper, Fishway Consulting Services (FCS)).

Executive Summary

Wilcannia Weir is to be replaced to improve water security for the community of Wilcannia. To provide for fish passage a fishway is included in the project. The present report provides the conceptual basis for the design of the weir and fishway; with design criteria and a preliminary arrangement.

Background

Weirs along the Barwon-Darling (Baarka) River provide in-river storage for town water supplies when there are zero flows in droughts. At other times, when the river is flowing, in-river storage is not needed. The key environmental impacts of these weirs – and the proposed solutions for the Wilcannia project – are they:

i. Back water up and eliminate flowing water reaches, which are habitats for River mussels, River snails and juvenile Murray cod – these are significant in Aboriginal culture. The proposed Wilcannia Weir needs to be an extra 1m higher to store additional water in droughts, which would back water up and inundate a further 19 km.

   Proposed Solution: include gate(s) in the weir that only raise the weirpool storage 1m when zero flows are expected; that is, the crest is "flexible".

ii. Prevent transparency of inflows or delivery environmental flows when the weirpool is below the crest;

   Proposed Solution: include gate(s) in the weir with an invert level below the existing weir crest level to enable weirpool inflows to be discharged downstream. The assessed town water supply secure yield is not dependent on ongoing inflow capture given a full weirpool storage at the commencement of river flow drought conditions.

iii. Limit migration of fish and turtles.

   Proposed Solution: include a fishway for upstream and downstream passage, and overshot gate(s) and an associated plunge pool for complementary downstream passage.

Proposed Weir

Two weir options were considered:

i. a "fixed crest" option that is permanently raised 1m. As mentioned above, this would permanently inundate an additional 19km of flowing water habitat. This option would have a maximum head differential (difference in upstream and downstream water levels) of 4.01m, which would result in a 37 baffle fishway that is 153m long (assuming a nominal 1:36 gradient).

ii. a "flexible crest" option that is only raised 1m when there is zero flow, or zero flows are expected. Modelling has shown that the 19 km of flowing water habitat upstream would be preserved approximately 70% of the time.

   This option would have a maximum head difference of 4.01m when not passing flows and storing water, and 3.01m when the river is flowing, which would result in a 28 baffle fishway that is 115m long (assuming a nominal 1:36 gradient).

   Preliminary analysis suggests that a 2.75m head differential would operate for 99% of head differentials of 3.01m or less and has been used for preliminary concept design.

The "flexible crest" option with a fishway operating for a 2.75m head differential was selected by WaterNSW for progression to concept design. The weir operates in two modes:

i. "drought mode", when it is capturing or storing water, and the head differential is typically between 3.01 and 4.01m; and

ii. "normal mode", when it is passing river flows and the head differential is less than 3.01m.

There are transition periods between the two modes, where the head differential is between 3.01m and 4.01m with the fishway outside its optimum operating range, combined with flow passing downstream. This occurs because as the weir starts to capture water there is an intended gradual ramp-down of flows downstream rather than a sudden stop. The ramp-down is aimed at meeting ecological objectives of a more-natural reduction in flows, particularly to enable fish to seek refugia. This situation can also occur when translucency/transparency of storage inflows or delivered environmental flows is required and the weir is in "drought mode" with a high headwater level.

In "drought mode" there can be "false starts" when zero flows are expected and the weir enters "drought mode", but zero flows do not occur and the weir then returns to "normal" mode.

Proposed Fishway

The key design objectives of the fishway are to:

i. Provide suitable entrance attraction conditions:

   – Maximise proportion of river discharge through fishway. Target minimum 10% of river discharge via fishway at high river flows - this aspect is critical for fishway functionality because there are large migrations of fish in the Barwon-Darling (Baarka) River on flow pulses (e.g. 5,000-10,000 ML/day).

   – Ensure entrance is located at the upstream limit of fish migration and that the combined structure arrangement and gate operations guide fish to the fishway entrance.

ii. Provide suitable passage conditions:

   – Within the fishway channel to pass the size range of migrating native fish (50-1300mm) upstream and downstream, from low flows up until "drown-out" when fish can pass directly over the weir, which may also be enhanced by favourably designed abutments;

   – Through the weir with overshot gate(s) and a downstream plunge pool (important for the survival of fish [especially eggs and larvae] migrating downstream);

   – For turtles at low flows by incorporation of internal ramps over baffle slot sills and bypass ramps around upstream fishway isolation gate barriers.

Using these objectives, the three main fishway options considered were:

Option 1. Cast in-situ vertical-slot fishway;

Option 2. Precast concrete fishway in surrounding sheet piles (as per SFIP);

Option 3. Rock channel fishway with precast ridges in surrounding sheet pile.

<u>Option 2</u> was selected for concept design because:

i. functionally it provided high attraction with a high discharge fishway during flow pulses, with excellent passage of high biomass; combined with anticipated suitable turbulence for passage of a high range of fish species and sizes, and

ii. it potentially provides low construction time and risk – because of pre-fabricated units and the opportunity for the upstream sheet pile cofferdam to be retained as the fishway sides - with comparable and potentially lower cost.

Initial design criteria for the Option 2 fishway are:

- 2.75m max differential head (to be refined);
- 2.53m headwater range (depends on number of weir outlet gates: more gates would reduce headwater range);
- 5.03m tailwater range;
- 10.4m wide internal channel (8.0m wide used for moderate flows; 4m wide used for low flows);
- 4.25m long pools (between baffle centres);
- 0.110m baffle head loss (nominal gradient 1:36.36 / true gradient 1:38.64);
- 114.75m long with 27 pools;
- Minimum internal depth of 0.94m at a weirpool level of RL 65.71 mAHD (matches existing weir);
- Precast concrete baffles that have a castellated V-profile with side slopes of 1V:2.25H which requires CFD and physical modelling to confirm design.

Next stages

- Hydrodynamic modelling of minimum 19 km reach upstream of the existing weirpool extent with different gate discharges and headwater levels.
- Assessment to link hydrodynamic model with a daily hydrological model to quantify spatio-temporal impacts on flowing water habitats and to confirm gate discharge capacity requirements.
- Investigation of the effects of the number and size of gates on headwater, drown-out and fishway design. (Note that more gates are likely to reduce headwater range, reduce the drown-out flow and provide lower fishway cost but would increase weir cost due to additional outlet gates).
- Evaluate the function, design and cost implications of the fishway designed for 2.75m and 3.01m differential heads.
- CFD and physical modelling is required to optimise the fishway arrangement integrated into the weir structure in relation to entrance attraction conditions, location of upstream limit of fish migration and positioning of the entrance, and also to confirm suitable internal fishway hydraulic conditions focused on baffle geometry and associated turbulence. These investigations have the potential to require significant modification of the fishway concept and for the provision of additional weir outlet gate(s).

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Glossary

Term	Definition
Differential head (ΔH)	Difference between water surface levels upstream and downstream of a hydraulic structure.
Headwater level (HWL)	Water level immediately upstream of a control structure that is not affected by any significant draw-down or related disturbance.
Left and Right	Reference to *left* and *right* is with respect to the view in the downstream direction, in accordance with industry standard practice.
Percentile	Term used to indicate thresholds or boundary values in frequency distributions. For example, the 95th percentile is that value which marks off the lowest 95 percent of observations from the rest and exceeds all but 5 percent of the values; the 50th percentile is the same as the median value (i.e. middle value in a ranked list of all values).
Tailwater level (TWL)	Water level immediately downstream of a structure that is beyond the zone of any high energy flow and/or turbulent water.

Abbreviations and Notations

≈ or ~	approximately equal to
AEP	annual exceedance probability
AHD or mAHD	Australian Height Datum (in metres)
CH or Ch	chainage
CTF	commence-to-flow and cease-to-flow
D/S or d/s	downstream
DEM and DTM	digital elevation model and digital terrain model
FSL ǀ NFSL & DFSL	full supply/storage level ǀ 'normal' and 'drought' mode FSL
GL	gigalitres (1 x 10^9 L)
HWL	headwater level (upper pool or storage level)
ML and ML/day or ML/d	megalitres (1 x 10^6 L); and megalitres per day
nom	nominal
NS and NSL	natural surface; and natural surface level
Q	flowrate or discharge
RL	reduced level relative to an established datum (typically AHD)
SFIP	Water NSW Strategic Fishway Implementation Project
TWL	tailwater level
typ	typical
U/S or u/s	upstream
WL and WSL	water level and water surface level
w.r.t.	with respect to

1. Introduction

The Wilcannia Weir Replacement Project is providing improved water supply security for the town of Wilcannia during drought periods when the river ceases to flow. Consistent with the Water Management Act 2000 (WMA 2000) and the Fisheries Management Act 1994 (FMA 1994), the project also aims to minimise impacts on water-dependent biota and habitats. The FMA 1994 is specifically responsible for fish, molluscs (gastropods, such as aquatic snails; and bivalves, such as mussels) and crustaceans (crabs, shrimps, yabbies). The present report is focused on the provision of fish passage, which is covered under Section 218 of the FMA 1994, and overlaps with minimising impacts on aquatic habitats for fish and gastropods.

2. Background

2.1 Hydrology and Hydrodynamics

Hydrology is the change in river discharge or flow (e.g. expressed in units of ML/day) through time, while hydrodynamics is the change in hydraulic conditions (e.g. water level, depth, velocity and turbulence) through time. In river ecology, hydrodynamics describes a key division in aquatic habitats between visibly *flowing water* (lotic) and *stillwater* or *pool* (lentic) habitats. This concept underpins the Wilcannia Weir Replacement Project which aims to improve water security and minimise impacts on aquatic habitats.

The Barwon-Darling (Baarka) River drains the Northern Basin of the Murray-Darling River system and has a semi-arid hydrology; which means it flows through drylands and has periods of zero discharge.

Under natural conditions the river flowed for over 90% of the time overall, and in droughts it flowed for 85% of the time at Wilcannia[1]. In wet decades it could flow continuously for 19 years, while in dry decades it had cease-to-flow periods that were commonly less than a month but could extend to over 11 months (1902 Federation Drought).

These flows in the river generated *flowing water* habitats for most of the time, even in droughts. This is significant because the ecology of river channels is divided into *flowing water* (lotic) and *still-water* (lentic) or pools. *Flowing water* is a key habitat for River mussels, Darling River snails and juvenile Murray cod. River mussels and snails are found in Aboriginal middens for over 10,000 years and Murray cod is a totem for many Aboriginal groups.

There are two contemporary threats to *flowing water* habitats: (1) weirpools, which back water up and create a pool habitat (presently applies to 40% of the Barwon-Darling [Baarka]); and (2) extended periods of low flows due to diversion of flow upstream. The present project has no influence on upstream diversions but can influence the operation and impacts of a higher Wilcannia weirpool. Hence, a major driver of the project is minimising the impact on upstream *flowing water* habitats at Wilcannia, by having a weir that only raises the weirpool when zero flows are expected.

As well as near-perennial baseflows, under natural conditions the river had near-annual flow pulses that were generally contained within the deeply-incised river channel, and less frequently, large, overbank floods[2]. Under current developed conditions, the regular flow pulses have reduced frequency and magnitude due to diversions upstream, but when they do occur, they are a major stimulus for fish migration.

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[1] Mallen-Cooper, M., and Zampatti, B.P. (2020) Restoring the ecological integrity of a dryland river: why low flows in the Barwon-Darling River must *flow*. *Ecological Management & Restoration*, 11.

[2] Puckridge J, Sheldon F, Walker KF, Boulton A (1998) Flow variability and the ecology of large rivers. Marine and Freshwater Research, **49**, 55-72.

2.2 Threatened Aquatic Fauna

The Barwon-Darling (Baarka) River is listed by the NSW Department of Primary Industries as an *endangered ecological community*. The river also contains:

- the critically endangered Darling River Snail, which has recently been found upstream at Tilpa[1] and are present in middens at Wilcannia,
- silver perch and Murray cod, which are listed as vulnerable,
- endangered populations of Eel-tailed Catfish (or freshwater catfish) and Olive perchlet - although the latter species is known to be present upstream and downstream it has not specifically been recorded in the Barwon-Darling (Baarka) River.

2.3 Ecological Objectives

For aquatic fauna there are three key ecological objectives that influence the design and operation of the Wilcannia Weir Replacement Project:

1. Minimise impacts on upstream *flowing water* habitats caused by a raised weirpool.

   Proposed Solution: include gate(s) in the weir that only raise the weirpool storage when zero flows are expected.

2. Provide the capability to deliver transparency or translucency of inflows or delivered environmental flows (when the weirpool is below crest level) for the benefit of downstream habitats. This would include the objectives of maintaining both *flowing water* refugia and *stillwater* (pool) refugia.

   Proposed Solution: include gate(s) in the weir with an invert level below the existing weir crest level to enable weirpool inflows to be discharged downstream. The assessed town water supply secure yield is not dependent on ongoing inflow capture given a full weirpool storage at the commencement of river flow drought conditions (refer to *Section 5*).

3. Provide upstream and downstream fish and turtle passage.

   Proposed Solution: include a fishway for upstream and downstream passage, and overshot gate(s) and an associated plunge pool for complementary downstream passage.

3. Fish and Turtle Passage

3.1 Fish Ecology

There are 15 native fish species in the Barwon-Darling (Baarka) River system (*Table 3.1*). Some of these species remain relatively common, while others have declined significantly. The common species are *generalist species* that utilise a range of habitats and importantly, complete their life cycle in the river distance between weirs. The native species that have declined are: i) *channel specialist* species that migrate long distances (100s km), potentially over multiple weirs, and ii) *wetland specialists* that move within and between wetlands. Numerous small-bodied fish species (20-50mm) that are common in channel habitats do not require fish passage to sustain their present populations, but their movements can contribute to food webs, biodiversity, and long-term population resilience.

In *Table 3.1* below, freshwater fish found in the lower Barwon-Darling (Baarka) River are shown with migration direction and size, orange shading is used to indicate those that are the *primary design focus*, and blue highlight are a *secondary design focus*. It is important to note that all fish that need to migrate past or move between upstream and downstream river reaches and habitats will benefit from the provision of the proposed fishway. The identified species, sizes and swimming abilities of the fish identified as the primary focus represent a broad range of hydraulic design requirements and criteria that has been developed for the proposed fishway.

Table 3.1 Freshwater fish found in the lower Barwon-Darling (Baarka) River.

Fish Species	Key Migration Direction: Longitudinal ↕ Lateral ↔ Facultative ()	Fish Length
Golden perch	↕ ↔	• ● O
Silver perch	↕	● O
Murray cod	↕ (↔)	• ● ●
Freshwater catfish	↕ (↔)	O • ●
Southern purple-spotted gudgeon	↔	•
Olive perchlet	↔	•
Bony herring	↕	●
Spangled perch	↕	●
Murray–Darling rainbowfish	↕	•
Flat-headed gudgeon	↕	•
Un-specked hardyhead	↕	•
Carp gudgeons	↕	•
Dwarf flat-headed gudgeon	↕	•
Australian smelt	↕	•
Darling River hardyhead	↕ ↔	?

Fish length in table

O	Eggs and larvae
•	Very small (20-50mm)
•	Small (50-80mm)
●	Medium (80-500mm
●	Large (500-800mm)
●	Very large (800-1300mm)

The *primary design focus* (orange shading) for fish passage in river channels is upstream migration for fish from 50mm to 800mm in length, which includes juveniles and adults; and downstream passage of eggs and larvae. For upstream migration, fish passage is required from small pulses of flow, up to higher flows that drown-out the weir.

Adult Murray cod can complete their life cycle between weirs if there is flowing water habitat with woody debris. However, adult fish are likely to be important for recolonising after drought events that result in substantial mortalities within a river reach (e.g. hypoxic blackwater, hypoxic thermal stratification / algal blooms). Hence, a design focus is to enable passage of young adult Murray cod (500-800mm). Although only anecdotal, large Murray cod (1.0 to 1.2 m) were observed moving upstream during low flows in the drought in 2019, presumably seeking refugia. Hence, it would seem prudent to enable passage of these large fish at low flows at Wilcannia Weir.

These large cod need to pass rock bars (e.g. Christmas Rocks) downstream of Wilcannia before reaching the proposed new weir and fishway (~26 km upstream of Christmas Rocks). The minimum flow that these fish require to pass these rock bars can be used as a minimum for passing large cod in the proposed new Wilcannia weir fishway. We have made an assumption that 300 mm depth of submergence is needed over downstream rock bars to pass large cod, which would result in a minimum flow of approximately 60 ML/day at a relatively narrow rock bar (25m wide) with 0.3m depth passing at a velocity of around 0.1 m/s (slope 1 on 20,000). Smaller fish would probably pass this rock bar at 30 ML/day (0.2m depth).

The *wetland specialist* species require passage between the river and wetland and between wetlands. These species are likely to move between these habitats at high flows when there is a low differential head between these habitats and the main channel of the river.

3.2 Turtle Passage

In the last drought (2019) freshwater turtles were observed stranded and trapped in crevices in rock protection and in old fishways at existing Darling River weirs (Martin Mallen-Cooper, pers. comm). Ecological objectives for turtles in the present project are to enable:

i. upstream passage of turtles at very low flows (e.g. < 10 ML/day) and zero flows, and
ii. safe downstream passage at all flows.

3.3 Fishway Design Background

Fishway design has two components:

- <u>attraction</u> (ensuring fish can locate the fishway entrance), and
- <u>passage</u> (ensuring fish can ascend/descend the fishway).

Attraction Design

Upstream limit of migration

Fish that are migrating upstream swim to the *upstream limit of migration*. If there are high water velocities or turbulence at structure discharge areas, fish will seek a path adjacent to these zones.

The fishway design objectives are to:

i. locate the fishway entrance at the *upstream limit of migration*;
ii. create an *upstream limit of migration* that guides fish to the fishway entrance, which involves the design of crest, gates, abutments, overflow embankments and riverbank works; and
iii. ensure the fishway entrance and guiding attraction flow discharges are not masked by competing flows, turbulence and recirculating eddies.

These objectives apply to the range of flows over which fish are migrating.

Proportion of river flow in fishway

Fish are attracted to flow (i.e. discharge) and fishways have greater attraction for fish if they pass more of the river flow. Passing 100% of flow through the fishway is desirable but this only occurs in fishways that occupy the full width of the river; or at low river flows. Passing 10% of river flow through the fishway is a useful target for the upper range of flows, while at very low flows, all flow should be aimed at passing through the fishway.

Passage Design

Fishway passage design involves setting physical and hydraulic criteria which apply to the fishway channel that enable fish and other aquatic biota to pass effectively. These include:

- pool length and width,
- space (width and height) in baffle openings (if applicable),
- depth in pools,
- depth through baffles (if applicable),
- maximum turbulence,
- maximum water velocity,
- roughness (if applicable).

4. Fish Passage Objectives and Design Criteria

The ecology of the site results in specific objectives and design criteria for the passage of fish and turtles, which are listed in *Table 4-1* The criteria are applicable for the range of river flows that the weir would present a significant barrier to upstream fish passage or to fish mortality when passing downstream.

Table 4-1 Fish passage objectives and design criteria.

Fish Passage Objectives	Design Criteria & Requirements
Upstream Passage – Entrance Attraction Conditions	
Maximise river discharge through fishway	▪ 100% of river discharge in fishway is desirable. ▪ Maximise proportion of fishway discharge at low river flows. ▪ Target minimum 10% of river discharge in fishway at high river flows.
Weir design provides flow patterns that guide fish to fishway entrance	▪ Integrate design of crest, gates, abutments, overflow embankments and riverbank works with fishway structure to optimise downstream flow patterns for fish attraction to fishway. ▪ Ensure fishway entrance is not masked by competing flows, turbulence and recirculating eddies. ▪ Physical modelling of the weir and the downstream portion of fishway is highly beneficial to achieve this objective and reduce attraction risks. (Note: i) it is very costly to modify the structure after construction if attraction conditions are poor, ii) it is very difficult to predict flow patterns in the complex 3D space of a river and weir). ▪ Computational fluid dynamics (CFD) modelling can be used either: i) to assess different high-level options, or ii) to refine the final design at more detailed scales, where viscosity is limiting in a scale physical model.

Fish Passage Objectives	Design Criteria & Requirements
Fishway entrance easily located by fish and not bypassed	▪ Locate fishway entrance at the *upstream limit of migration*. This objective is also part of weir design and development of an integrated layout with the appropriate application of physical and/or CFD modelling. ▪ Entrance flow from fishway oriented downstream.
Upstream Passage – Internal Conditions	
Minimum size of fish = 50 mm	▪ Maximum turbulence of 35 W/m^3 (ref. C_d 0.7, typ. vertical-slot). ▪ Maximum velocity in *vena contracta* (if applicable) of 1.4 m/s (nominal 0.1m headloss). ▪ Minimum depth of 300 mm. (Note: depth for large fish is limiting in design).
Medium size of fish = 80 to 500 mm	▪ Maximum velocity in *vena contracta* (if applicable) of 1.7 m/s (nominal 0.15m headloss). ▪ Minimum depth of 500 mm. (Note: depth for large fish is limiting in design).
Maximum size of fish = 800 to 1300 mm	▪ Maximum turbulence of 90 W/m^3 (ref. C_d 0.7, typ. vertical-slot). ▪ Maximum velocity in *vena contracta* (if applicable) of 2.0 m/s (nominal 0.2m headloss). (Note: turbulence and water velocity for small fish are limiting in design). ▪ Minimum depth of 1.0m.
Passage of 1.0-1.2m adult Murray cod at low flows	▪ Minimum depth of 1.0m at approximately 60 ML/day.
Passage of turtles	▪ Enable turtles to safely crawl through fishway at low flows; and additionally, to crawl around fishway isolation gate(s) at the upstream end of the fishway in drought security periods.
Migration during low flows and large pulse flows e.g. 10,000-20,000 ML/day	▪ Operation of fishway from 60 ML/day up to drown-out. (Note 1: this determines the range of headwater and tailwater levels for operation of the fishway. "Drown-out" in the context of upstream fish passage is defined as conditions when passage of fish is anticipated directly over the weir and along abutments: <250 mm head differential if rocky banks, and <100 mm if vertical concrete abutment. Note 2: Min fishway discharge could be reduced in future by simple addition of baffle plates on lower slots).
Fishway exit gate headloss	▪ 50% fish max baffle headloss (Δh_{max}) for fishway exit gate provisions.

Fish Passage Objectives	Design Criteria & Requirements
Downstream Passage	
Drifting eggs and larvae, and fish 50-800 mm	▪ Overshot gates (rather than undershot gates) or fixed weir crests, with either: downstream plunge pool(s) that have a depth that is minimum 40% of the differential head (drop height); or shallow gradient downstream weir embankment or chute: slope 1V on 3H or flatter. (Note: design to avoid need for any downstream dissipator baffle blocks or similar abrupt obstructions intended to intercept high velocity flows). ▪ Maximum turbulence in fishway of 150 W/m^3. (Note: this is an estimate as there is no data on downstream passage of eggs and larvae in fishways).
Possible passage of adult Murray cod 800 to 1300mm over gate or crest but not considered an ecological priority and subject to limitations on discharge requirements	▪ Minimum depth for largest fish = 0.5m. (Note 1: large Murray cod have passed downstream over rockfill weirs with 0.5m depth but may also pass at shallower depths. Note 2: refer also to above criteria re downstream plunge pool depth requirements).

5. Weir Configuration

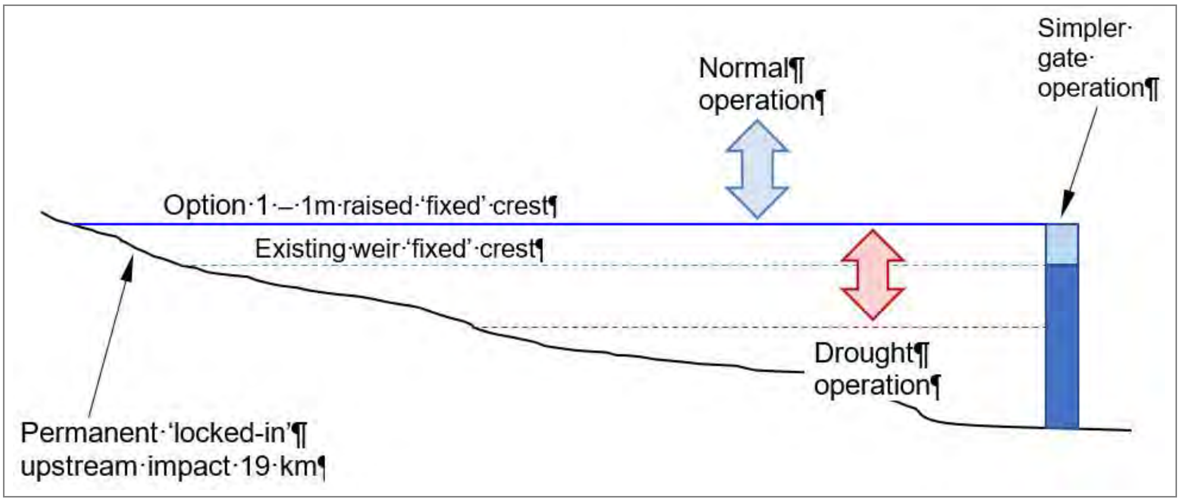
5.1 Options

Description

Two weir options were considered:

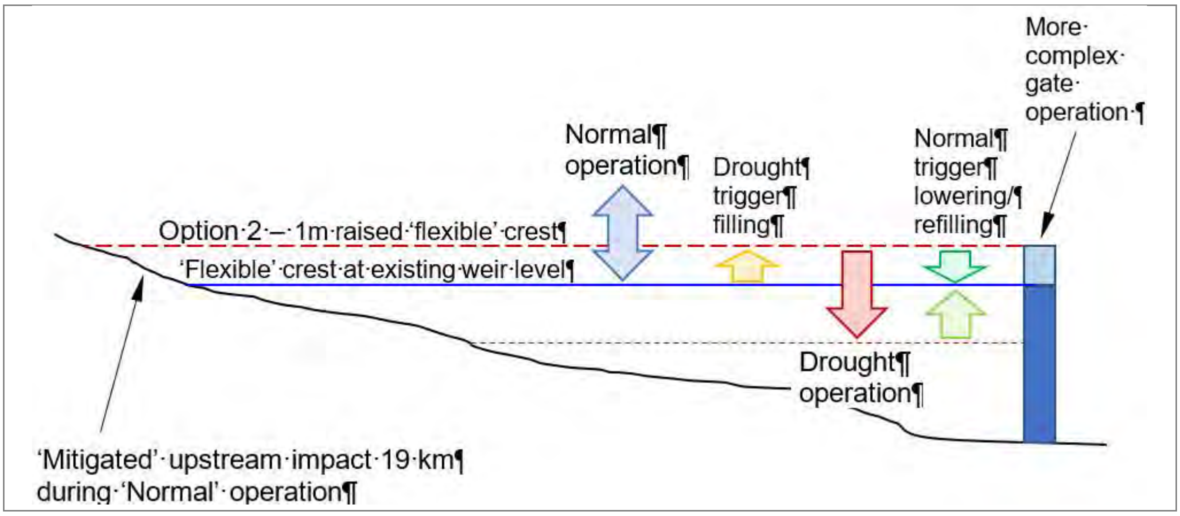
<u>**Option 1**. A “fixed crest” option</u>:

1m higher weir (compared to existing weir) operating with a minimum 1m higher weirpool headwater level when the river is flowing.



<u>**Option 2.** A "flexible crest" option with dual operating modes</u>:

1m higher weir operating in two modes: i) 'normal' mode with a minimum weirpool headwater level matched to the existing weir crest level when the river is flowing; and ii) 'drought' mode with headwater raised by 1m when zero flows are anticipated.



Evaluation

<u>Option 1</u> would cause an additional 19 km of non-flowing backwater that would permanently inundate existing *flowing water* habitat upstream and impact habitats of River mussels, River snails and nursery areas of Murray cod.

<u>Option 2</u> has been determined by WaterNSW as the preferred infrastructure design pathway because it would only produce non-flowing inundation of the additional 19 km when there were periods of zero flow (which are natural periods of *stillwater* [pool] habitat) or when impending near-zero flows were anticipated. Hence, this option met the key ecological objective of "minimising impacts on upstream *flowing water* habitats". Refer to recommended investigations below in relation to need for confirmation of adequacy of upstream flowing water habitat conditions and gate discharge capacity requirements.

5.2 Gate Design

<u>Weir Option 1</u> required a gated outlet in the weir crest aimed at passing saline water, which was requested by the Wilcannia community, and to provide transparency/translucency of environmental inflows.

<u>Weir Option 2</u> requires the same functions as Option 1 plus it needs to operate at lower headwater levels under flowing conditions to minimise the impact on upstream reaches of existing *flowing water* habitats. Sizing of the gated outlets and capacities were analysed (*Appendix A*) and two 3.5m wide overshot gates were selected for the preliminary concept design. However, the current stage of the project has not quantified the upstream impacts on *flowing water* habitats and a hydrodynamic model is needed as a next step to optimise this component of the project.

Recommended investigations in Detailed Design

The following are recommended to further inform design and quantify the benefits of the dual operating mode:

- Hydrodynamic modelling of minimum 19 km reach upstream of the existing weirpool extent with different gate discharges and headwater levels. It is envisaged that this model would extend upstream from the existing weir;
- Assessment to link hydrodynamic model with a daily hydrological model to quantify spatio-temporal impacts on *flowing water* habitats and to confirm gate discharge capacity requirements.

Appendix B provides a plot that provides some insight to the flow discharge requirements to achieve a specific velocity objective within the river reach comprising the main sections of the existing Wilcannia weirpool.

6. Headwater and Tailwater

Confirmation of the “flexible crest” option (Option 2), a weir crest height, and the outlet gate capacities, enables the headwater and tailwater level relationships to be developed. These relationships allow the operating ranges and corresponding differential heads to be determined for the combined weir and fishway structure, which are fundamental inputs to the design of any fishway option. A summary of key levels is shown in *Figure 6-1* and more detailed data is shown in *Figure 6-2*.

The maximum differential head is 3.01m, which would require 28 fishway baffles (0.11 m head loss per baffle) *plus* an additional 3 baffles to guard against a potential future tailwater lowering allowance of 0.33m. The initial head differential nominated for the fishway design is 2.75m, – which would require 25 fishway baffles *plus* an additional 3 baffles for tailwater lowering allowance. The 2.75m head differential is set, and depends on, a tailwater with a flow of 60 ML/day.

The headwater range is 2.53m, which is large for this height of weir. Typically, the headwater range for low-level, fixed-crest, weirs is 0.5m to 1.5m. The analysis for these levels and assessment of the headwater rating has assumed two 3.5m wide gates (*Appendix A*). Headwater range and drown-out would be less, with more gates in the weir crest, but the cost savings in the fishway height may be offset by the cost of additional gates; nevertheless, this may be a useful optimisation in detailed design.

Figure 6-3 provides the developed headwater and tailwater rating curves for the preliminary concept design, noting the ‘black’ line accounts for the current gate opening operational assumptions.

Figure 6-4 shows the plot of storage behaviour modelling results for simulated flow conditions and implementation of preliminary operating rules for ‘flow resumption’ on triggering of ‘normal’ mode coming out of ‘drought’ conditions.

Recommended Investigations in Detailed Design

- Investigate effects of the number and size of gates on headwater, drown-out and fishway design. (Note that more gates are likely to reduce headwater range, reduce the drown-out flow and provide lower fishway cost but would increase weir cost due to additional outlet gates).
- Evaluate the function, design and cost implications of the fishway designed for 2.75 m and 3.01 m differential heads.

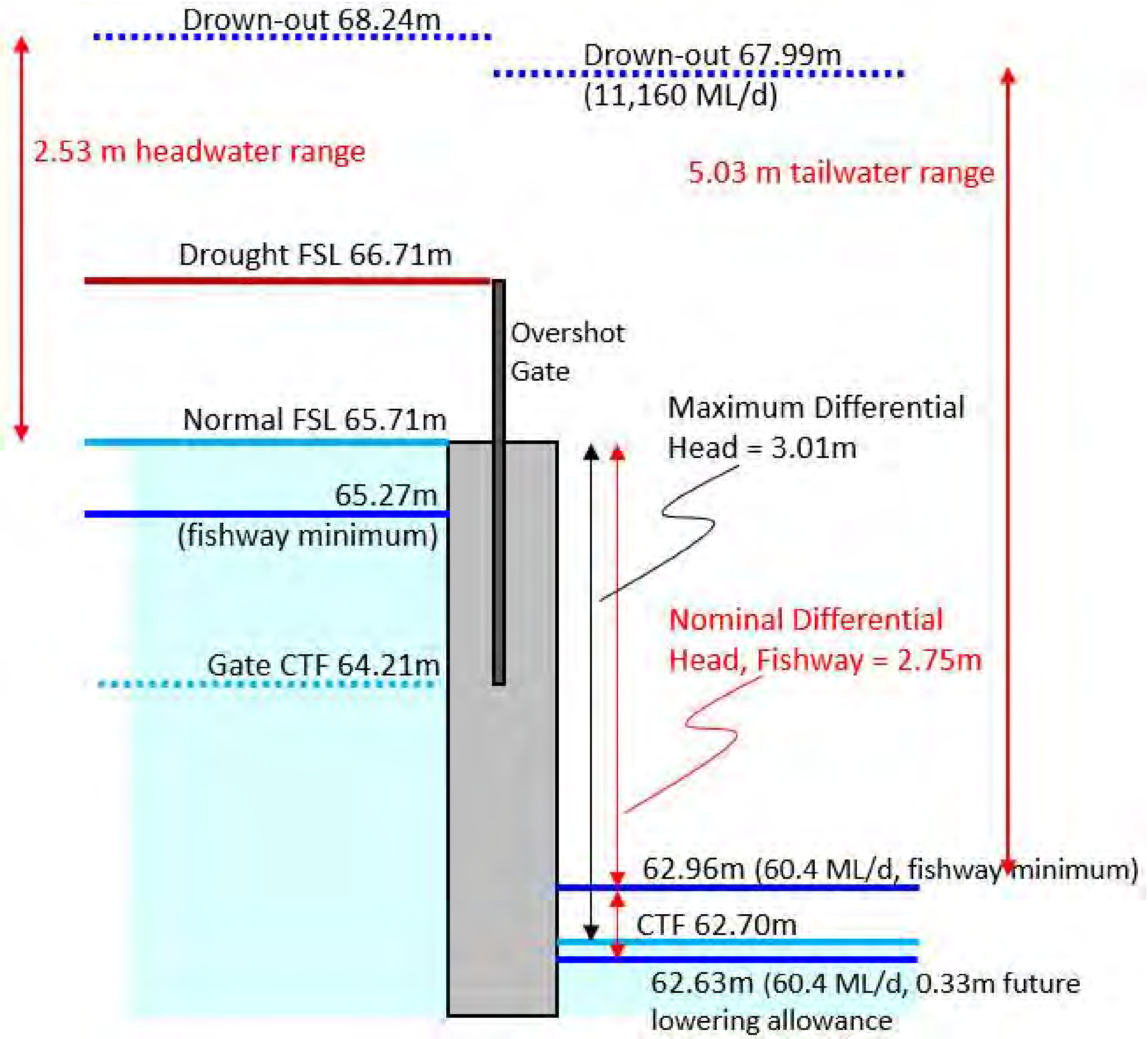


Figure 6-1 Summary of key levels for fishway operating in 'normal' flowing river conditions.

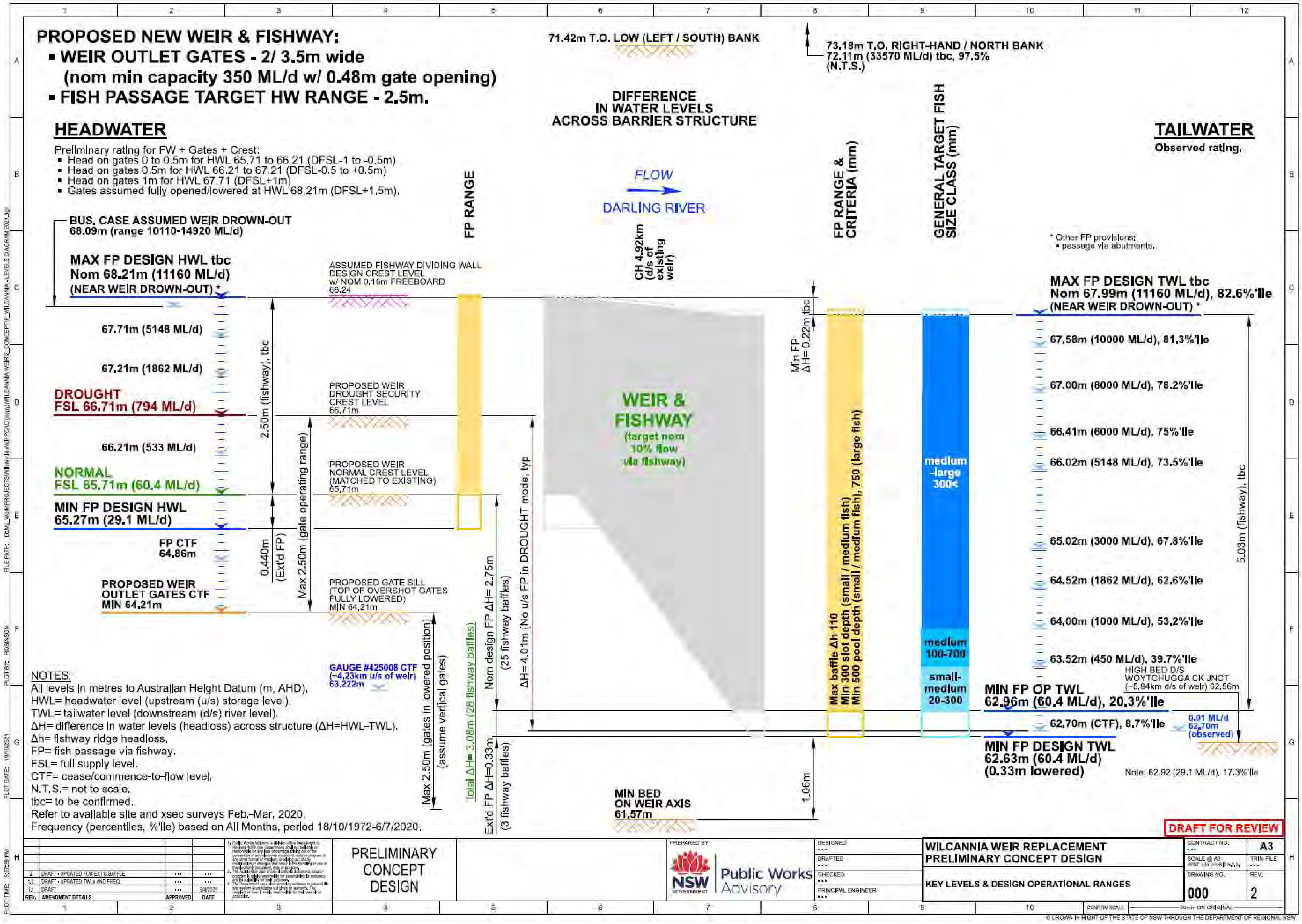


Figure 6-2 Key levels for fishway.

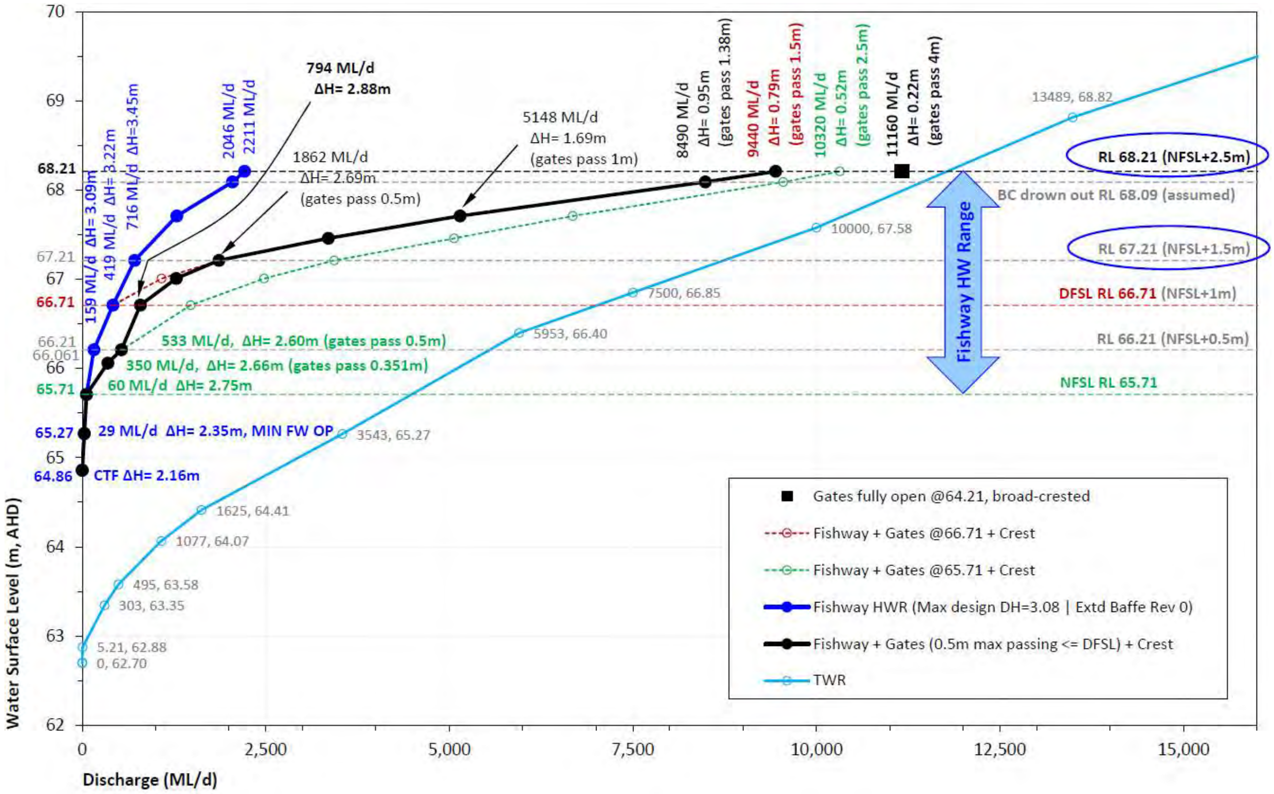


Figure 6-3 Preliminary concept headwater and tailwater rating curves.

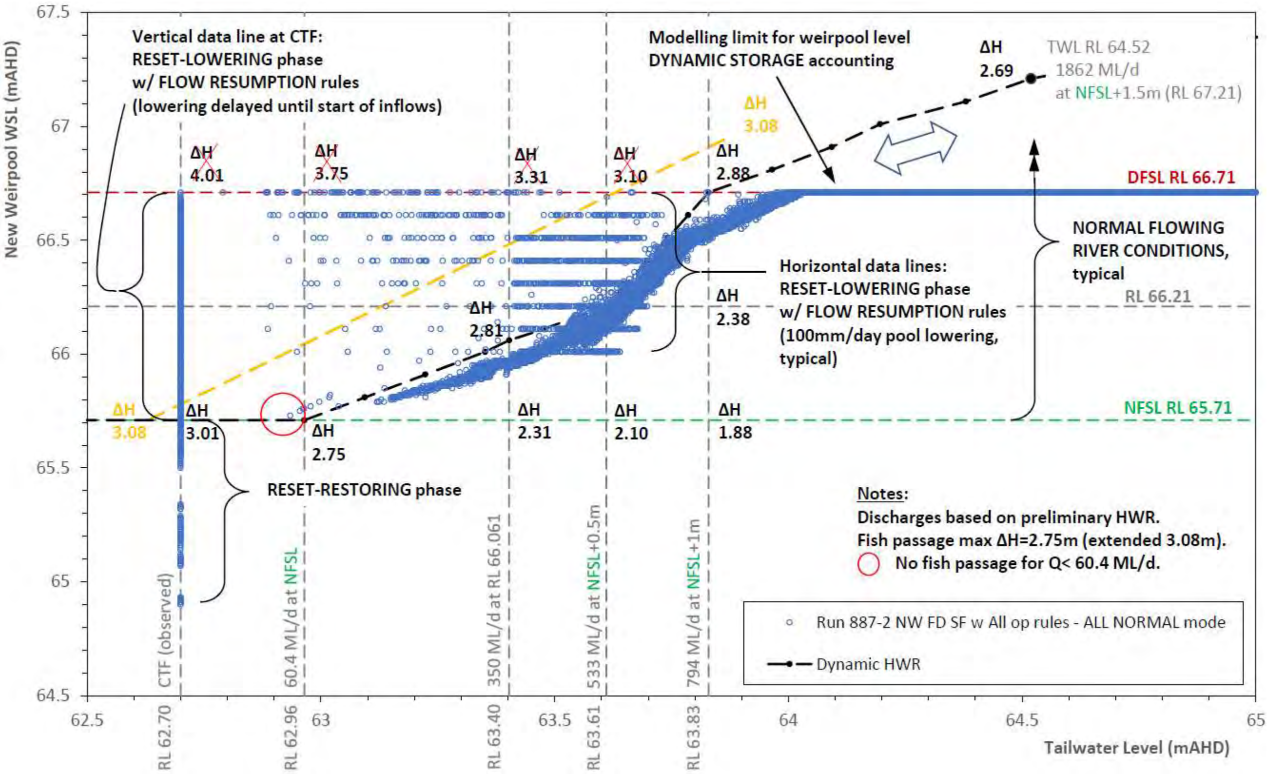


Figure 6-4 Indicative storage behaviour modelling results for proposed new weir in 'normal' mode with future demands and preliminary operating rules and simulated flows.

7. Fishway Options

The Strategic Fishway Implementation Program (SFIP) of WaterNSW investigated the function and costs of fishways in NSW with the aim of clarifying function and reducing cost. A significant finding was that the costs of fishways were highly dependent on:

i. construction risk, including perceived risk;

ii. construction time and

iii. design complexity

These findings led to:

- firstly, developing generic ecological and fish passage objectives that could be applied to bioregions and habitats (e.g. wetlands vs river channels), and
- secondly, developing a construction methodology that minimised risk, construction time and complexity.

The most common construction technique for fishways is cast *in-situ* concrete. The construction methodology developed in SFIP comprises:

i. enclosing the fishway in sheet pile, which:
   - serves as the coffer dam, and
   - reduces the height and weight of fishway concrete walls (because the sheet pile acts as the outer fishway wall),

ii. using a compacted soil base (instead of concrete pier foundations) because seepage paths are contained by the sheet piles and concrete weights are low, however, this may be countered by floatation risk,

iii. using low-height, interlocking pre-cast fishway units (minimising time on site).

A precast vertical-slot fishway was also a potential option, however, it was not specifically investigated in detail for the SFIP since other fishway types offered greater fish passage functionality and attraction discharge, although with potentially more constrained operating ranges.

The SFIP project developments were drawn upon and led to three options being considered for Wilcannia:

Option 1. Cast *in-situ* vertical-slot fishway,

Option 2. Precast concrete fishway in surrounding sheet piles (as per SFIP),

Option 3. Rock channel fishway with precast ridges in surrounding sheet pile.

Fishway Option 3 combines the SFIP construction methodology with the "Rock channel with precast ridge fishway" developed by Public Works Advisory and used at Kyogle on the Richmond River (*Figure 7-1*).

A high-level comparison of these three options is shown in *Table 7-1*. Functionally, all three can provide effective passage once fish have entered the fishway. However, the main differentiator in function, which is shown the table, is attraction discharge. The "cast *in-situ* vertical-slot fishway" has poor attraction discharge and does not meet, or approach, the criteria of 10% of discharge during flow pulses.

Construction time, complexity and risk is less with the two enclosed sheet pile options with precast concrete elements. These options have a large footprint (>11 m by 115 m) compared to a cast *in-situ* vertical-slot (2.8 m by 85 m) but the latter has walls up to 6 m high requiring significant foundations and piers, noting internal vertical-slot baffles would likely be precast. The enclosed sheet pile options have a maximum concrete height of 4 m which is only for the upper portion of the fishway, as the lower portion is submerged by tailwater and fish attraction is provided by high fishway discharge, while the flow contained by the high sheet pile walls (*Figure 7-2*).

Depending on site conditions and requirements for cut and fill foundation techniques there is a risk of differential settlement and floatation of the precast units that may add significant cost and complexity to address. If Option 3, the main alternative to Option 2, were to instead be pursued then the fishway concept would need to be significantly revisited to develop specific optimised design criteria, a fishway cross-section and baffle arrangement details.

No specific costings have been done for the current preliminary concept design stage. Despite the larger footprint of the enclosed sheet pile options, it is nevertheless expected that those options will cost less than a cast *in-situ* fishway and provide essential functionality.

The "precast concrete fishway in surrounding sheet pile" meets the key criteria and has the potential to be limited to reasonable construction complexity. Hence, this option has been developed for concept design. The "rock channel with precast ridges in surrounding sheet pile" remains a viable option and could be developed if the pre-cast concrete fishway develops high cost or complexity.

Figure 7-1 Rock channel with precast ridges at Kyogle on Richmond River, NSW.

Table 7-1 Comparison of three fishway options.

Item	Option 1 Cast *in-situ* vertical-slot fishway	Option 2 Precast concrete fishway in surrounding sheet piles (current design)	Option 3 Rock channel fishway with precast ridges in surrounding sheet piles (alternative design)
FUNCTION			
Attraction discharge	✓	✓✓✓	✓✓✓
Passage – wide size range	✓✓	✓✓✓	✓✓✓
Passage – large biomass	✓	✓✓✓	✓✓✓
Channel conditions (depth, turbulence)	✓✓	✓✓✓	✓✓
COST & COMPLEXITY			
Construction risk, time and complexity	✓	✓✓ **2.**	✓✓✓
Low capital cost	✓✓ **1.**	✓✓	✓✓✓ **3.**

Notes:

Key: ✓ Poor | ✓✓ Moderate | ✓✓✓ Best.

1. Option 1. Cost may be higher if additional weir outlet gates required, potentially a fully gated weir, to compensate for low fishway discharge capacity.
2. Option 2. Complexity may increase if significant challenges arise, for example, with constructability, joint sealing, and differential settlements.
3. Option 3. Cost may be higher if an additional weir outlet gate is required assuming fishway discharge capacity is less than Option 2.

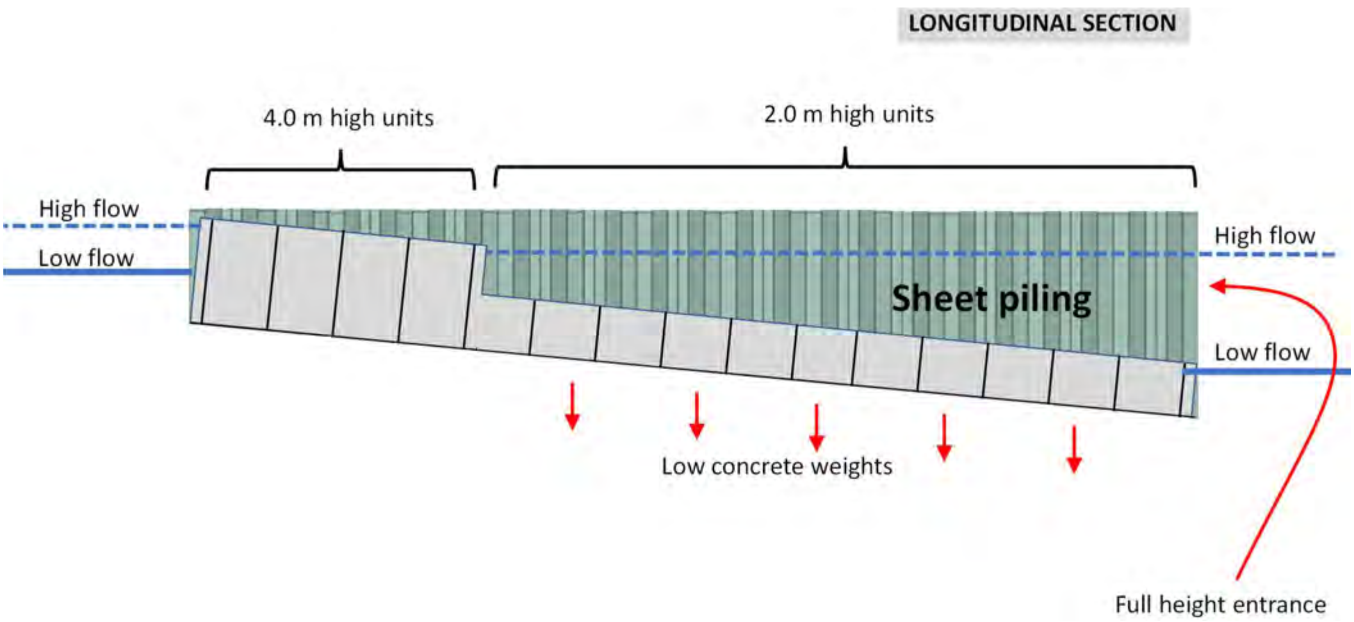


Figure 7-2 Fishway Concept Option 2 - Precast concrete fishway in surrounding sheet piles.

8. Applied Design Criteria and Fishway Configuration

The *Precast Concrete Fishway* (Option 2) would use a pool-and-ridge design with baffles that have a 'V' cross-section with evenly-spaced vertical-slot gaps, two deep slots for low flows, ramps for turtles at low flows, and an extension on the bank for high flows for the upper portion of the fishway. An overview of the baffle is shown in *Figure 8-1* and detail is shown in *Figure 8-2*.

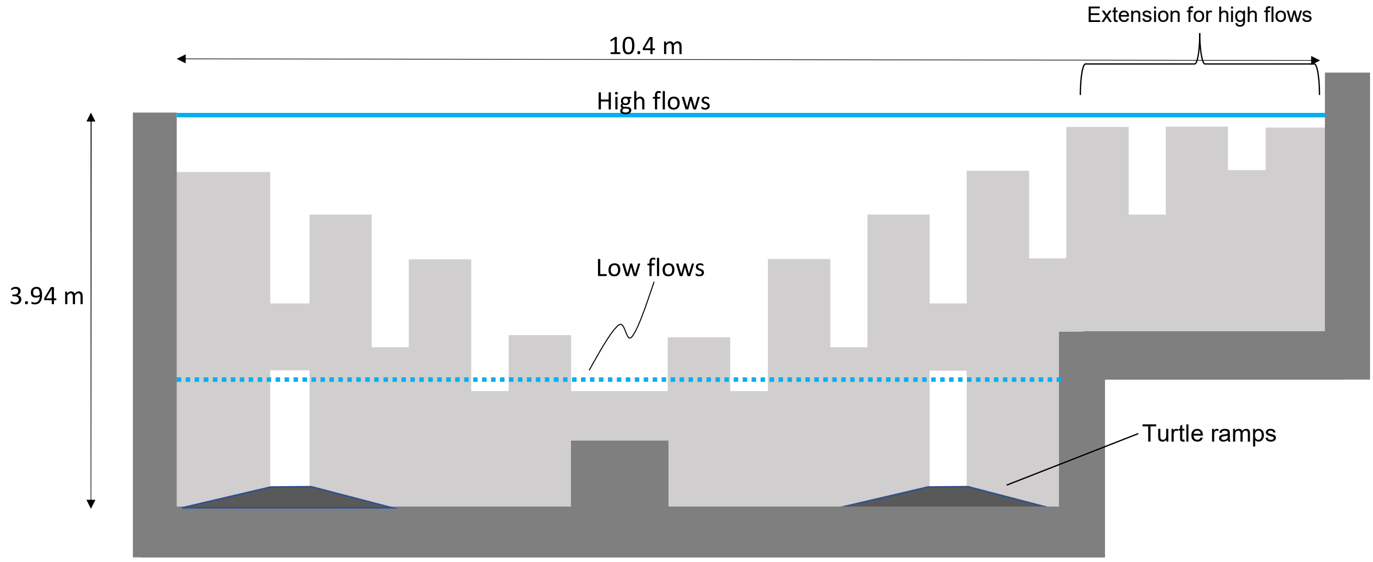


Figure 8-1 Overview of proposed baffle for Wilcannia fishway.

The baffles (or ridge elements) are proposed to be precast concrete panels to improve constructability and consistency of performance with theoretical hydraulic design. The fishway channel will be interlocking precast concrete units placed on a prepared and compacted soil base; note that the permanent surrounding sheet pile prevents seepage paths and undermining.

The design criteria applied to the proposed fishway concept are presented in *Table 8-1*.

A provisional fishway layout is shown in *Figure 8-3*. It is a near-straight channel recessed into the weirpool. Downstream looping arrangements were explored but the high discharge in the fishway requires a large turning pool, which added significantly to the fishway length. A looping arrangement also occupied a significant portion of the width of the river. The recessed arrangement places the fishway entrance generally adjacent to the two weir gates. Although high flows from the weir gates would likely create a recirculation in front of the fishway, the design intent is that high flows from the fishway would limit/prevent this from occurring to a determinantal extent.

Recommended Investigations in Detailed Design

CFD and physical modelling is required to optimise the fishway arrangement integrated into the weir structure in relation to entrance attraction conditions, location of upstream limit of fish migration and positioning of the entrance, and also to confirm suitable internal fishway hydraulic conditions focused on baffle geometry and associated turbulence. These investigations have the potential to require significant modification of the fishway concept and for the provision of additional weir outlet gate(s).

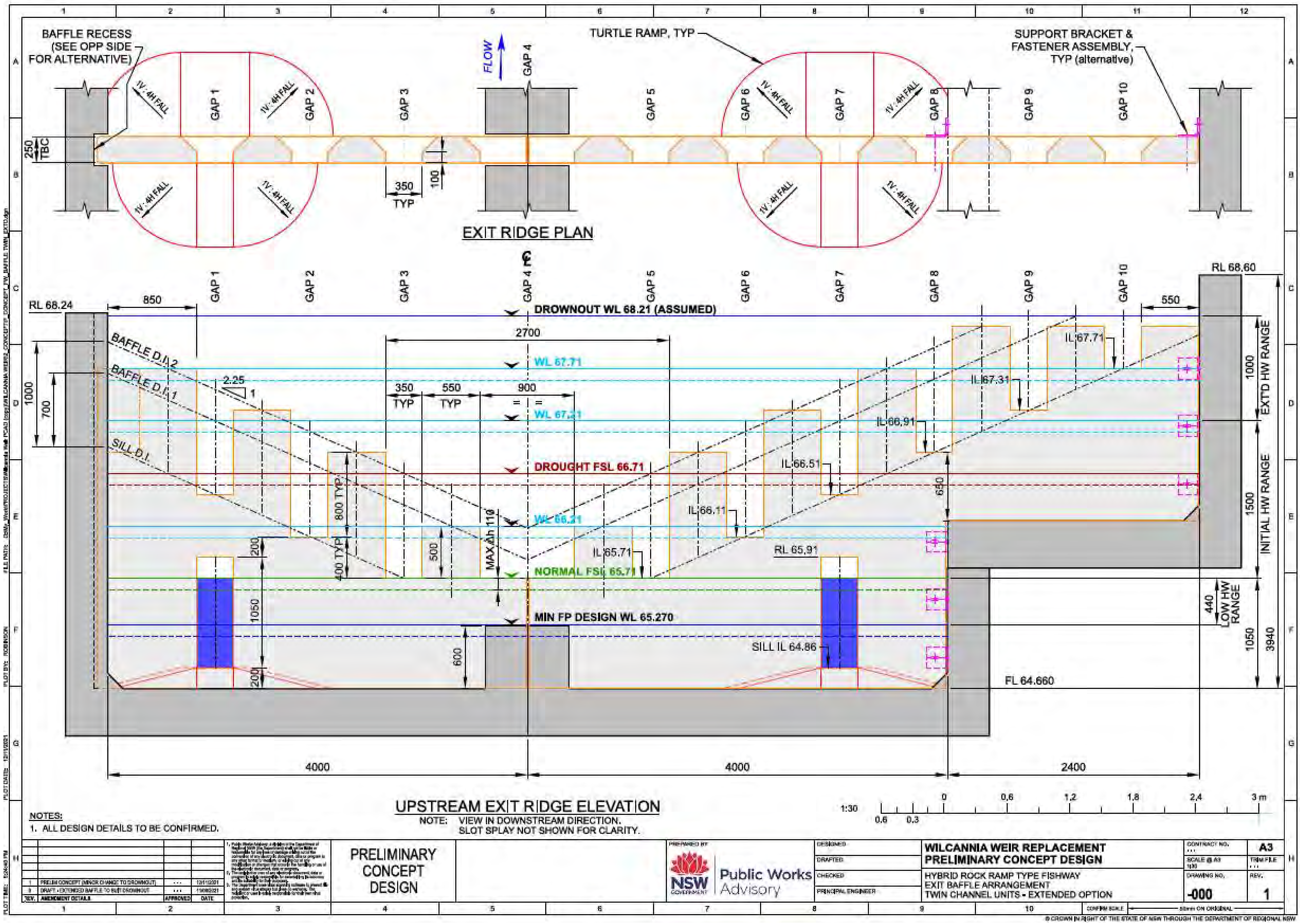


Figure 8-2 Detail of proposed baffle for Wilcannia fishway.

Table 8-1 Design criteria for precast concrete fishway in surrounding sheet piles.

Item	Concept Design	Comments
PHYSICAL		
Pools		
Pool length (internal) (typical baffle clear spacing)	typical 2000mm Propose 4000mm	Proposed increased pool length required due to need for high fishway discharge capacity. Length required to achieve project-specific slope criteria. Resting pool(s) differ, if any.
Pool length (typical baffle centre-centre spacing)	assumed 4250mm (to be later confirmed)	
Baffle thickness	assumed 250mm (to be later confirmed)	No standard criteria. 100mm through slot constriction then flared 45° outward on downstream side.
Pool width	8000mm	
Extended channel width for high flows	2400mm additional width	
Total fishway width (internal)	10400mm	
Resting pool baffle clear spacing	None	Potential to incorporate within a fishway turning bay, if any.
Baffles		
Baffle (ridge) cross-section shape	1 on 2.25 vee with a 2350mm wide central horizontal section	Steep side slope aimed at achieving large headwater operating range. Horizontal section is w.r.t. to Gaps 3 & 5 slot centrelines.
Baffle slot spacing	typical 900mm (centre to centre)	No criteria. Gaps 3 & 5 are at 1175mm centres w.r.t. the fishway central slot (Gap 4) and the fishway channel centreline.
Typical baffle unit projection height	500mm for Gaps 3, 4 & 5 1000mm for Gaps 2 & 6 700mm for Gaps 1 & 7 (at gap slot centreline)	No criteria. Height is relative to the gap slot sill level and w.r.t. to the design intent (D.I.) lines.
Baffle slot sill height (typical)	min 100 - 200mm Propose: ▪ 200mm for submerged bottom slots in Gaps 1 & 7 ▪ 1050mm for central Gaps 3, 4 & 5 ▪ 1450mm for upper slots in Gaps 2 & 6 ▪ 1850mm for outside Gaps 1 & 7	Standard criteria range. Height is relative to the fishway channel bed. Proposed high sill heights are aimed at >750mm pool depth at near NFSL for large fish and for minimisation of high discharge internal turbulence. Sill heights vary for remaining gaps

Item	Concept Design	Comments
Baffle slot width (typical)	300mm (at slot sill level) Propose: ▪ 350mm typical ▪ 900mm for centre Gap 4)	Typical standard criteria. Slots to be symmetrical about gap slot centreline. Propose rectangular gap slots that are wider than standard with aim of achieving increased fishway discharge and passage of large adult Murray cod at this significant gateway structure to the northern Murray-Darling Basin
Slope		
Longitudinal fishway slope	Nom. slope 1 on 35-40 Propose: ▪ nom slope 1 on 36.36 ▪ true slope 1 on 38.64	Criteria range. *Nominal* slope criteria is based on the clear spacing length between adjacent baffles. Refer to Item – '*Typical baffle clear spacing*' below for proposed length. *True* slope is based on the centre-centre spacing length between adjacent baffles. Refer to Item – '*Typical baffle centre-centre spacing*' below for proposed length.
Length		
Fishway length	114.750 m (4250 mm pool length by 27 pools)	
HYDRAULIC		
Max baffle (ridge) headloss, Δh_{max}	100 to 115mm Propose 110mm	Criteria range. Criteria targeted at existing/extant fish species and sizes for site location within catchment / basin and to suit other fishway criteria. Adopted high-range Δh_{max} to minimise fishway length and increase discharge capacity. CFD/physical modelling should include investigation of field observed behaviour that results in increased respective headloss over the upstream 2 or 3 baffles nearest to the exit. This behaviour is expected to be attributable to slower approach velocities off the weirpool with consequent higher contractions (lower C_d values) compared to the downstream portion of the fishway. Varied baffle slot geometry near the exit is to be considered in detailed design.
Max slot velocity	1.47 m/s (at vena-contracta)	Theoretical velocity criteria attributable to proposed Δh_{max}.
Average slot velocity	1.18 m/s (at gap slot constriction)	Not a typical performance metric. Average velocity based on an adopted slot coefficient of discharge (Cd) of 0.8.
Slot depth over sill	Min. 300mm Propose 740mm within submerged bottom slots in Gaps 1 & 7 at near NFSL for larger fish	Typical criteria for smaller fish in rock ramp fishways. Minimum depth criteria apply on downstream side of target operational slots and allows for slot headloss. Minimum depth proposed to be satisfied at NFSL+0.410m for the three (3) central Gaps 3, 4 & 5.

Item	Concept Design	Comments
		Submerged slots at bottom of Gaps 1 & 7 provide minimum depth of 0.74m for large and other fish during flowing conditions at NFSL and above prior to sufficient depth being achieved in the upper slots.
Typical pool depth	Min. 400 / 500mm Propose min 940mm	Standard criteria for smaller fish in rock ramp fishways. Minimum depth satisfied at NFSL – at the upstream end of each pool. Increased depth aimed at larger fish and minimisation of high discharge internal turbulence.
Resting pool depth	not applicable	
Pool velocity	n/a	Criteria not typically applied to this type of design.
Turbulence	35 W/m^3	Proposed design turbulences downstream of the flowing slot gaps are to be later confirmed.

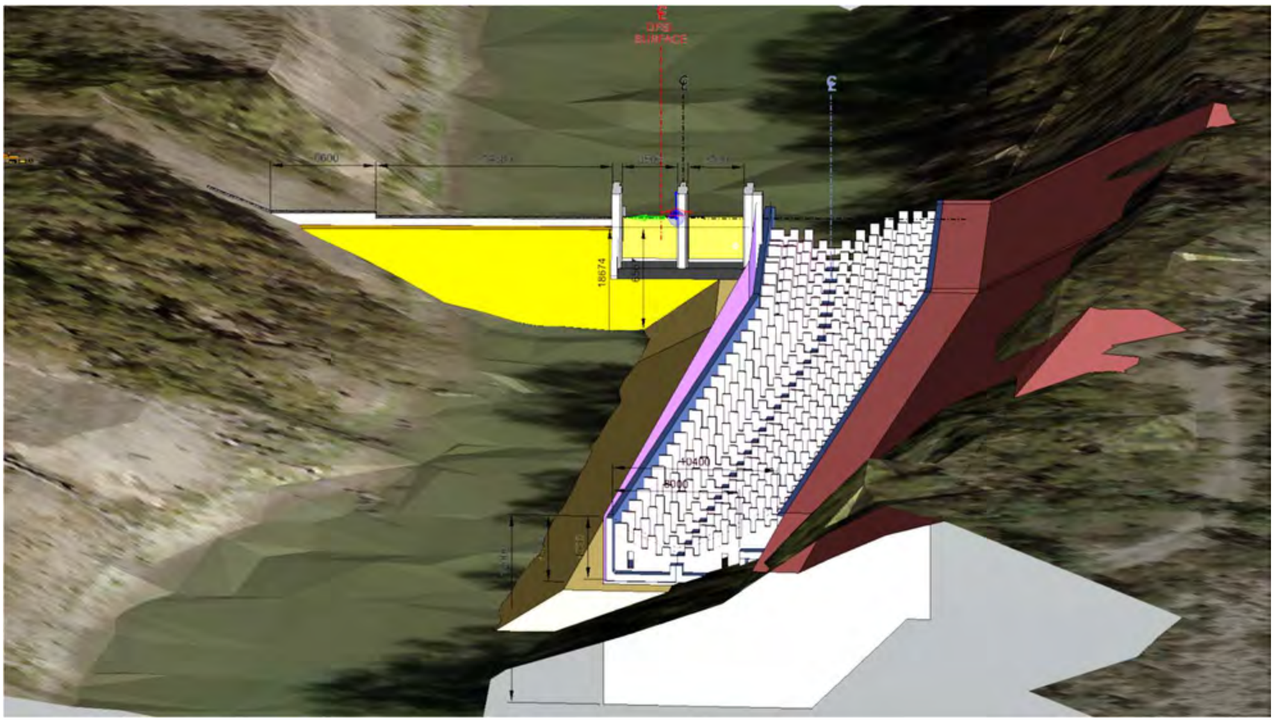


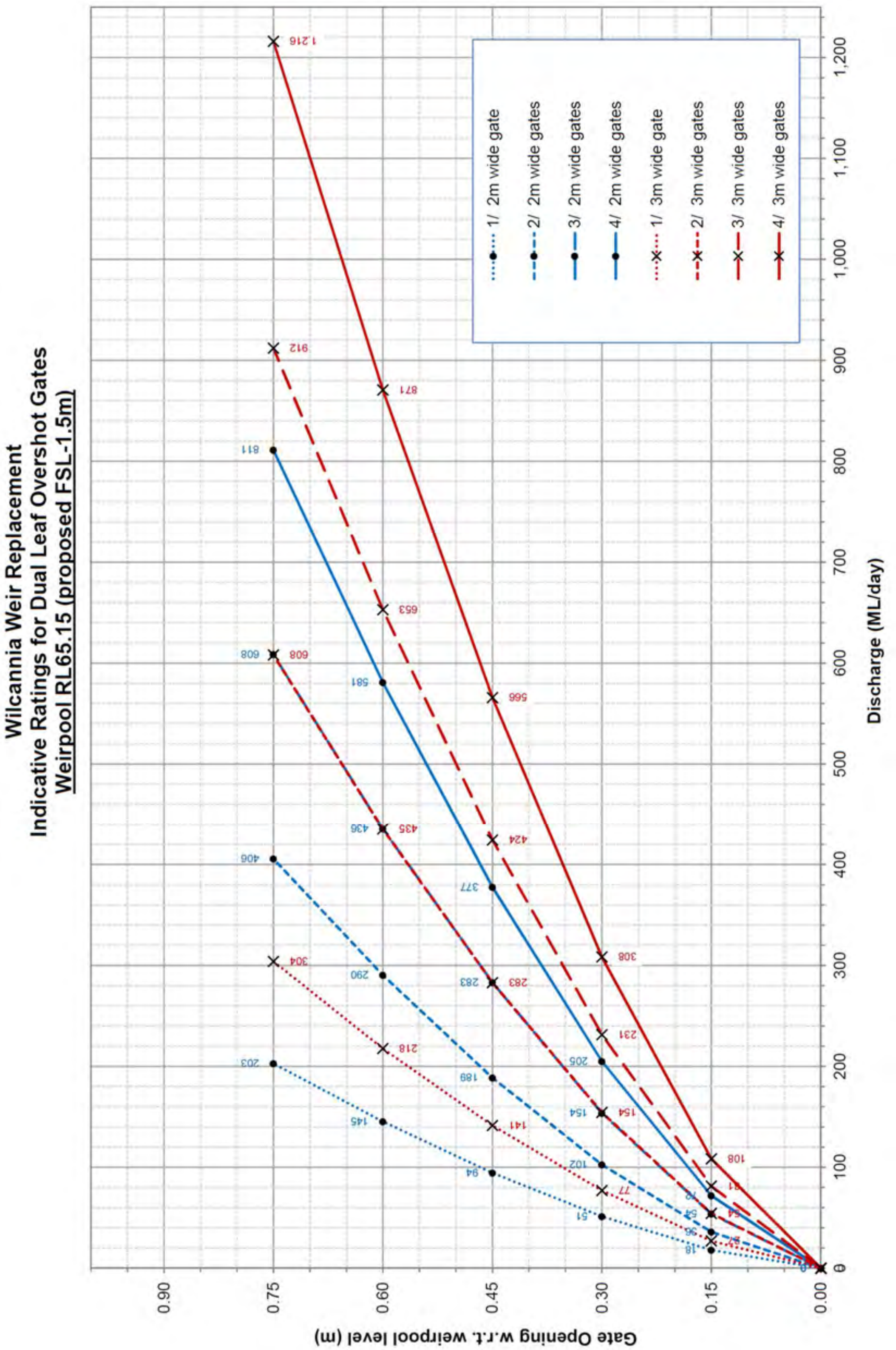
Figure 8-3 3D view of preliminary weir and fishway concept arrangement (excl. fishway gates) – view in downstream direction.

9. Next Stages

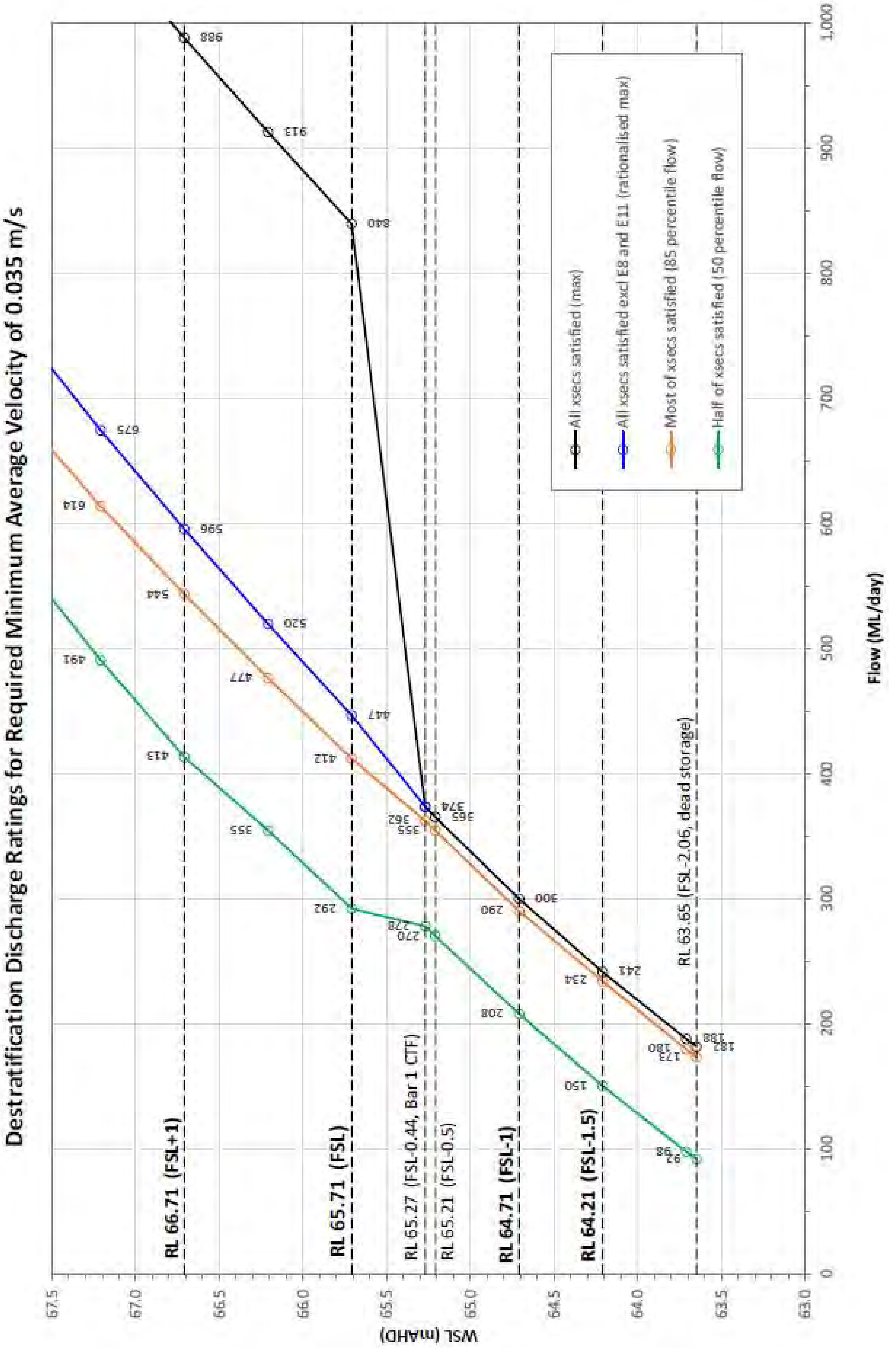
The concept design has identified areas that require investigation and review to confirm design criteria, prior to detailed design. These comprise:

- Hydrodynamic modelling of minimum 19 km reach upstream of the existing weirpool extent with different gate discharges and headwater levels. It is envisaged that this model would extend upstream from the existing weir.
- Assessment to link hydrodynamic model with a daily hydrological model to quantify spatio-temporal impacts on *flowing water* habitats and to confirm gate discharge capacity requirements.
- Investigation of the effects of the number and size of gates on headwater, drown-out and fishway design. (Note that more gates are likely to reduce headwater range, reduce the drown-out flow and provide lower fishway cost but would increase weir cost due to additional outlet gates).
- Evaluate the function, design and cost implications of the fishway designed for 2.75 m and 3.01 m differential heads.
- CFD and physical modelling is required to optimise the fishway arrangement integrated into the weir structure in relation to entrance attraction conditions, location of upstream limit of fish migration and positioning of the entrance, and also to confirm suitable internal fishway hydraulic conditions focused on baffle geometry and associated turbulence. These investigations have the potential to require significant modification of the fishway concept and for the provision of additional weir outlet gate(s).

Appendix A Discharge through different gate combinations for proposed Wilcannia Weir



Appendix B Weirpool destratification flow ratings (v=0.035m/s)



Appendix D. Mapping of upstream flowing water habitat impacts

Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

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200 0 200 400 600 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
100 ML/d - BAR 2

FIGURE NO.
EV100-13
Rev. 0

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Notes:
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WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
100 ML/d - BAR 3

FIGURE NO.
EV100-14
Rev. 0

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WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
200 ML/d - BAR 2

FIGURE NO.
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Rev. 0

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EXISTING VELOCITY
200 ML/d - BAR 3

FIGURE NO.
EV200-14
Rev. 0

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WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
350 ML/d - BAR 2

FIGURE NO.
EV350-13
Rev. 0

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U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
350 ML/d - BAR 3

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U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
600 ML/d - BAR 2

FIGURE NO.
EV600-13
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Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

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U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
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FIGURE NO.
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U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
800 ML/d - BAR 2

FIGURE NO.
EV800-13
Rev. 0

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WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
800 ML/d - BAR 3

FIGURE NO.
EV800-14
Rev. 0

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WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
1400 ML/d - BAR 2

FIGURE NO.
EV1400-13
Rev. 0

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MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
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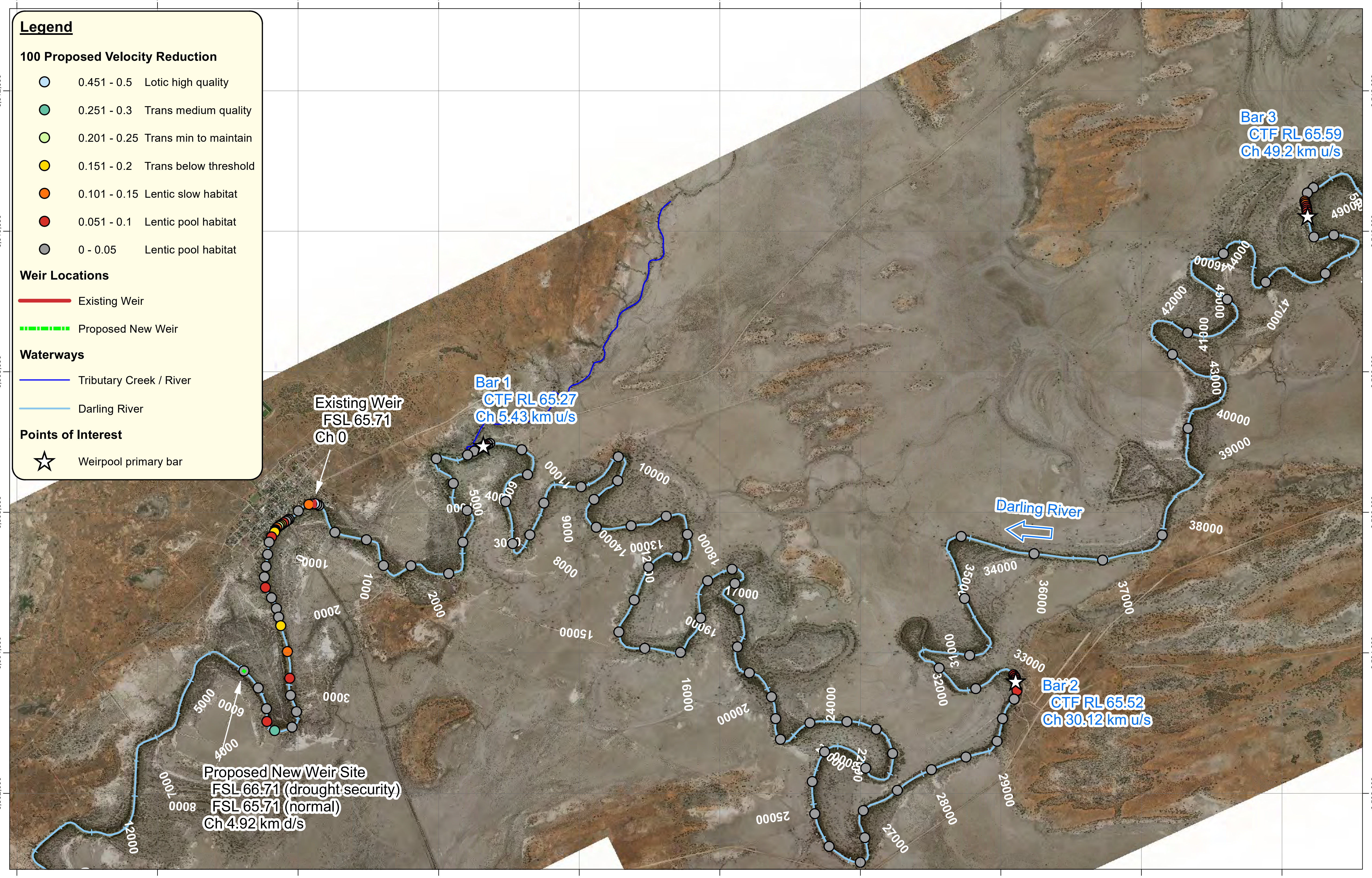

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Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

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1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
100 ML/d - SHEET 1 of 3

FIGURE NO.
EV100-1
Rev. 0

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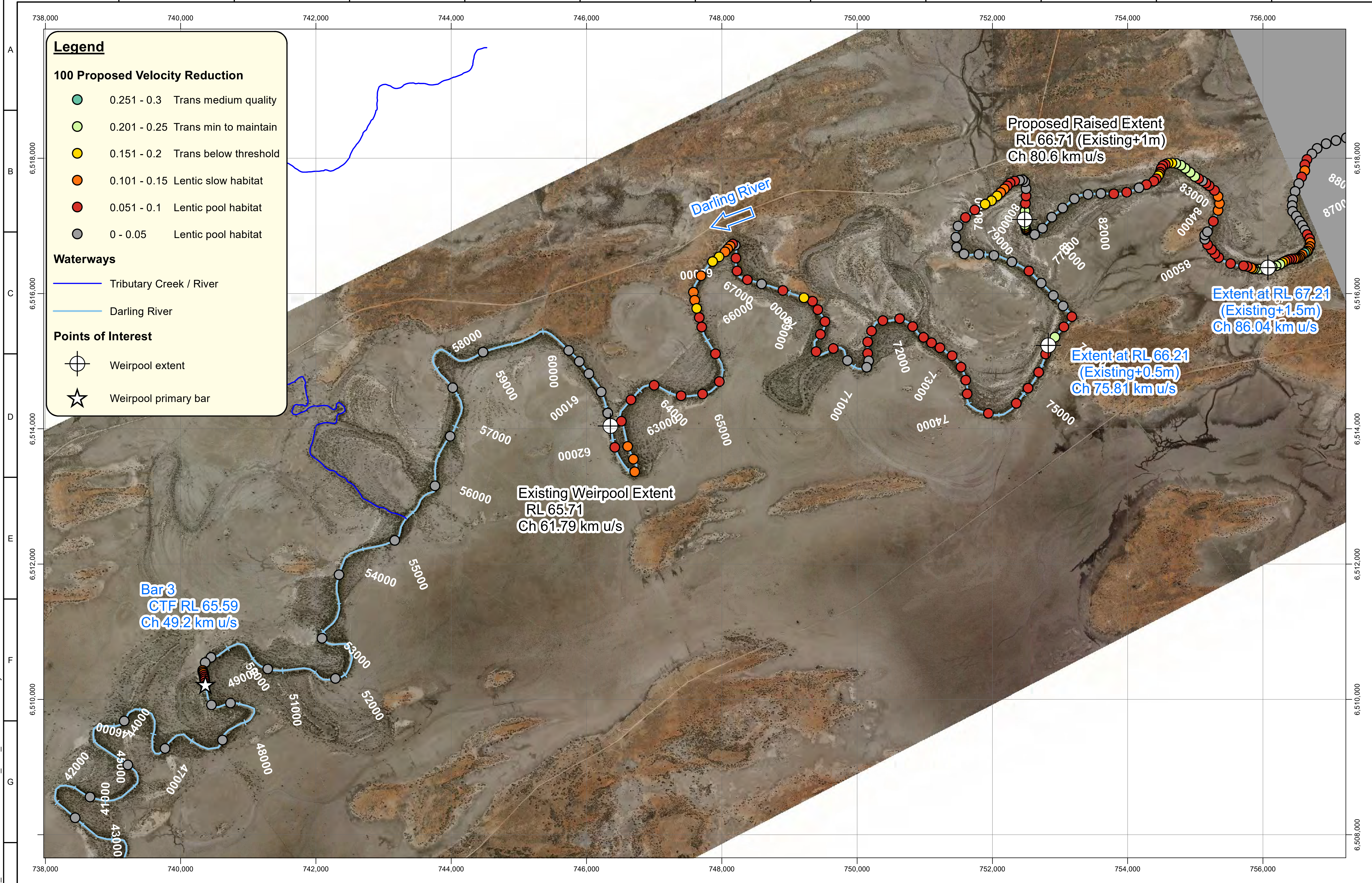

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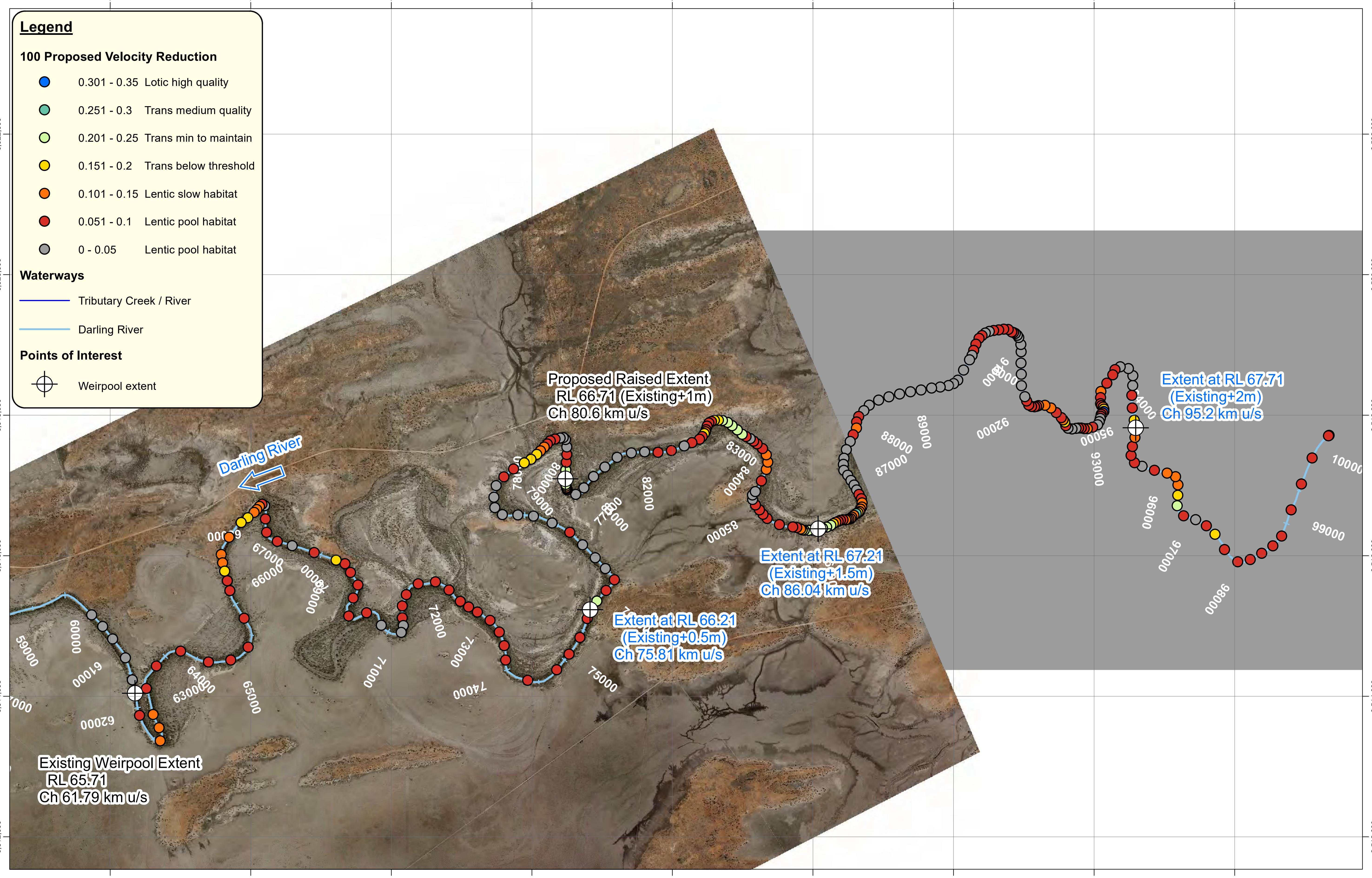
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
100 ML/d - SHEET 2 of 3

FIGURE NO.
EV100-2
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

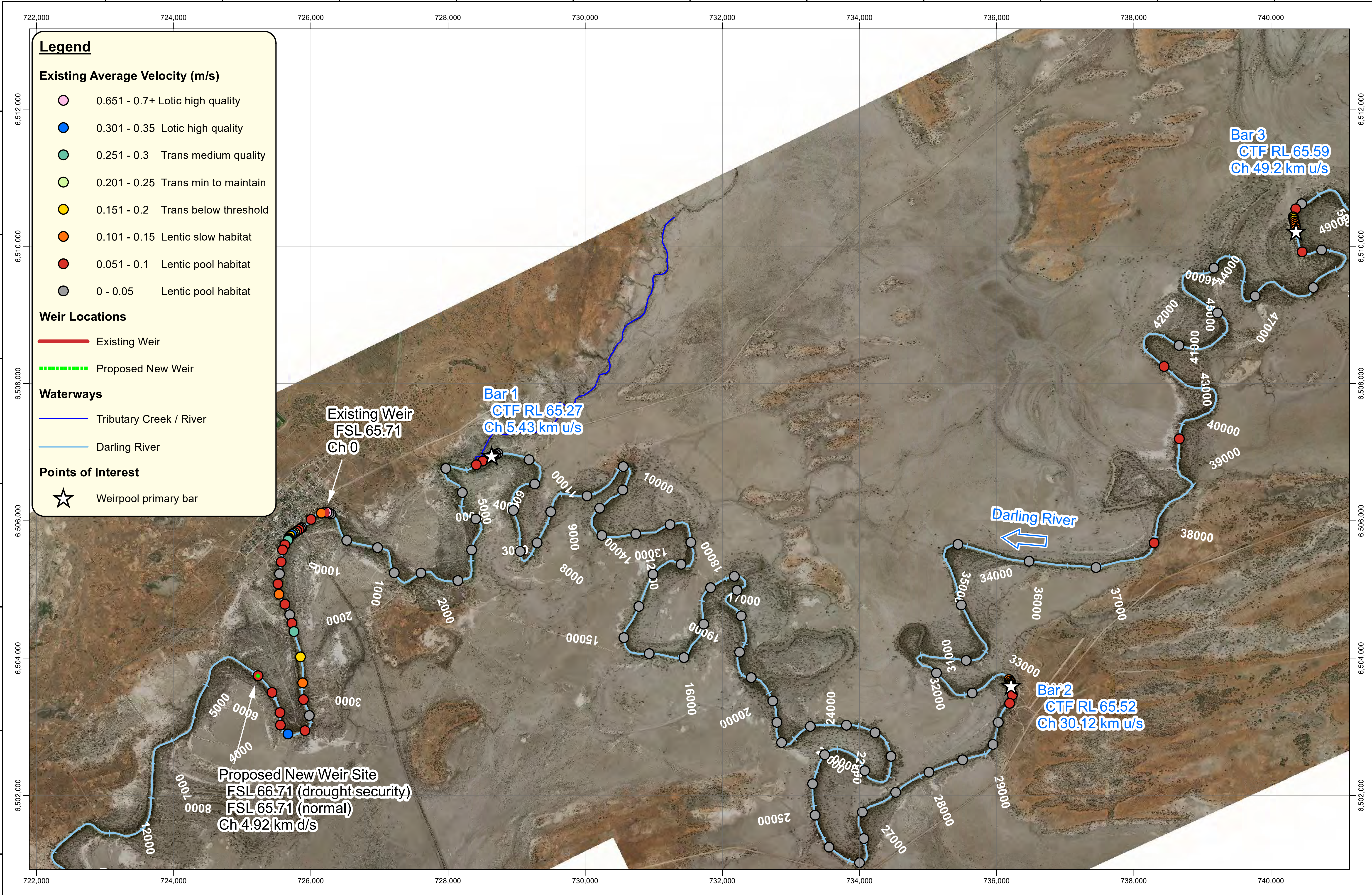
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
100 ML/d - SHEET 3 of 3

FIGURE NO.
EV100-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd

Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

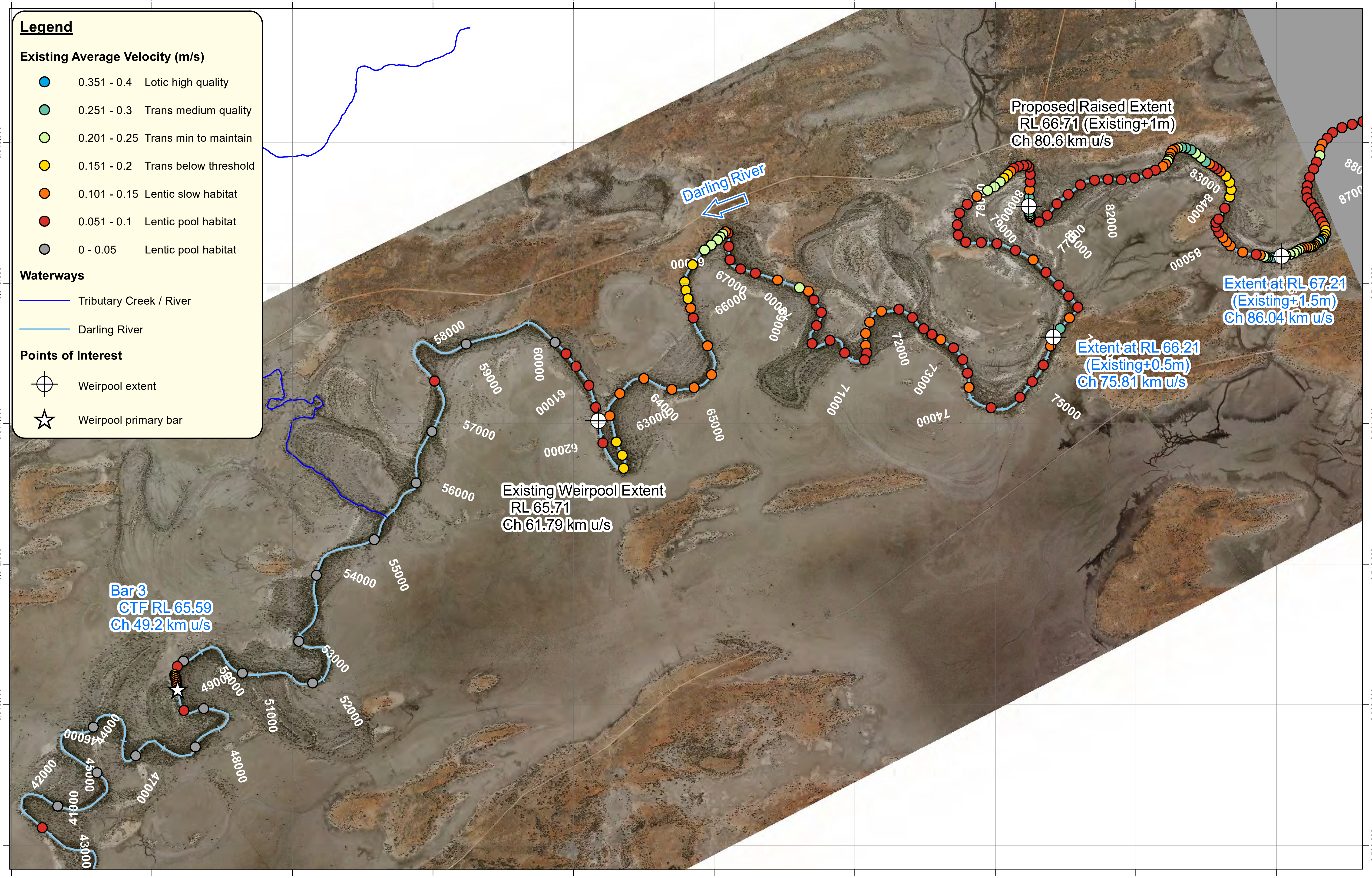
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
200 ML/d - SHEET 1 of 3

FIGURE NO.
EV200-1
Rev. 0



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

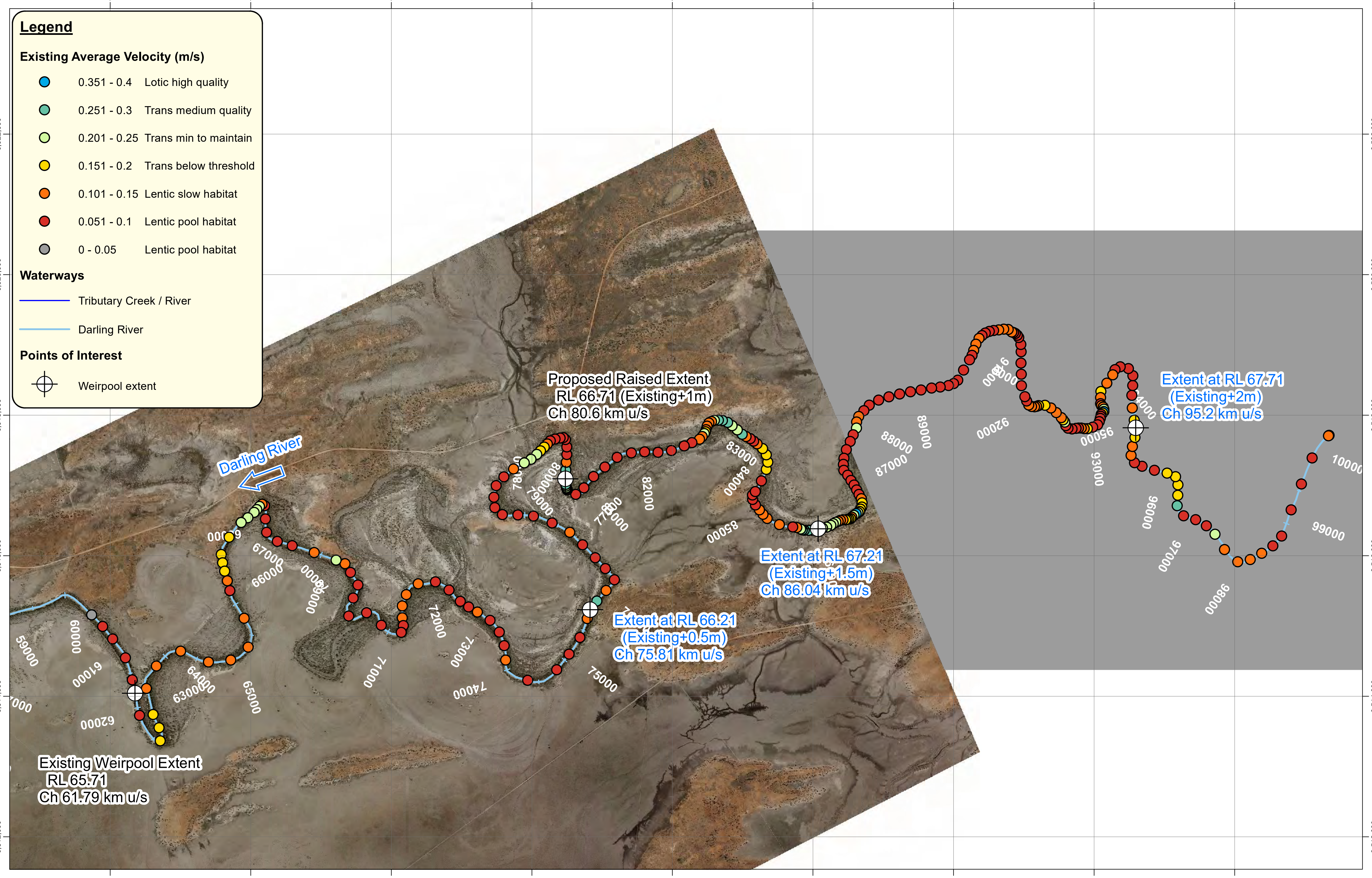
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
200 ML/d - SHEET 2 of 3

FIGURE NO.
EV200-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

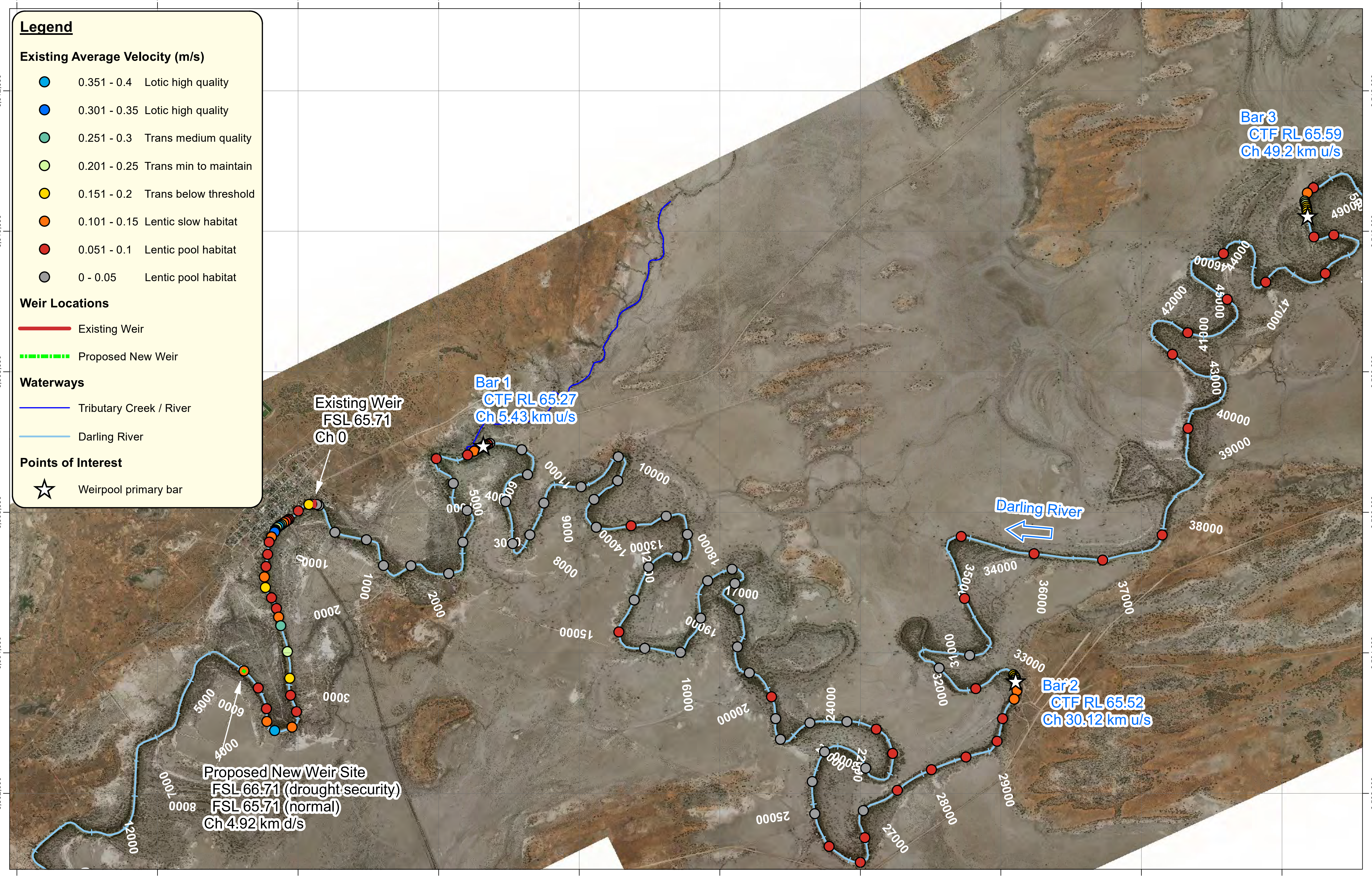
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
200 ML/d - SHEET 3 of 3

FIGURE NO.
EV200-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

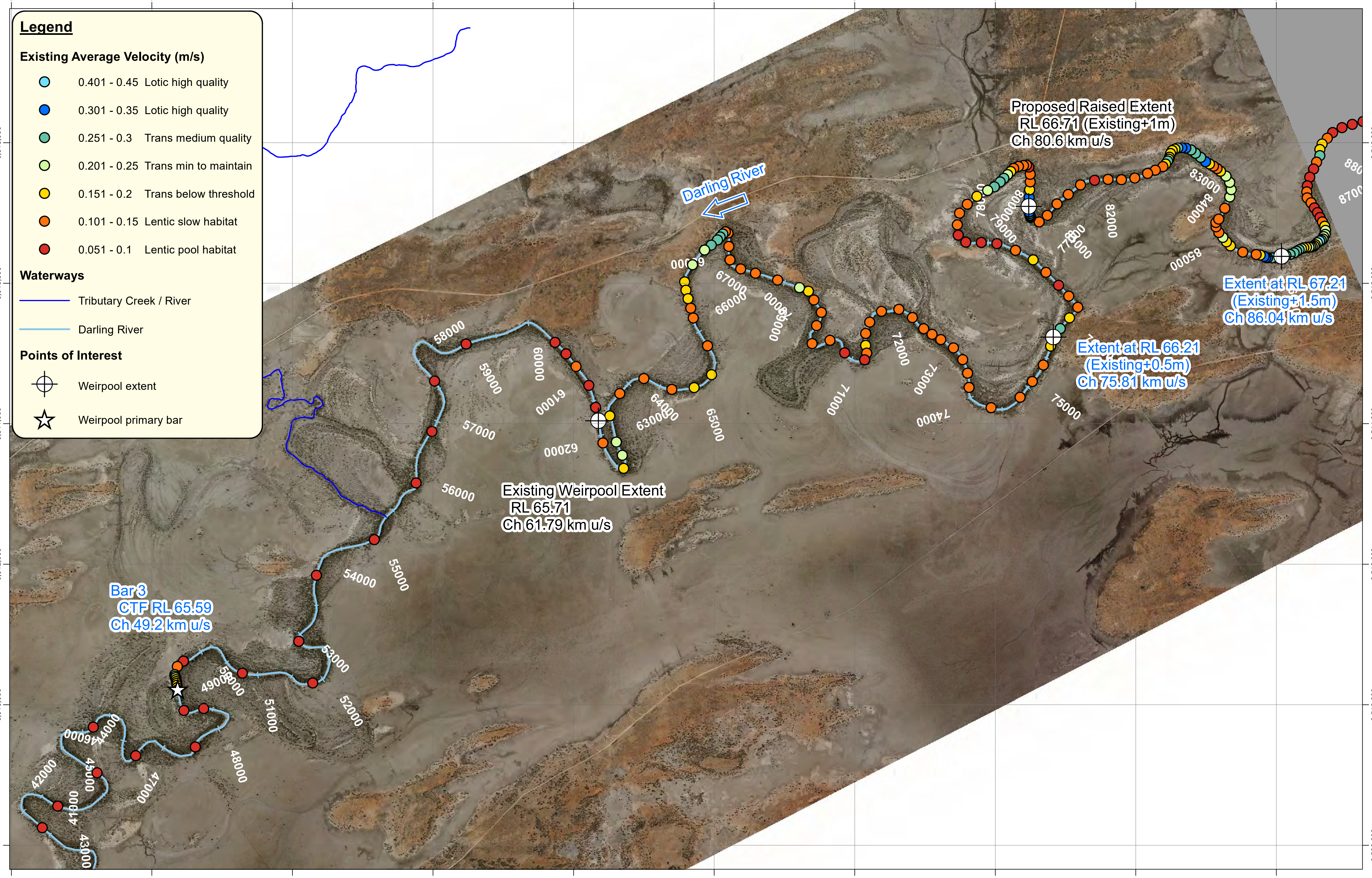
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
350 ML/d - SHEET 1 of 3

FIGURE NO.
EV350-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

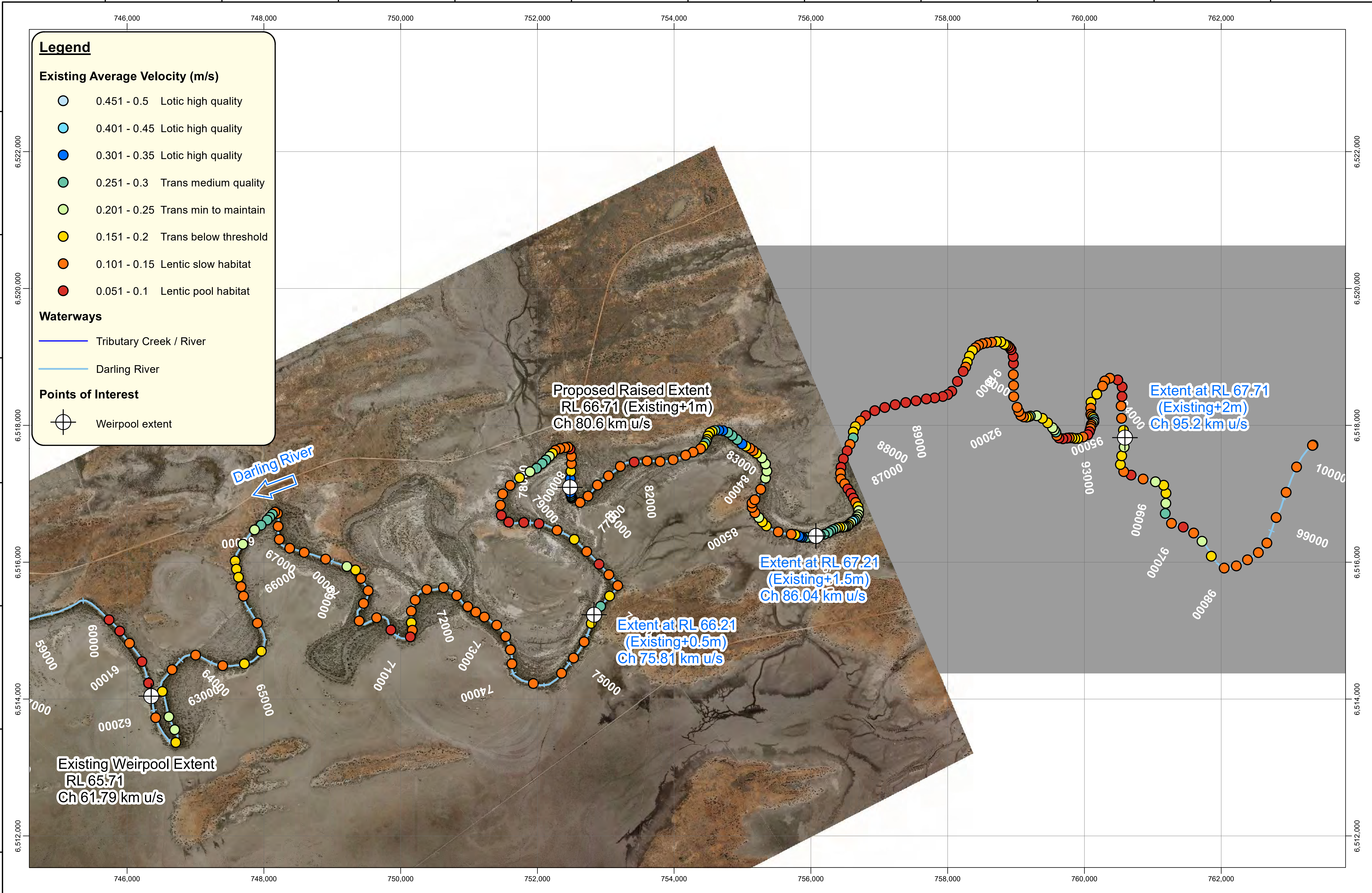
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
350 ML/d - SHEET 2 of 3

FIGURE NO.
EV350-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

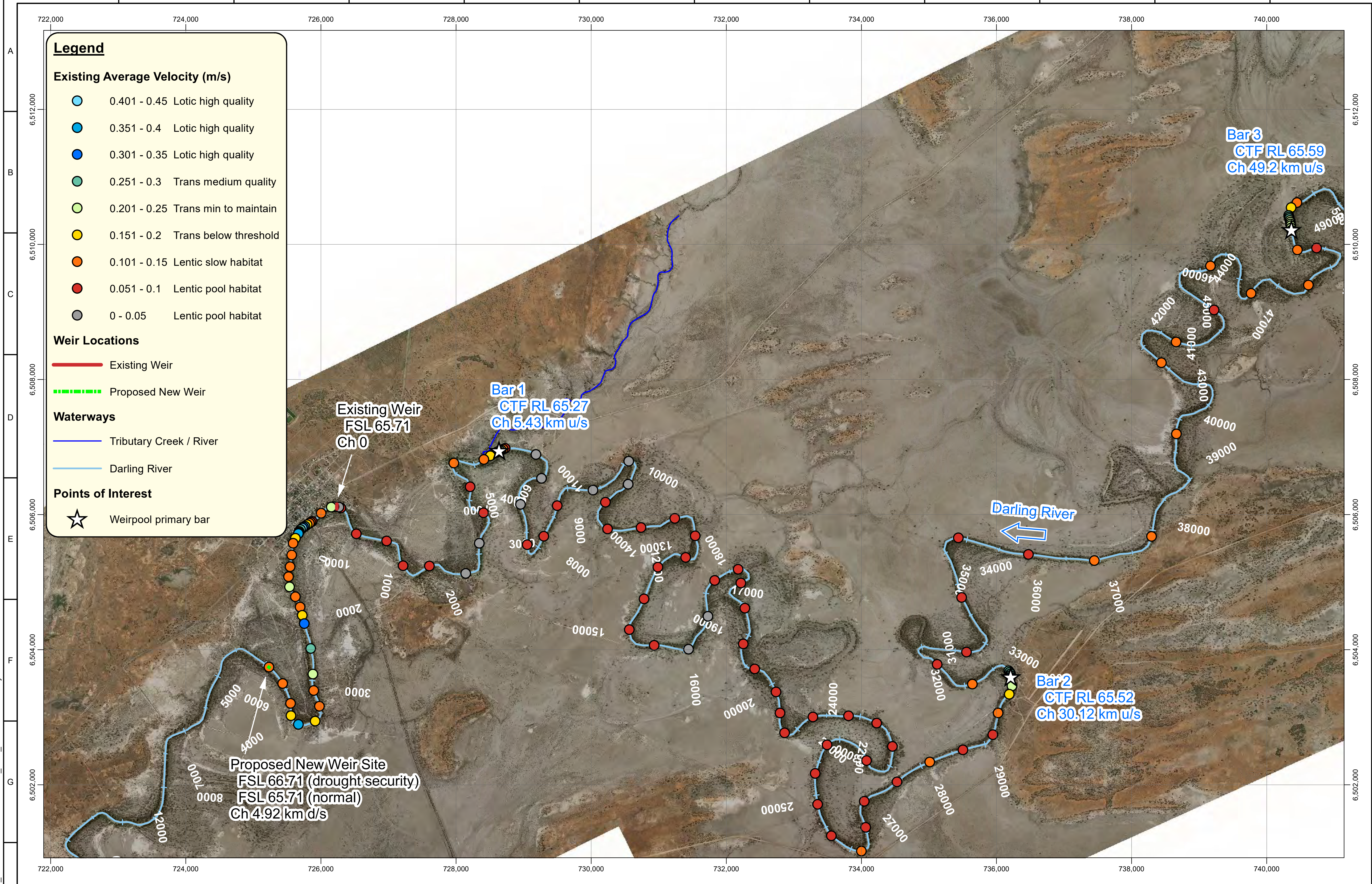
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
350 ML/d - SHEET 3 of 3

FIGURE NO.
EV350-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

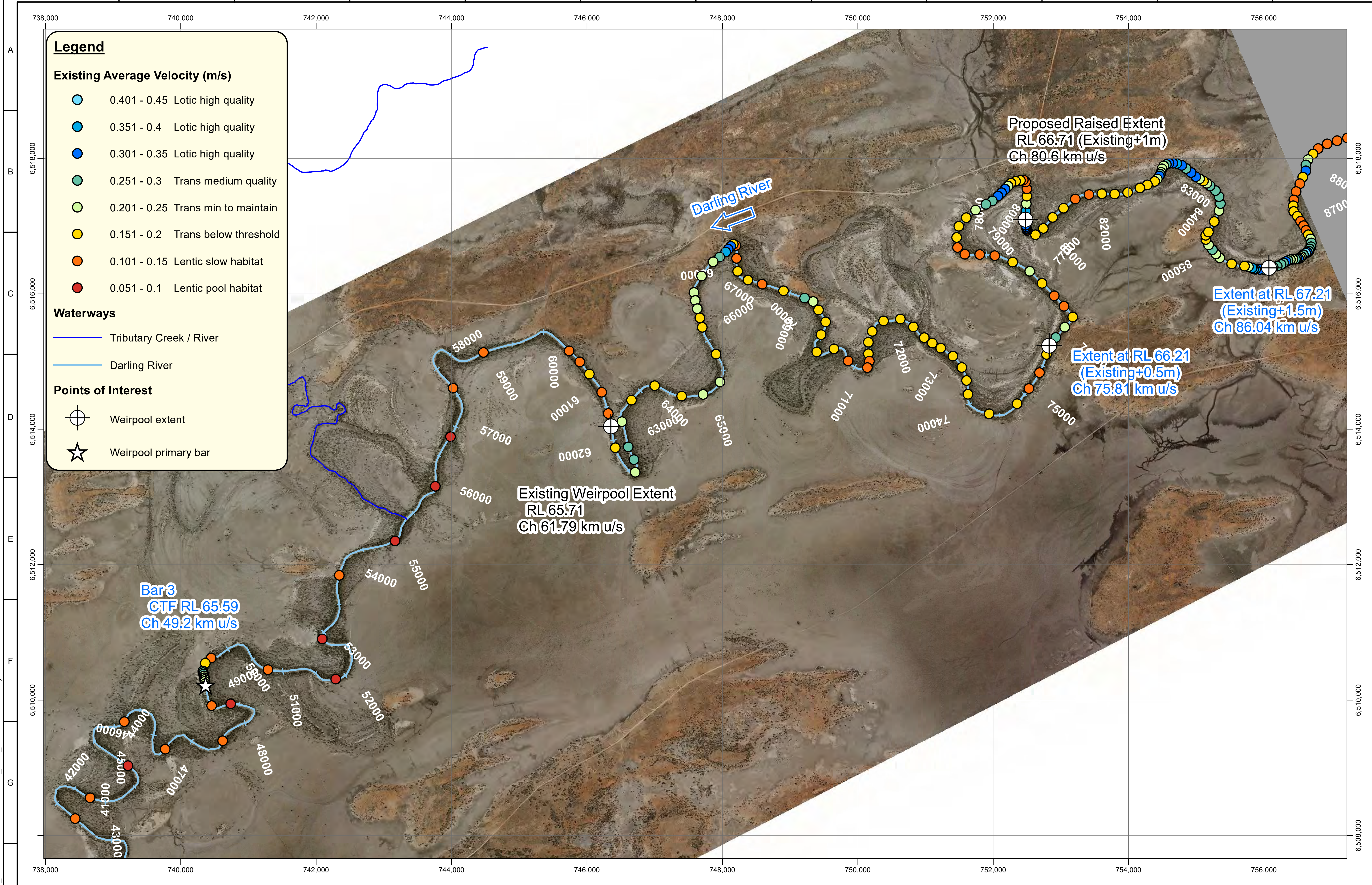
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
600 ML/d - SHEET 1 of 3

FIGURE NO.
EV600-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

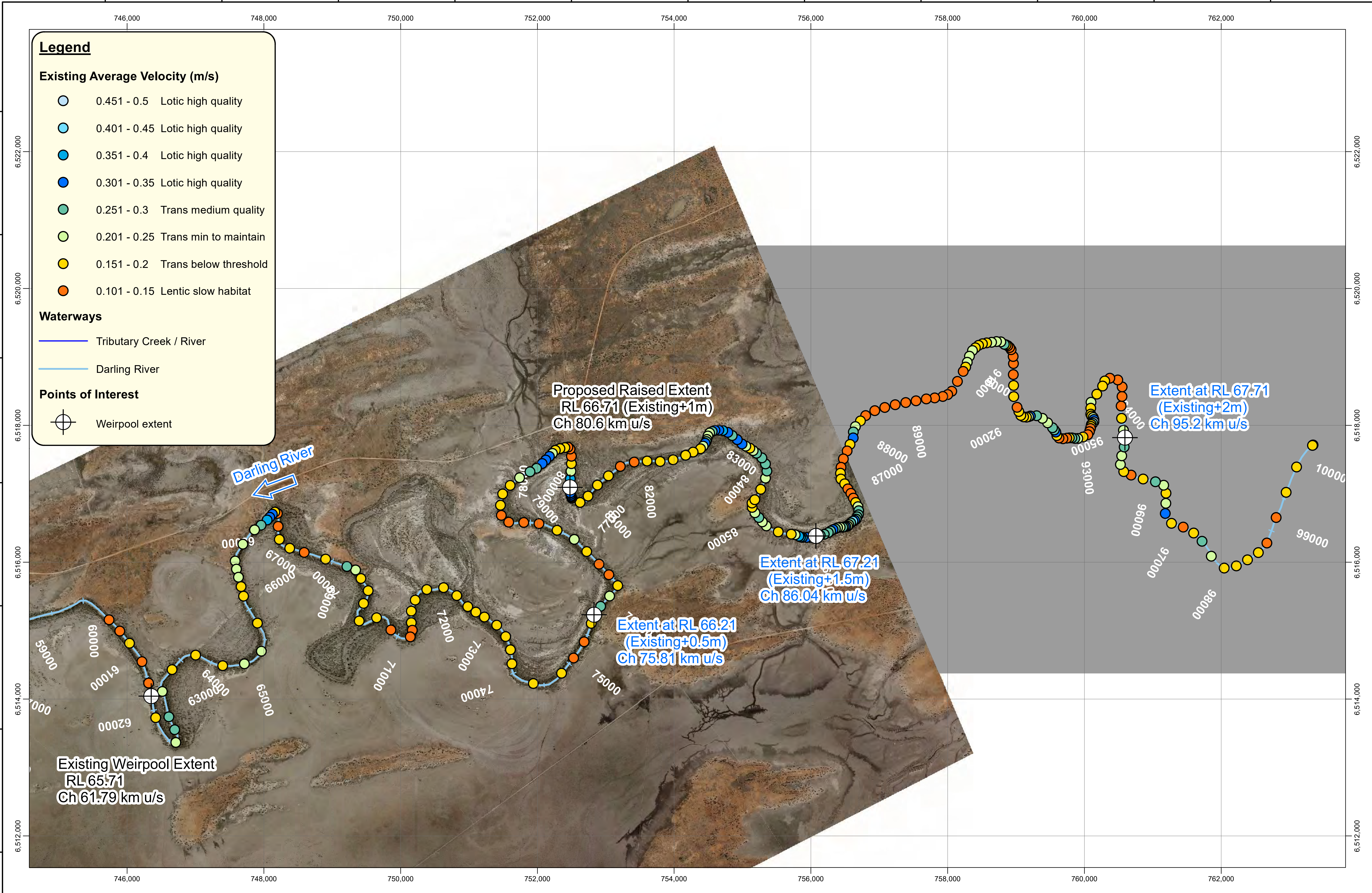
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
600 ML/d - SHEET 2 of 3

FIGURE NO.
EV600-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

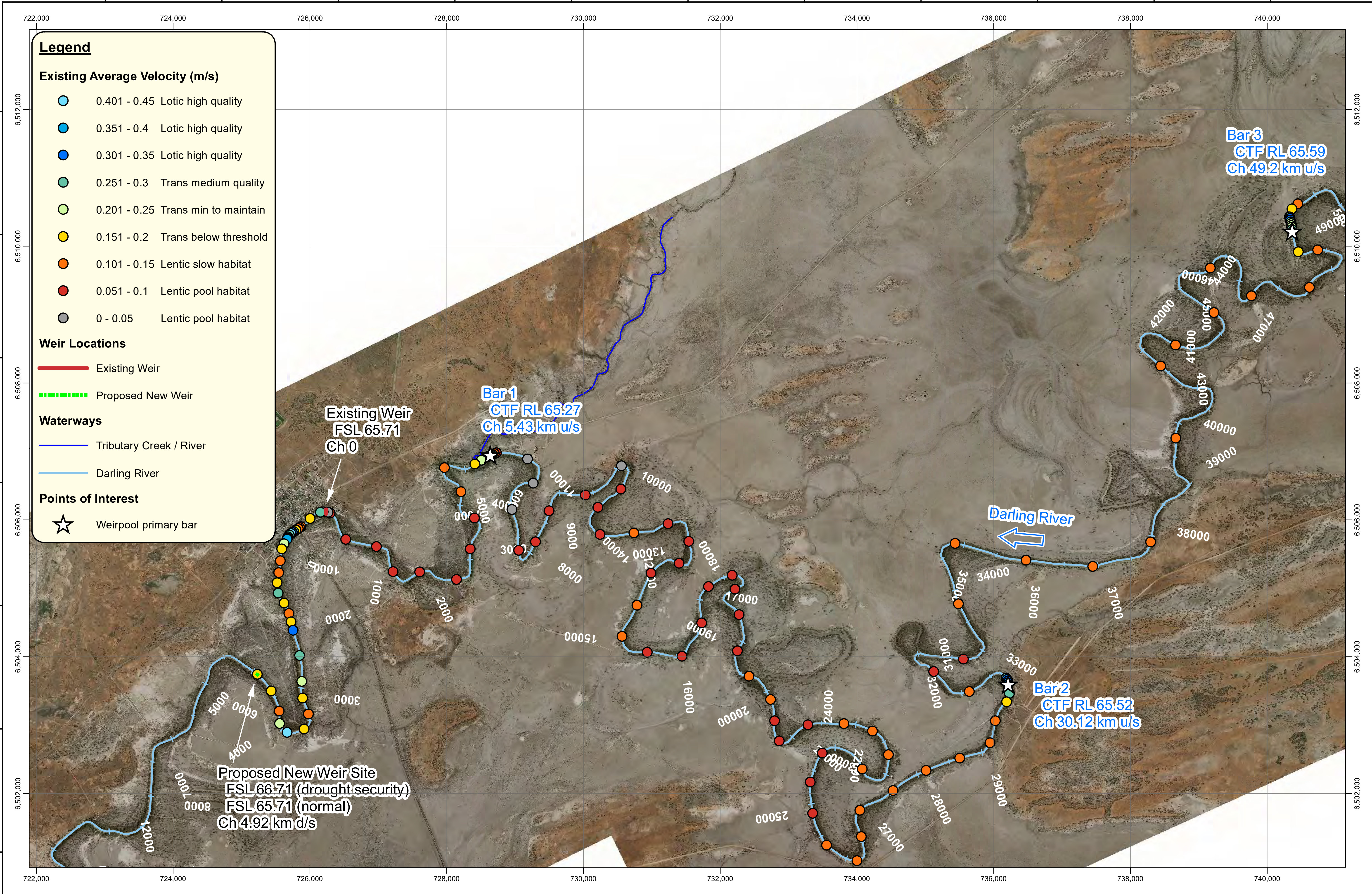
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
600 ML/d - SHEET 3 of 3

FIGURE NO.
EV600-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

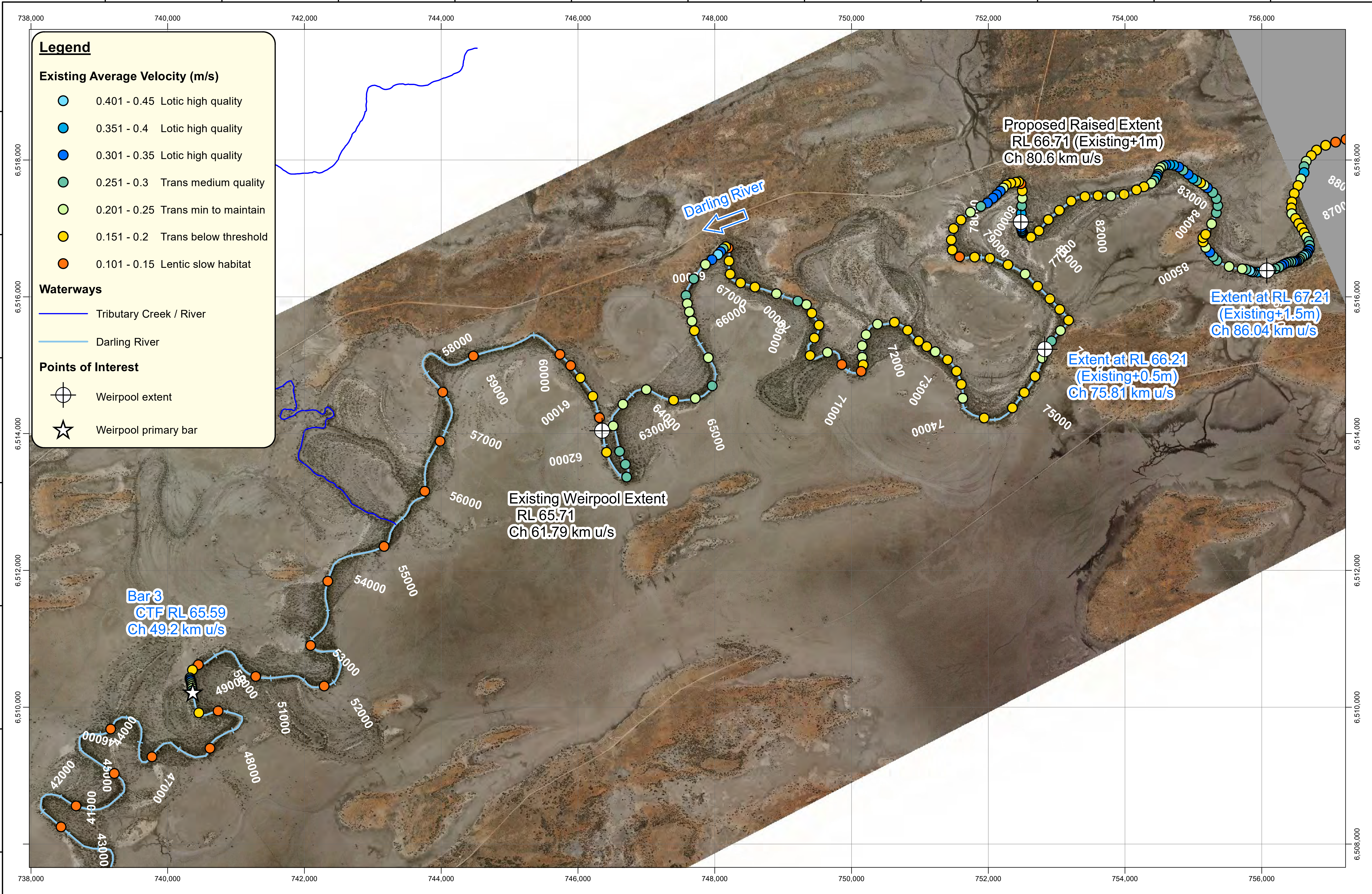
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
800 ML/d - SHEET 1 of 3

FIGURE NO.
EV800-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

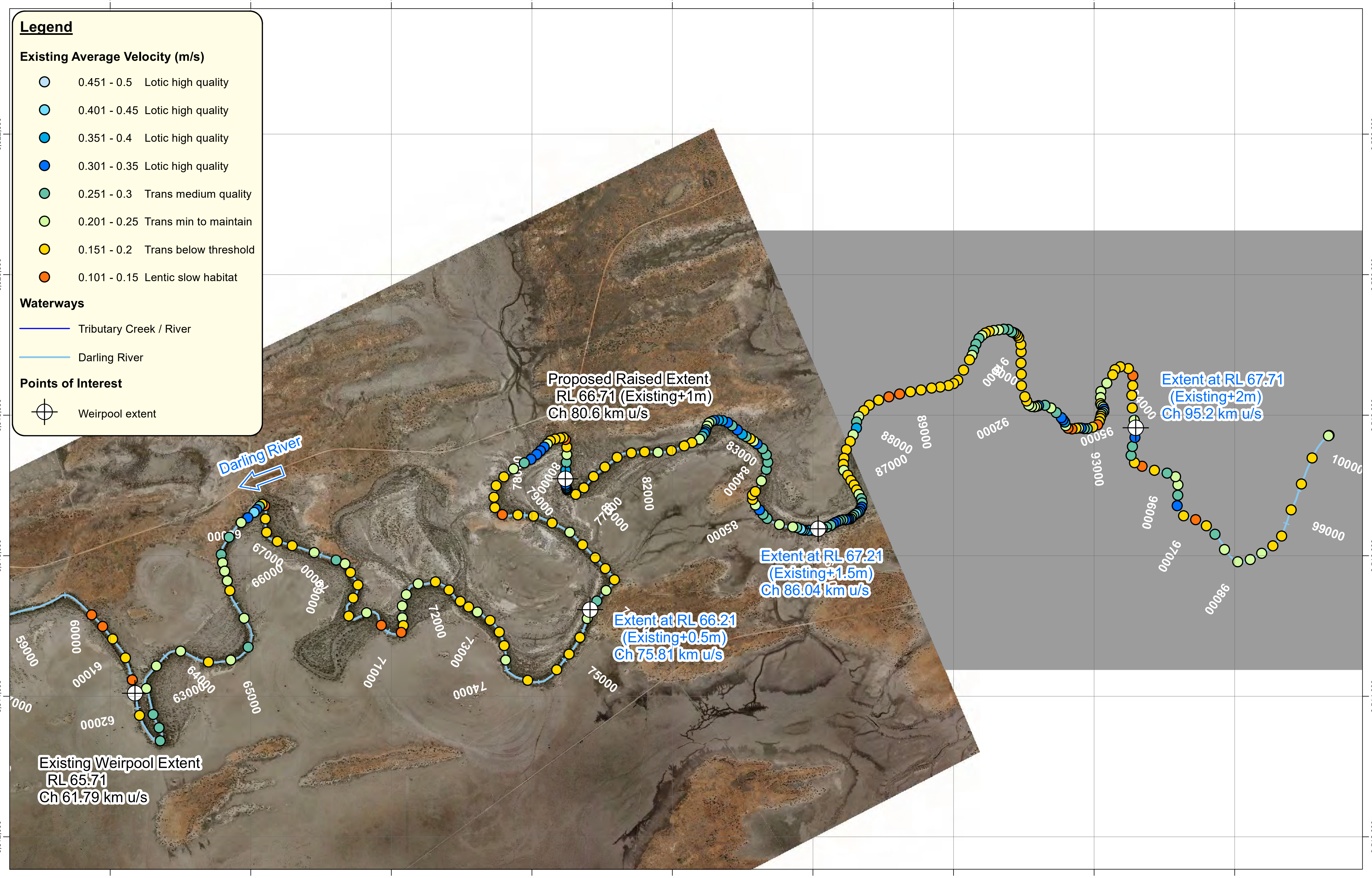
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
800 ML/d - SHEET 2 of 3

FIGURE NO.
EV800-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

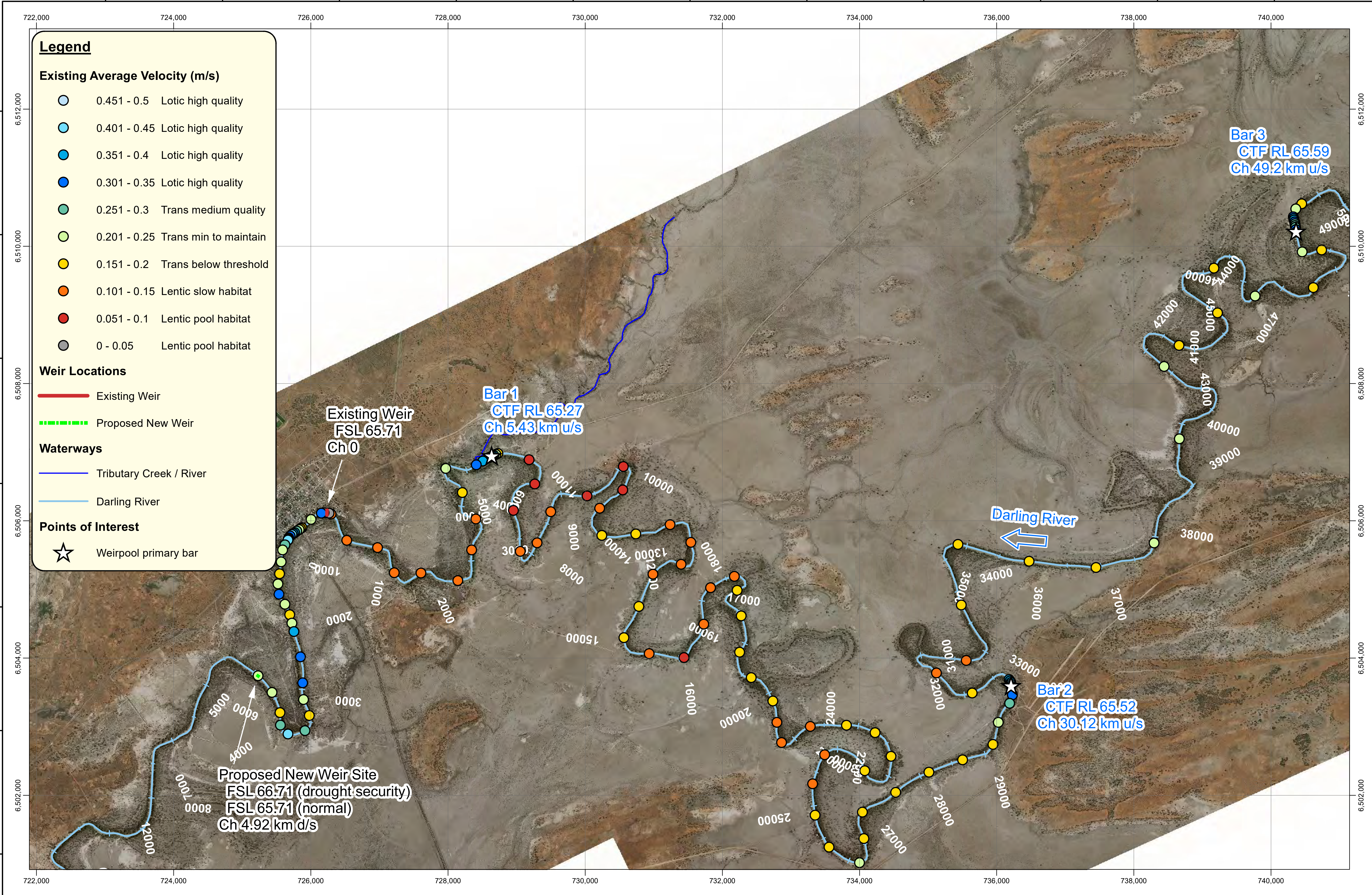
MGA94 ZONE 54

NSW Government | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
800 ML/d - SHEET 3 of 3

FIGURE NO.
EV800-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

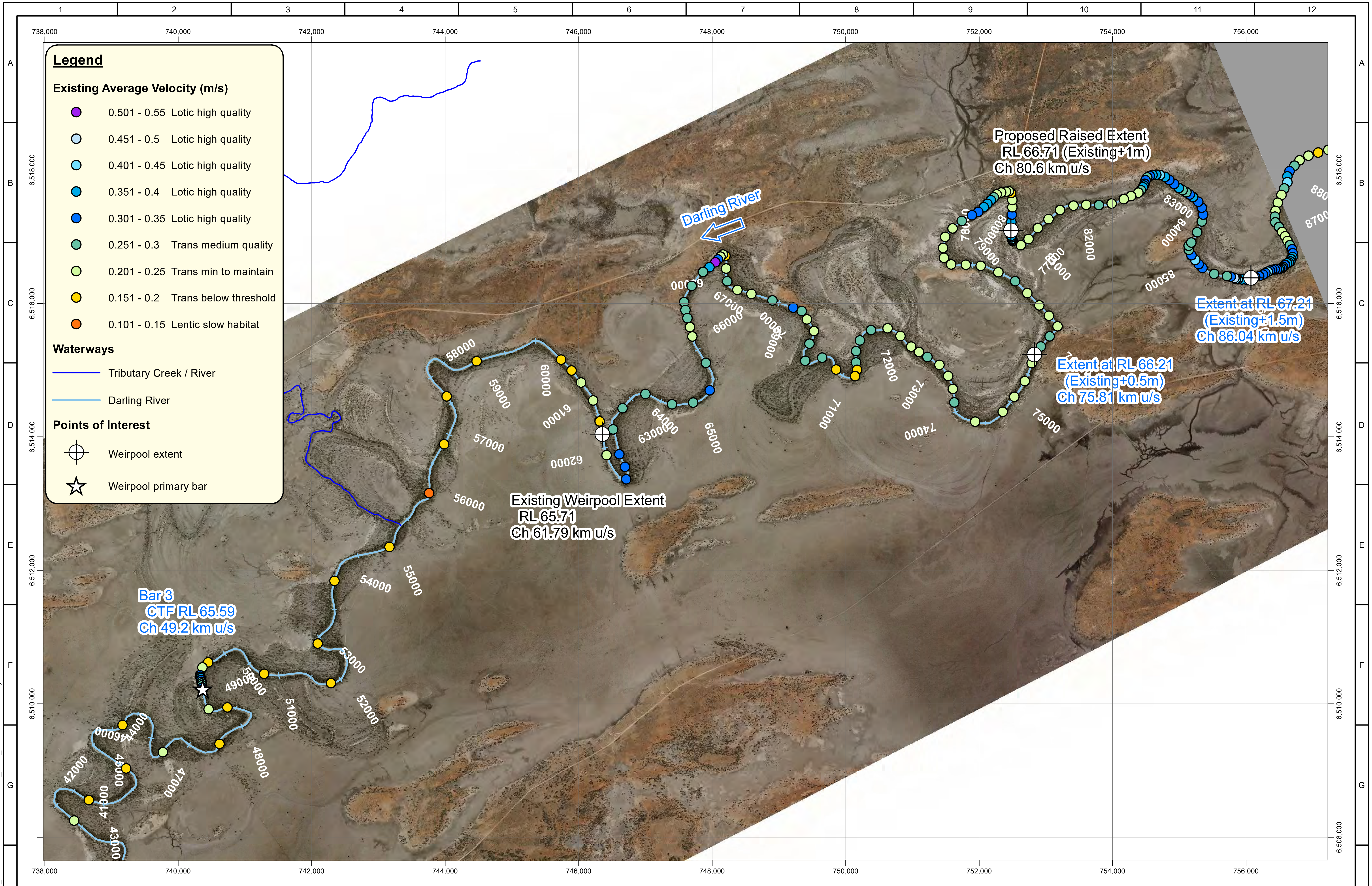
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
1400 ML/d - SHEET 1 of 3

FIGURE NO.
EV1400-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

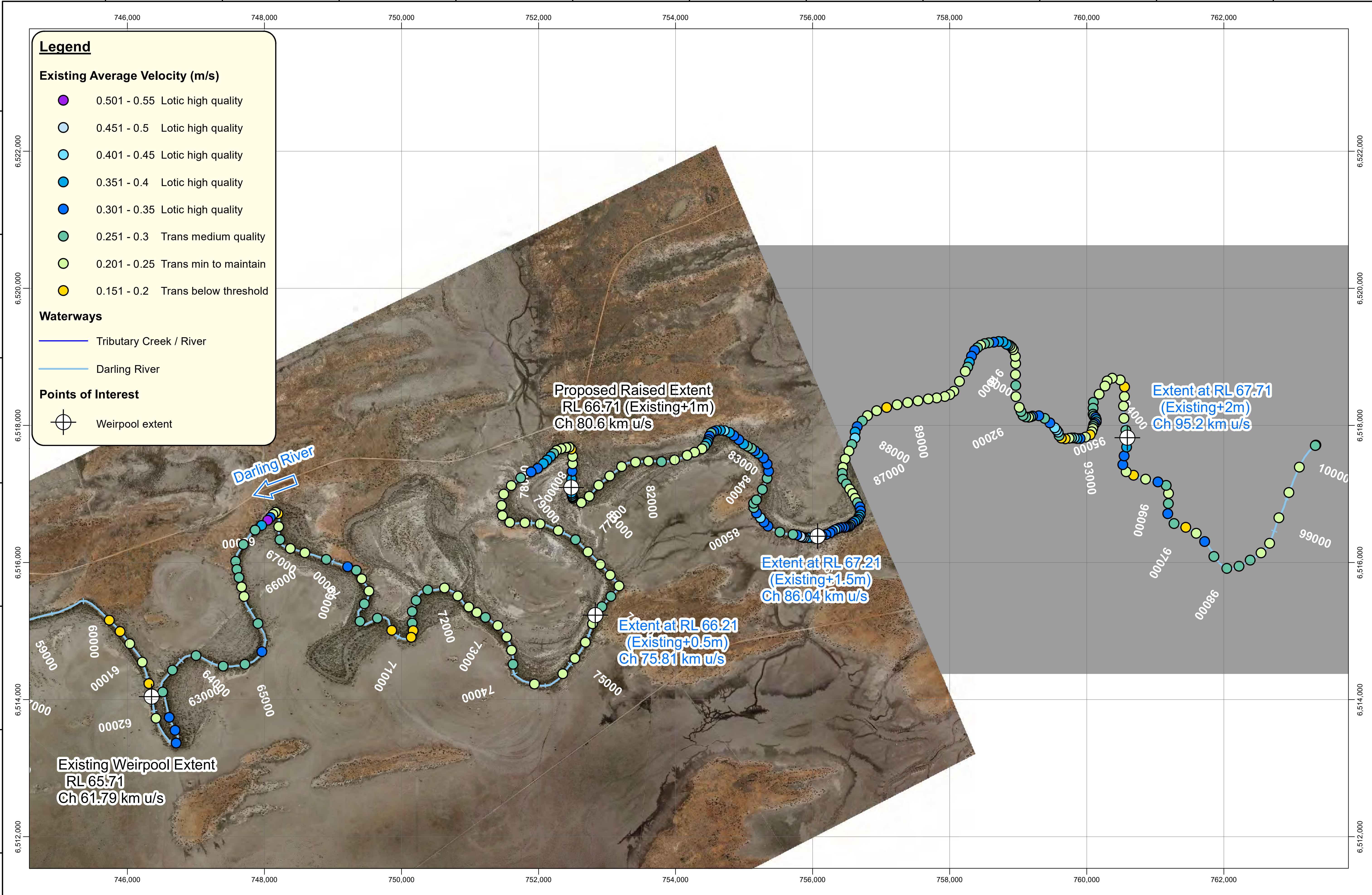
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
1400 ML/d - SHEET 2 of 3

FIGURE NO.
EV1400-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000
Metres

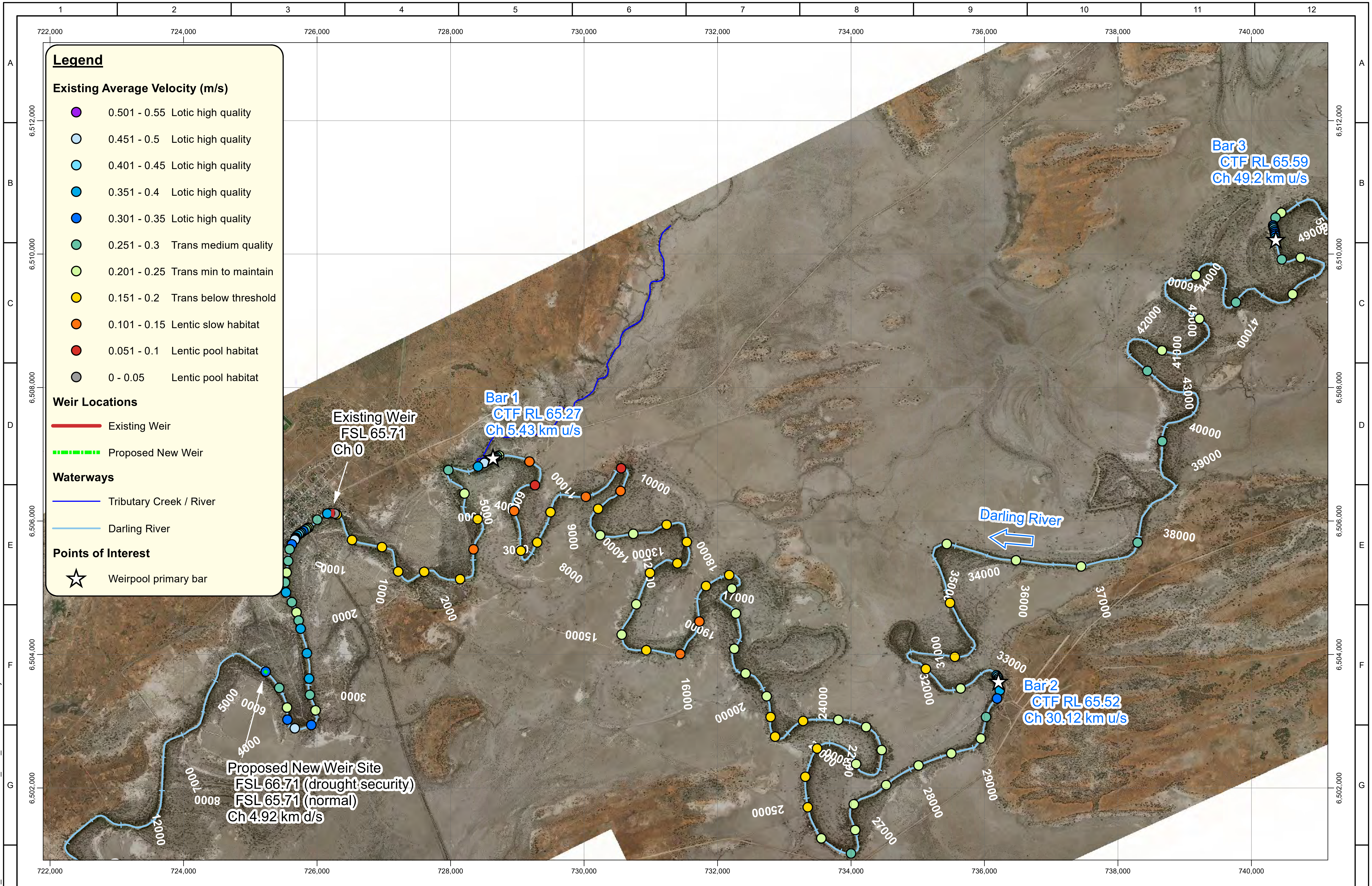
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
1400 ML/d - SHEET 3 of 3

FIGURE NO.
EV1400-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd

Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

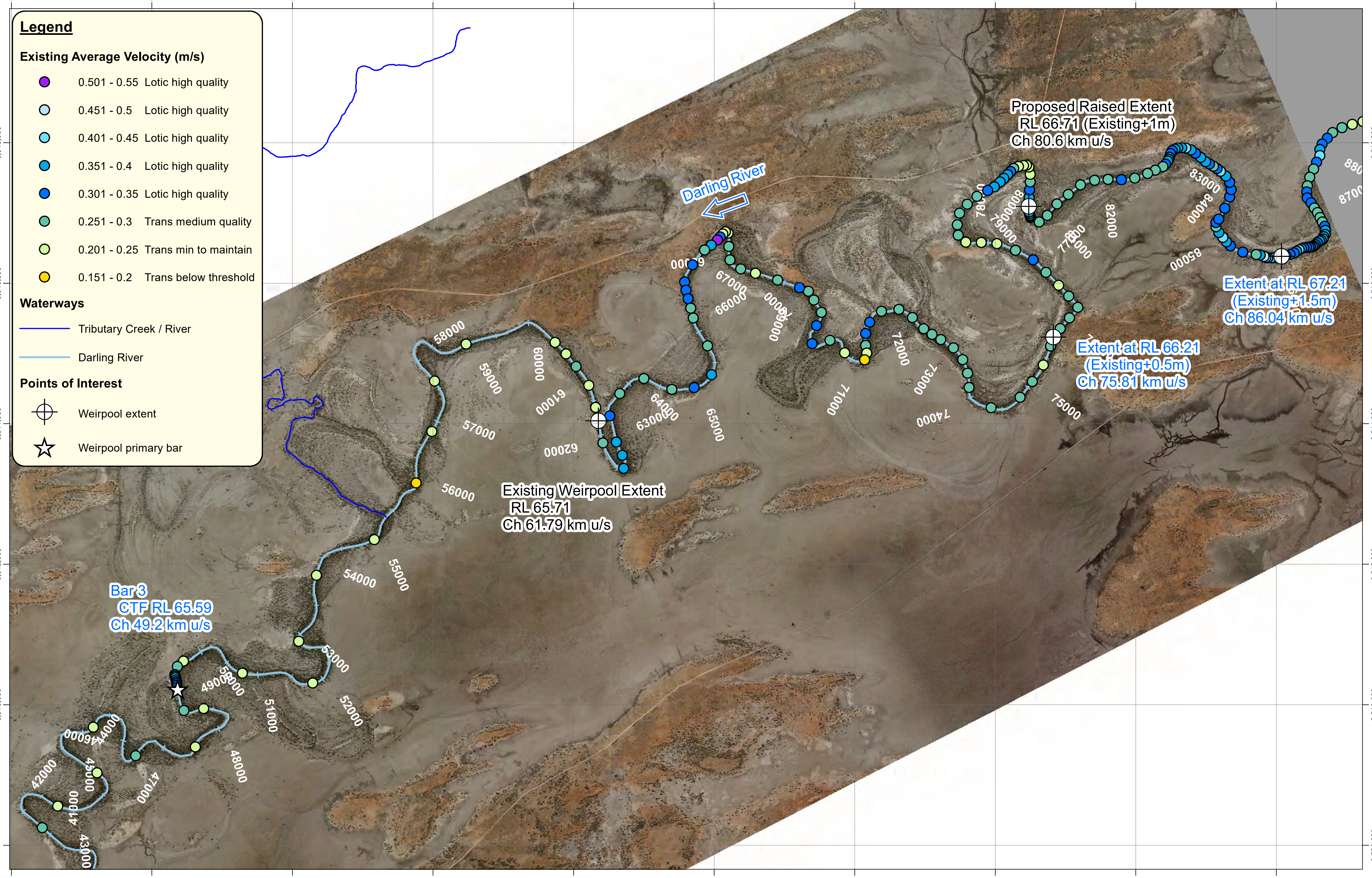
1:50,000
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
2000 ML/d - SHEET 1 of 3

FIGURE NO.
EV2000-1
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

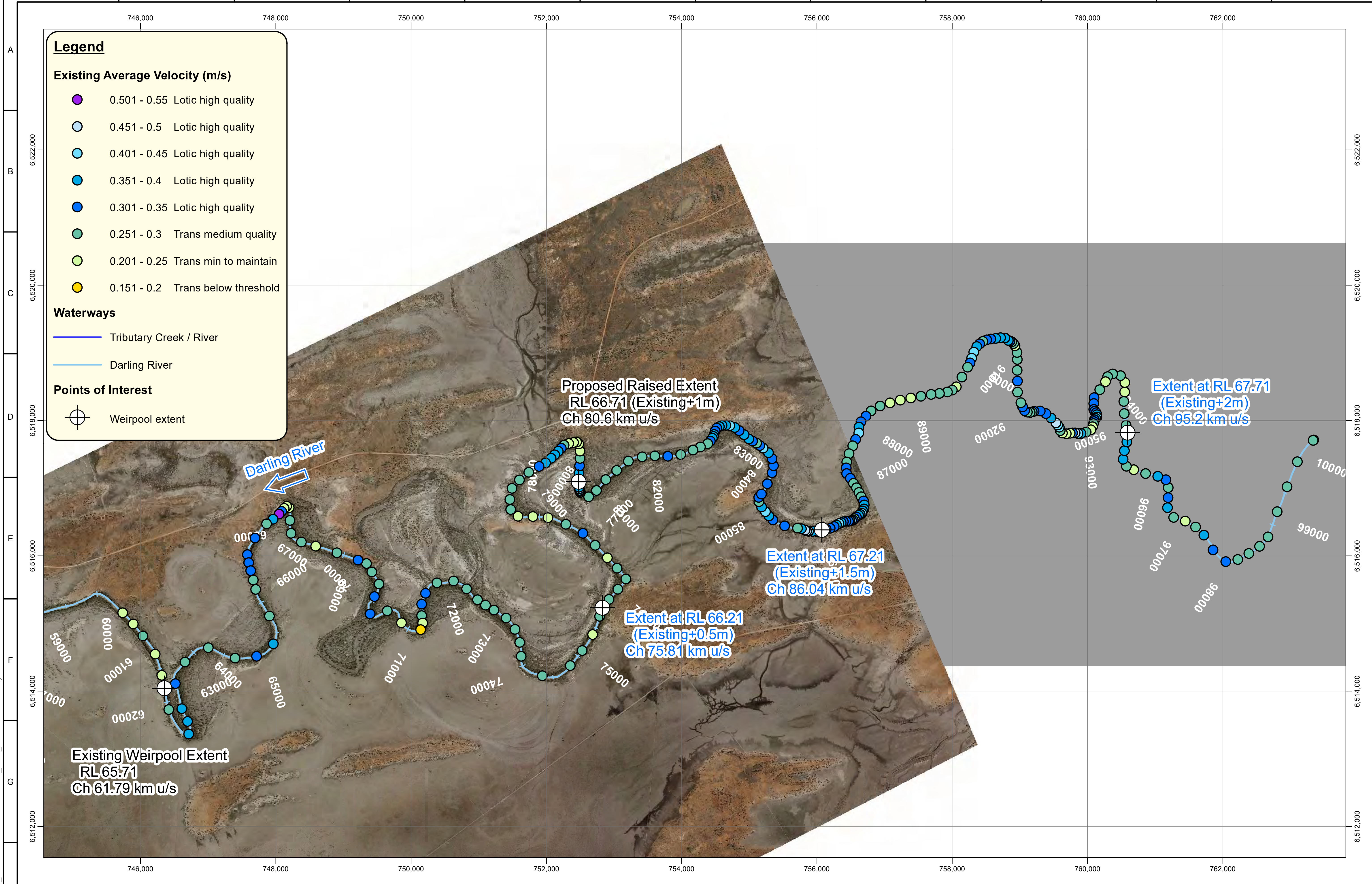
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
2000 ML/d - SHEET 2 of 3

FIGURE NO.
EV2000-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

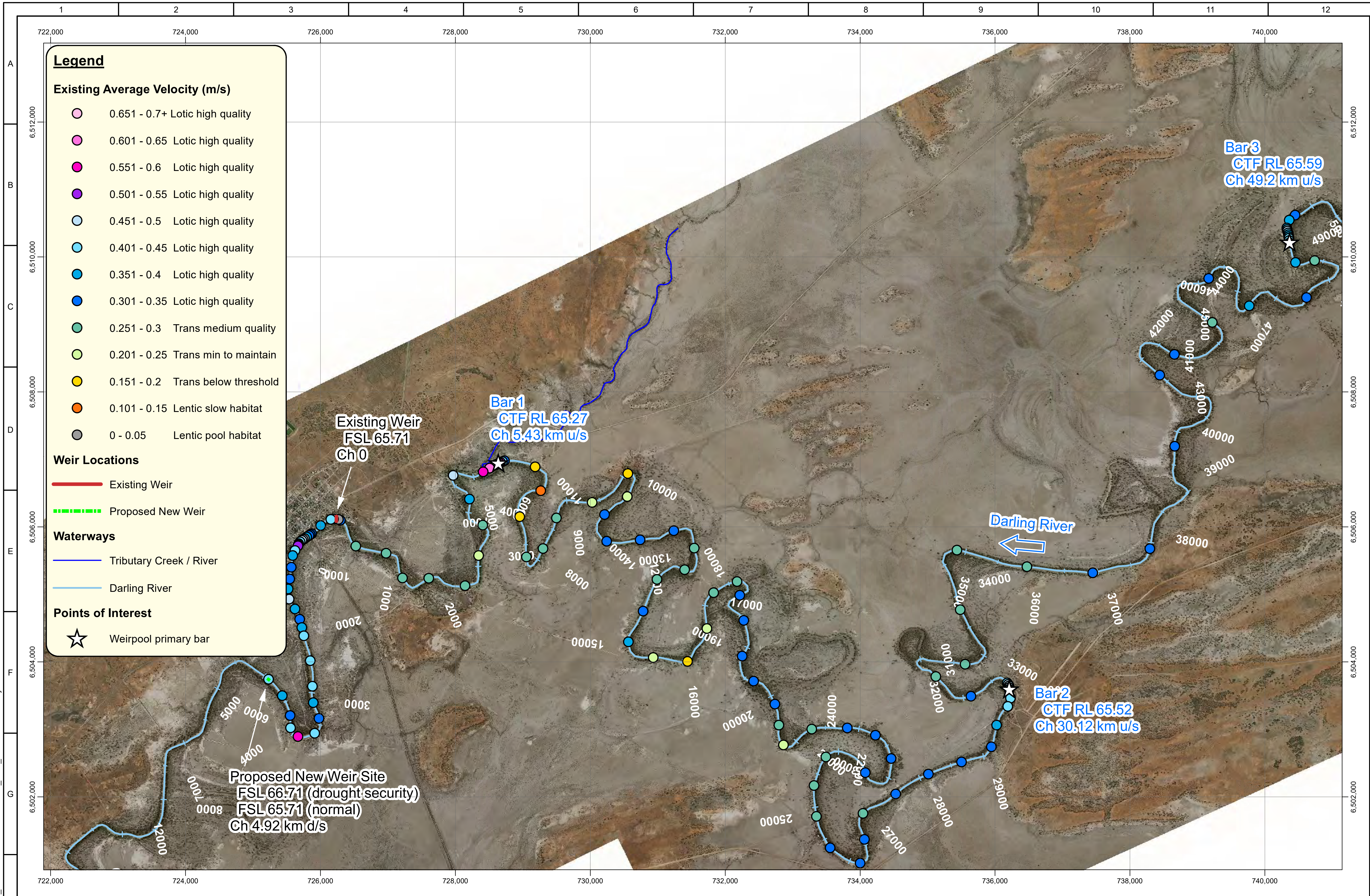
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
2000 ML/d - SHEET 3 of 3

FIGURE NO.
EV2000-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

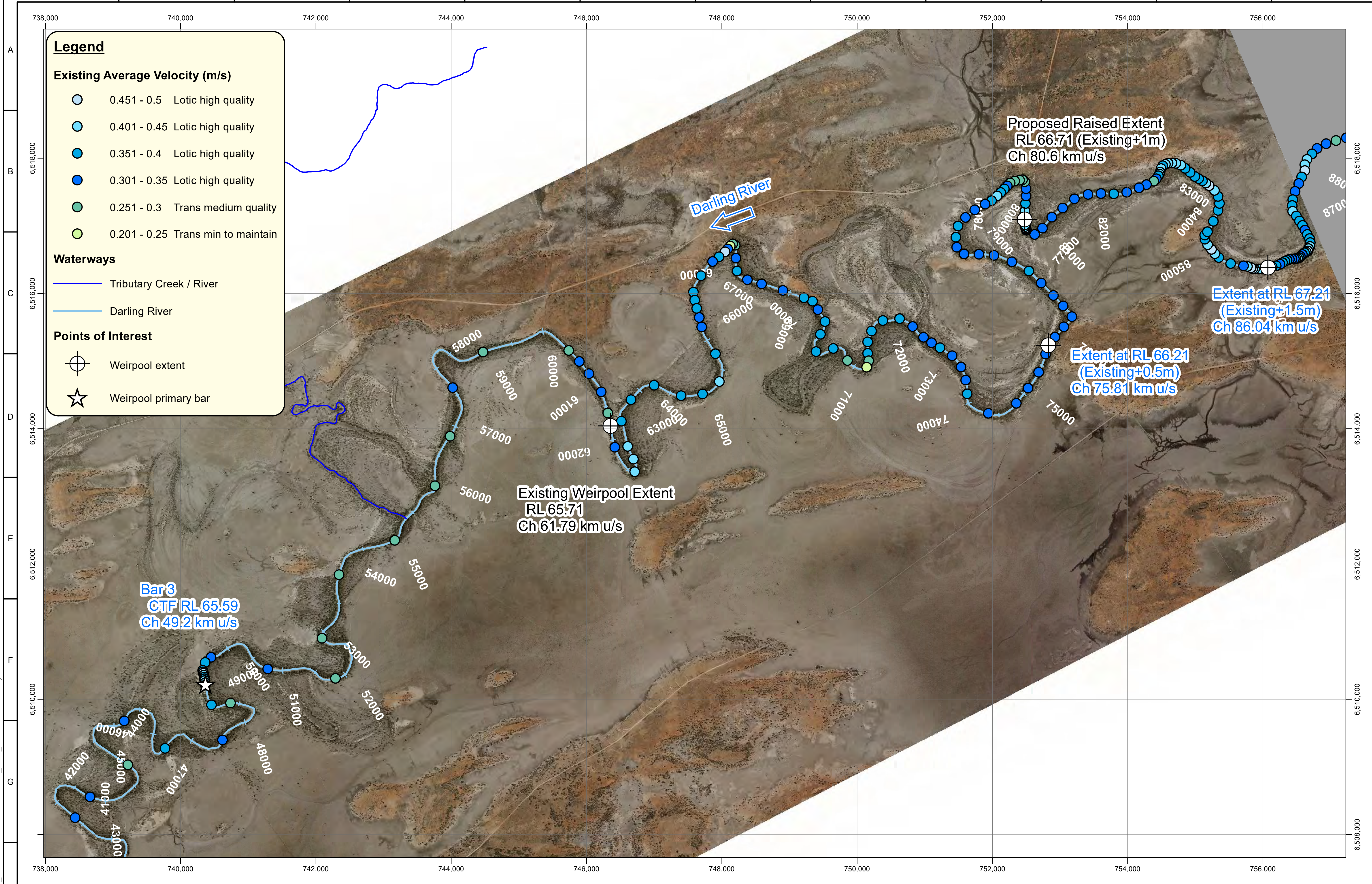
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
3500 ML/d - SHEET 1 of 3

FIGURE NO.
EV3500-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

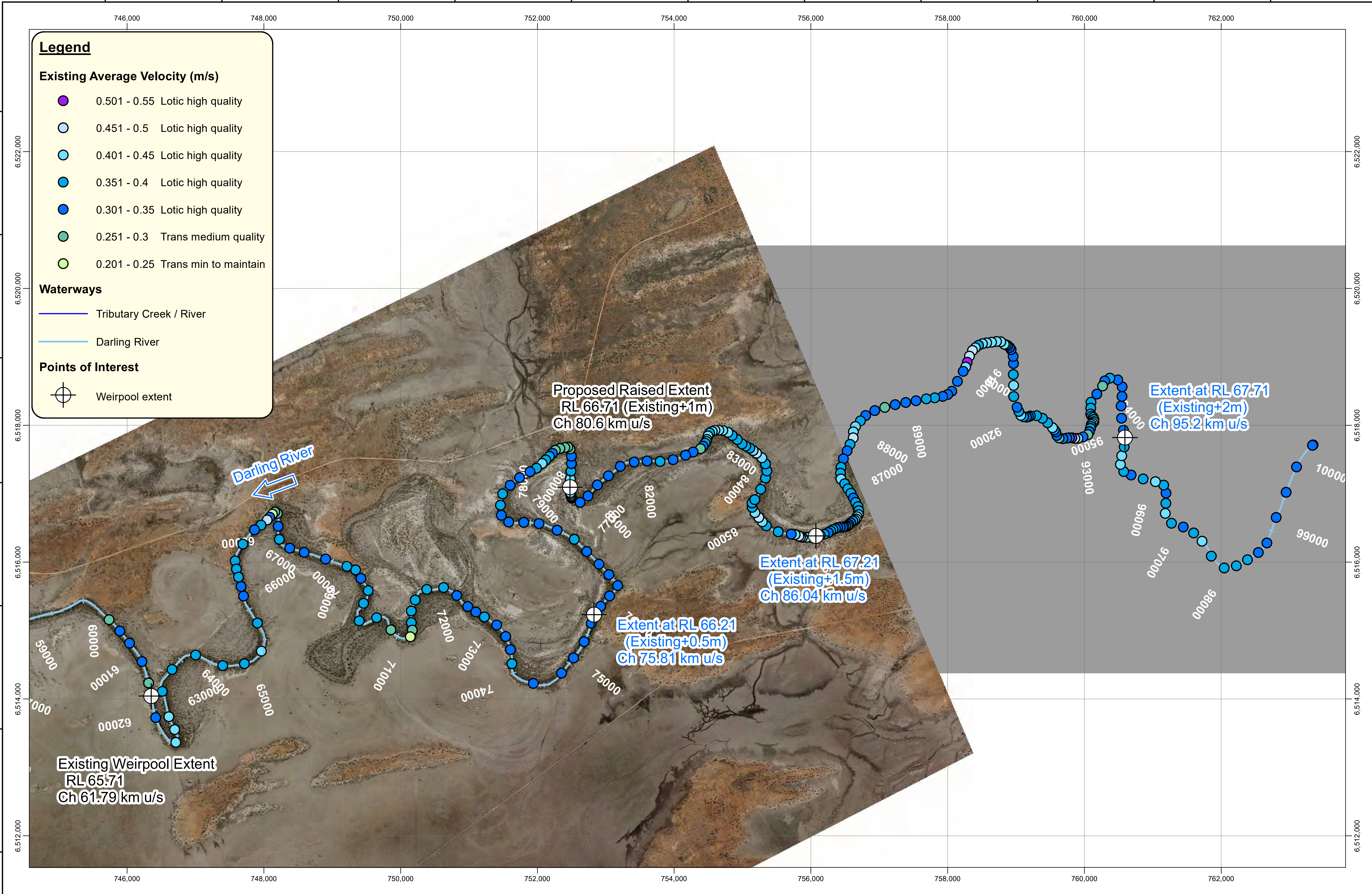
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
3500 ML/d - SHEET 2 of 3

FIGURE NO.
EV3500-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

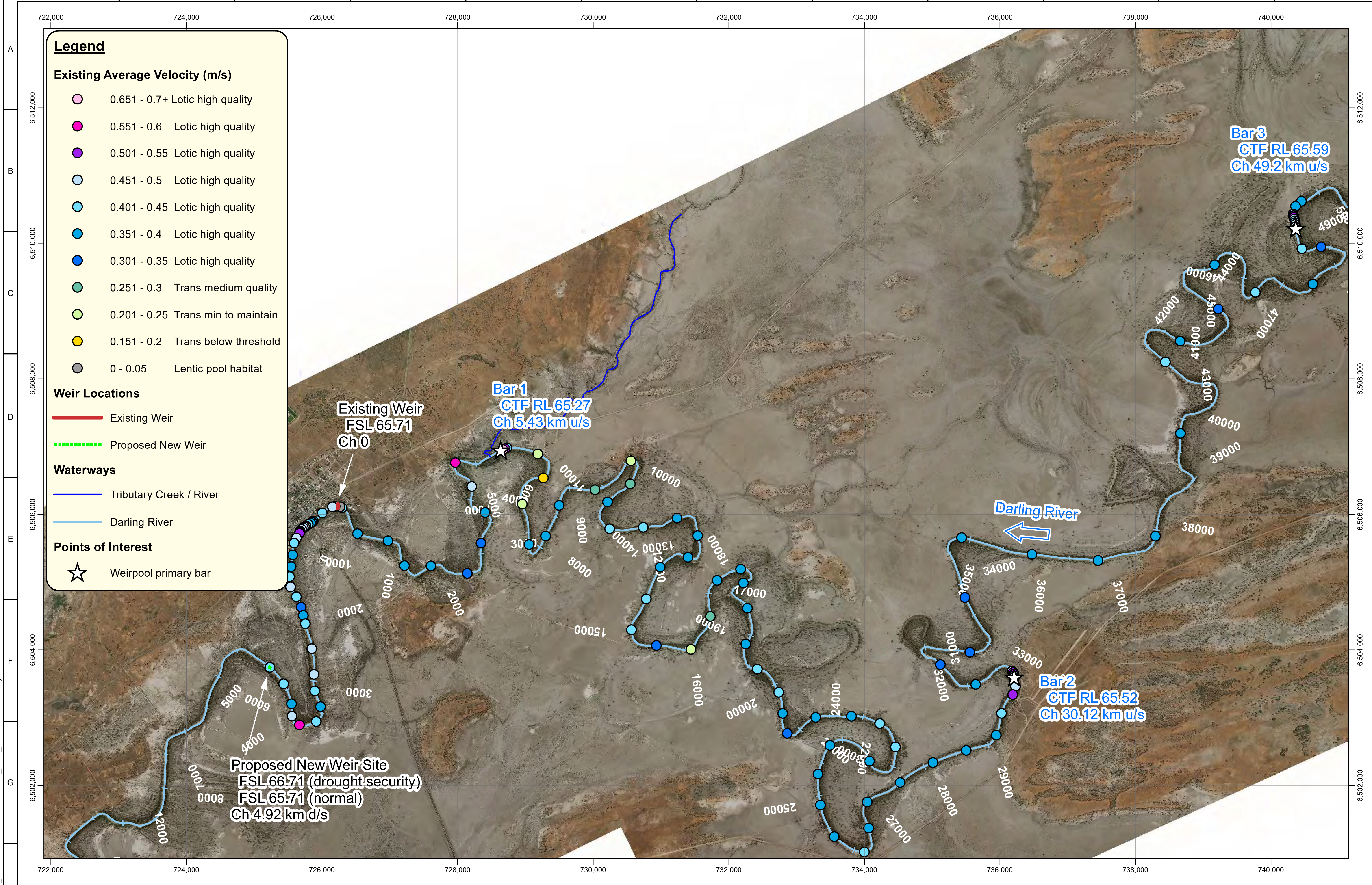
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
3500 ML/d - SHEET 3 of 3

FIGURE NO.
EV3500-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

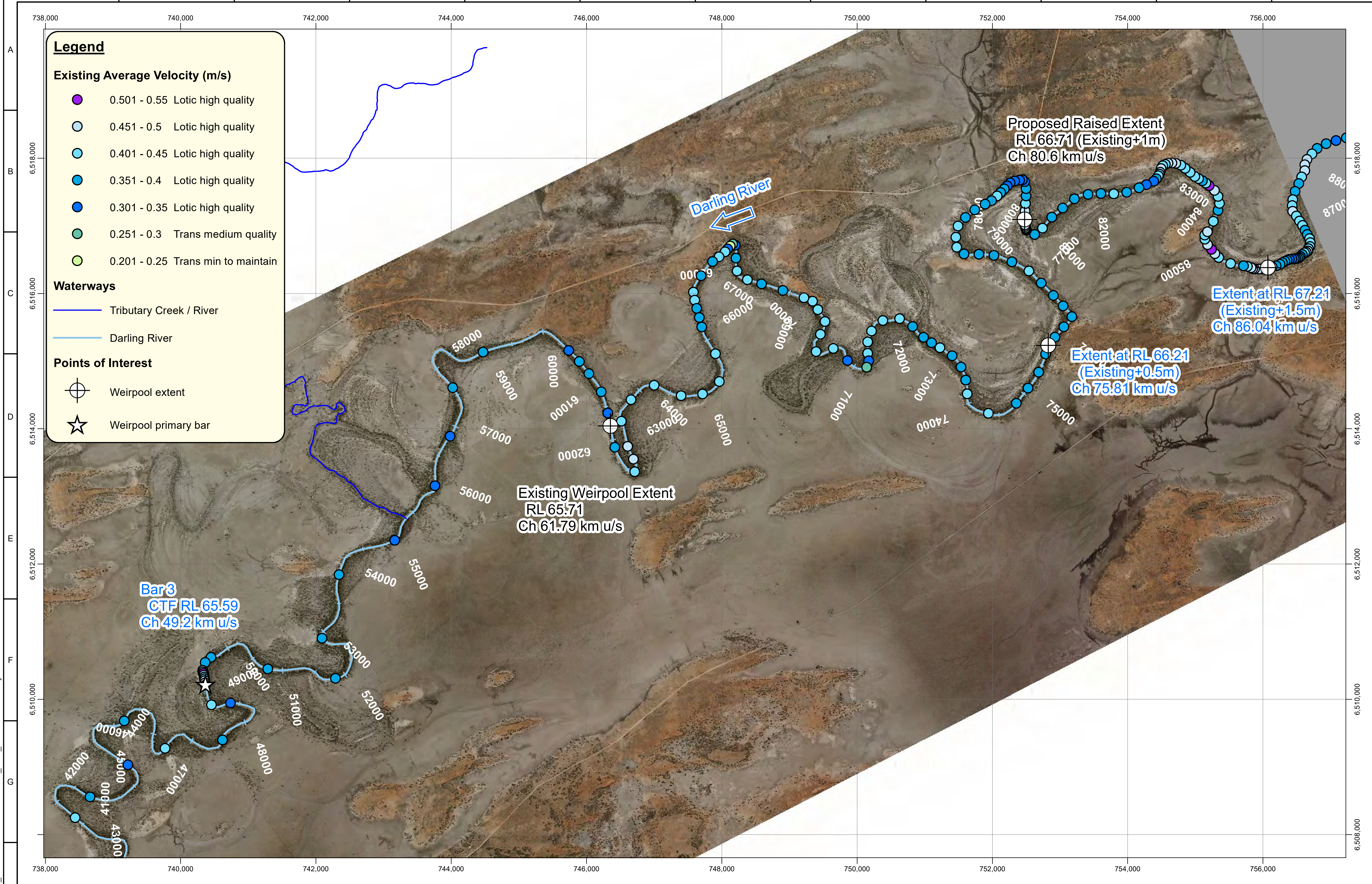
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
5000 ML/d - SHEET 1 of 3

FIGURE NO.
EV5000-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

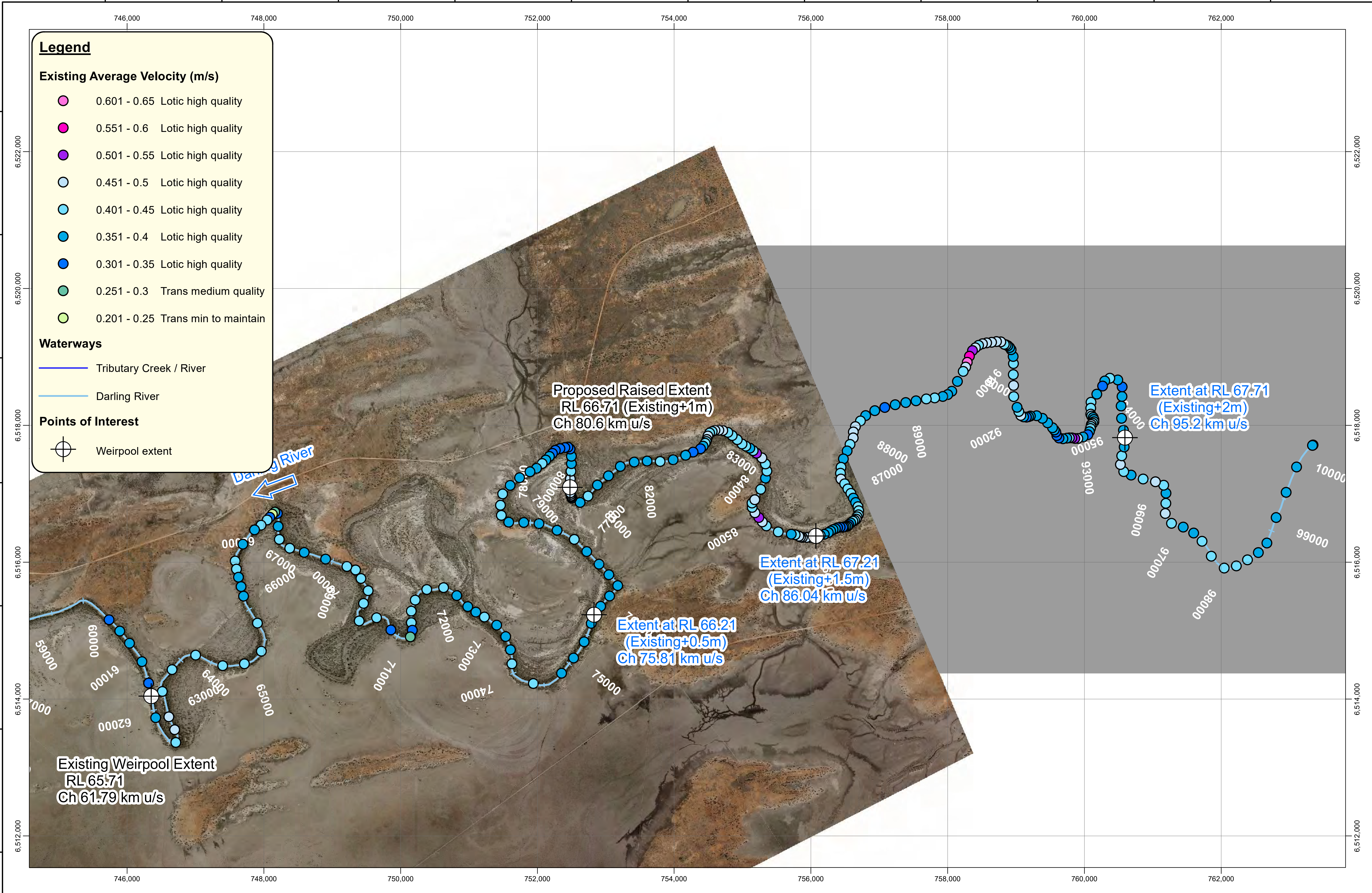
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
5000 ML/d - SHEET 2 of 3

FIGURE NO.
EV5000-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

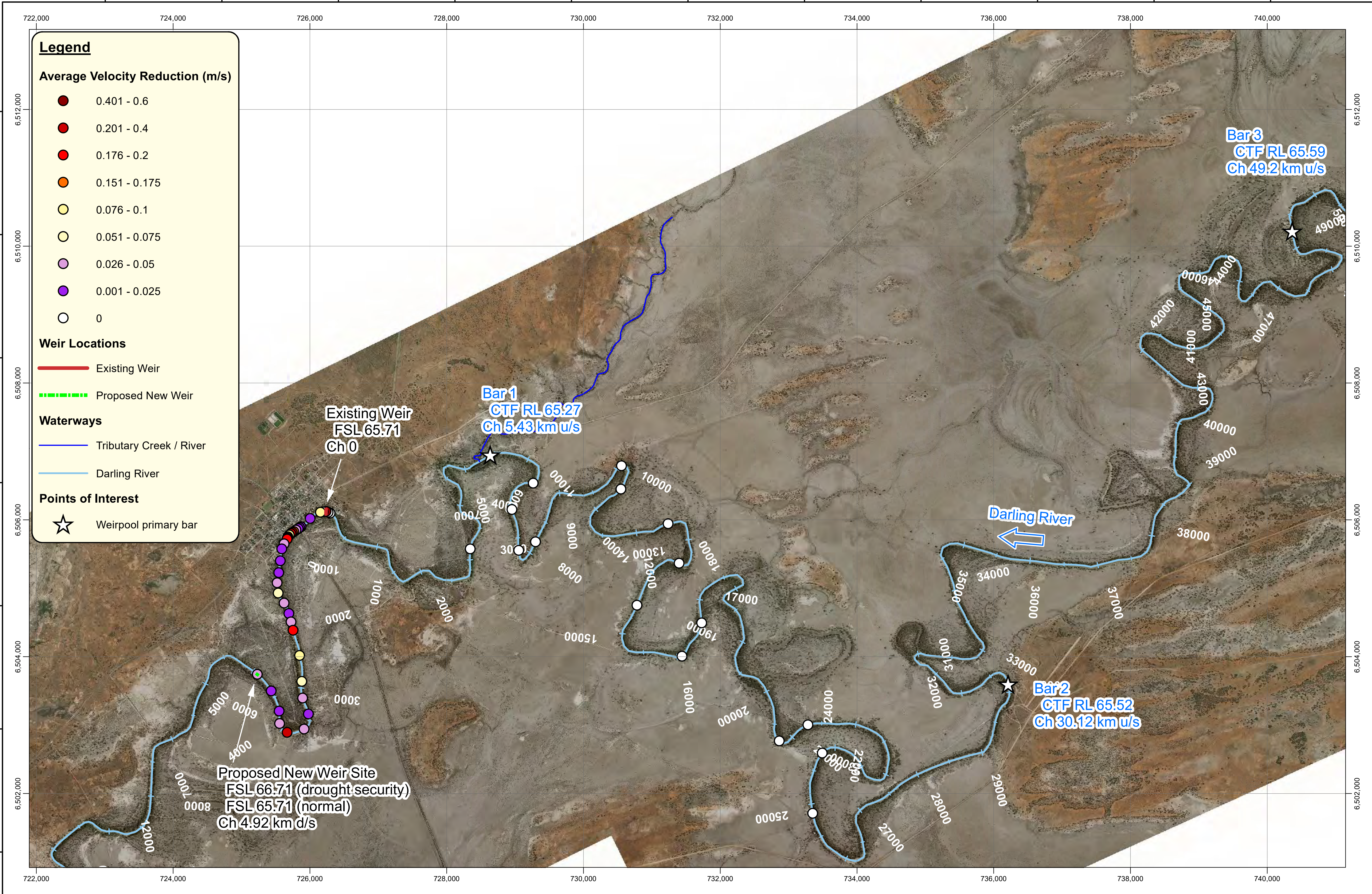
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
EXISTING VELOCITY
5000 ML/d - SHEET 3 of 3

FIGURE NO.
EV5000-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

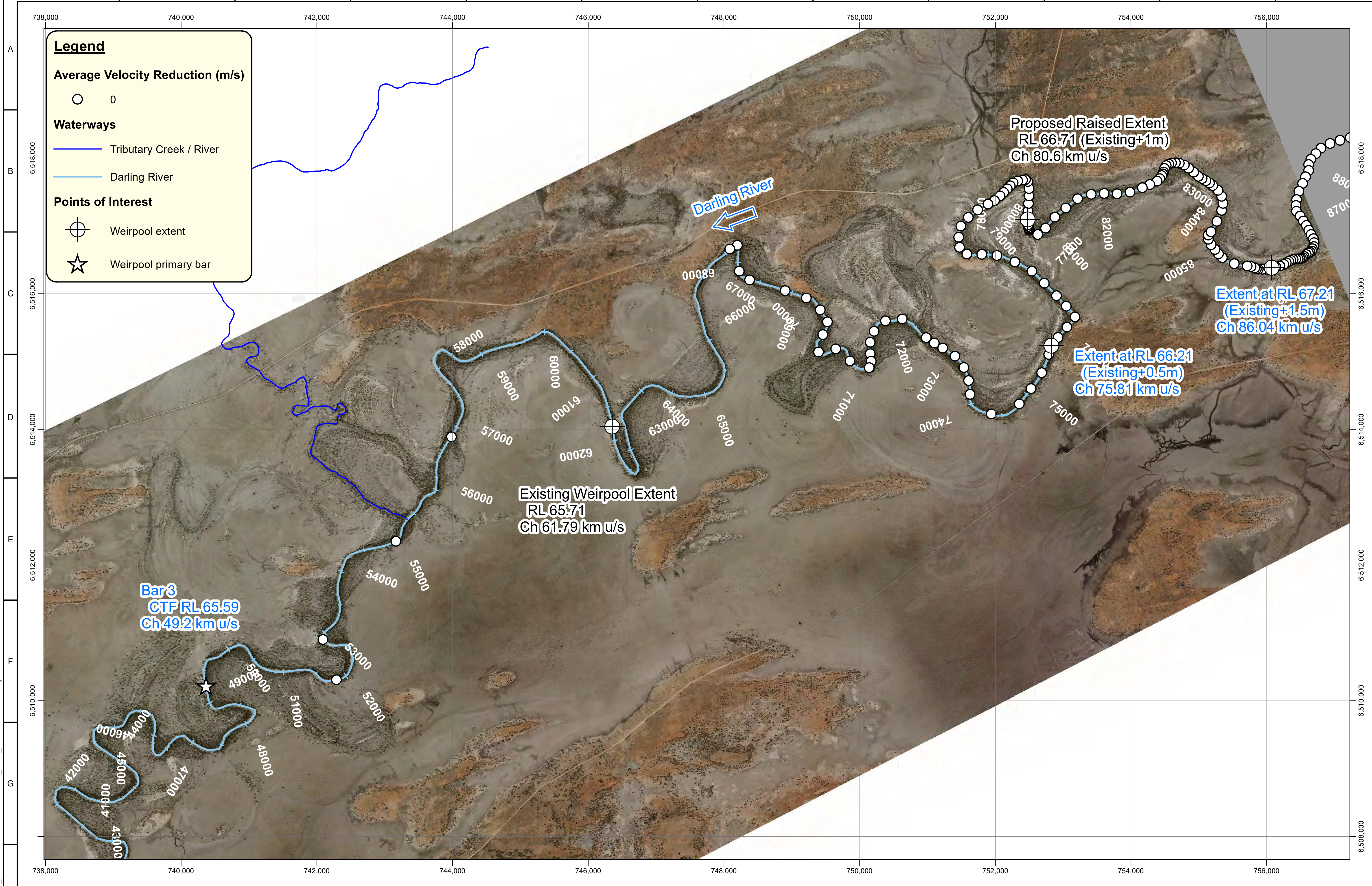
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
100 ML/d - SHEET 1 of 3

FIGURE NO.
VR100-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

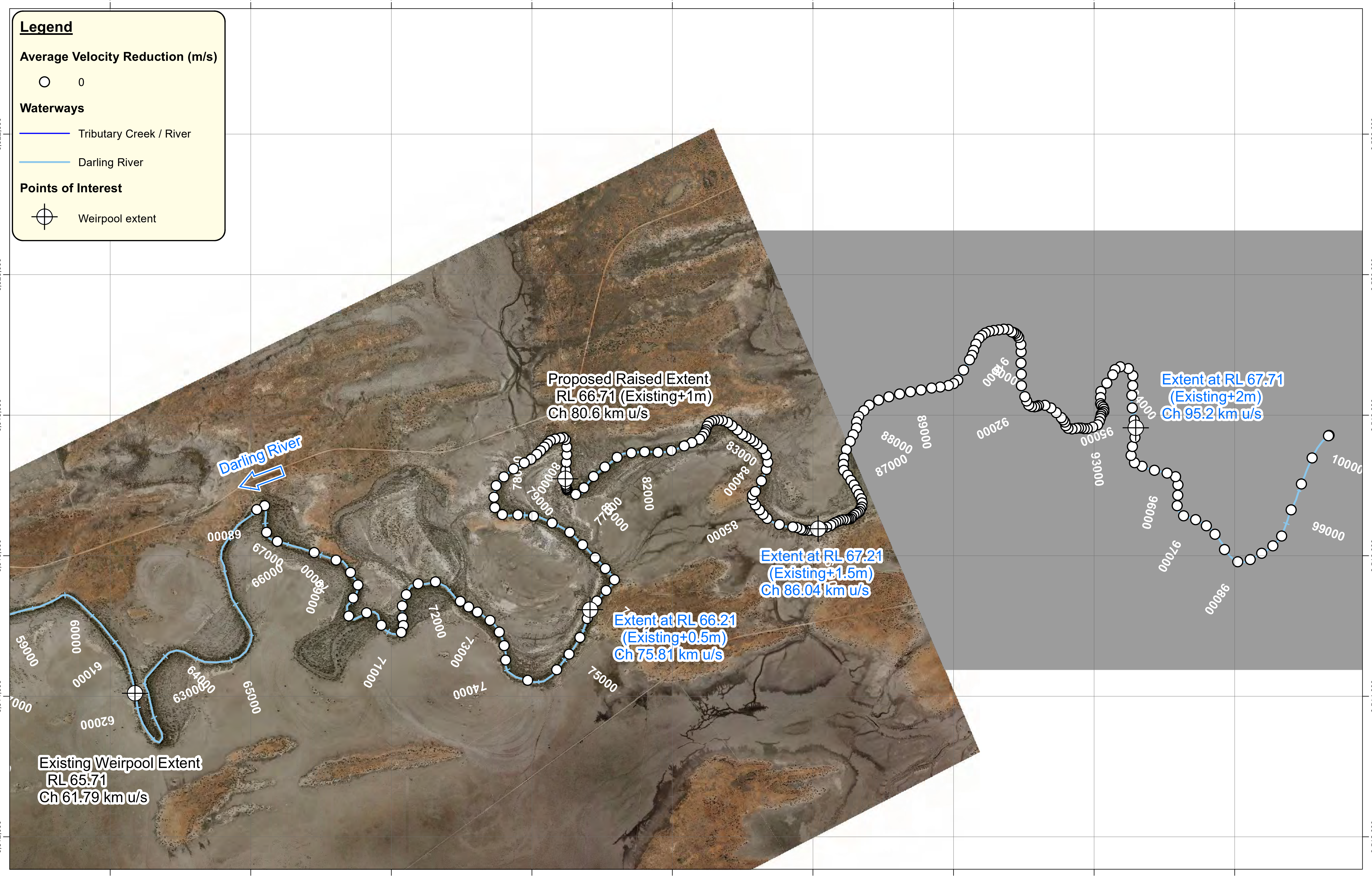
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
100 ML/d - SHEET 2 of 3

FIGURE NO.
VR100-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

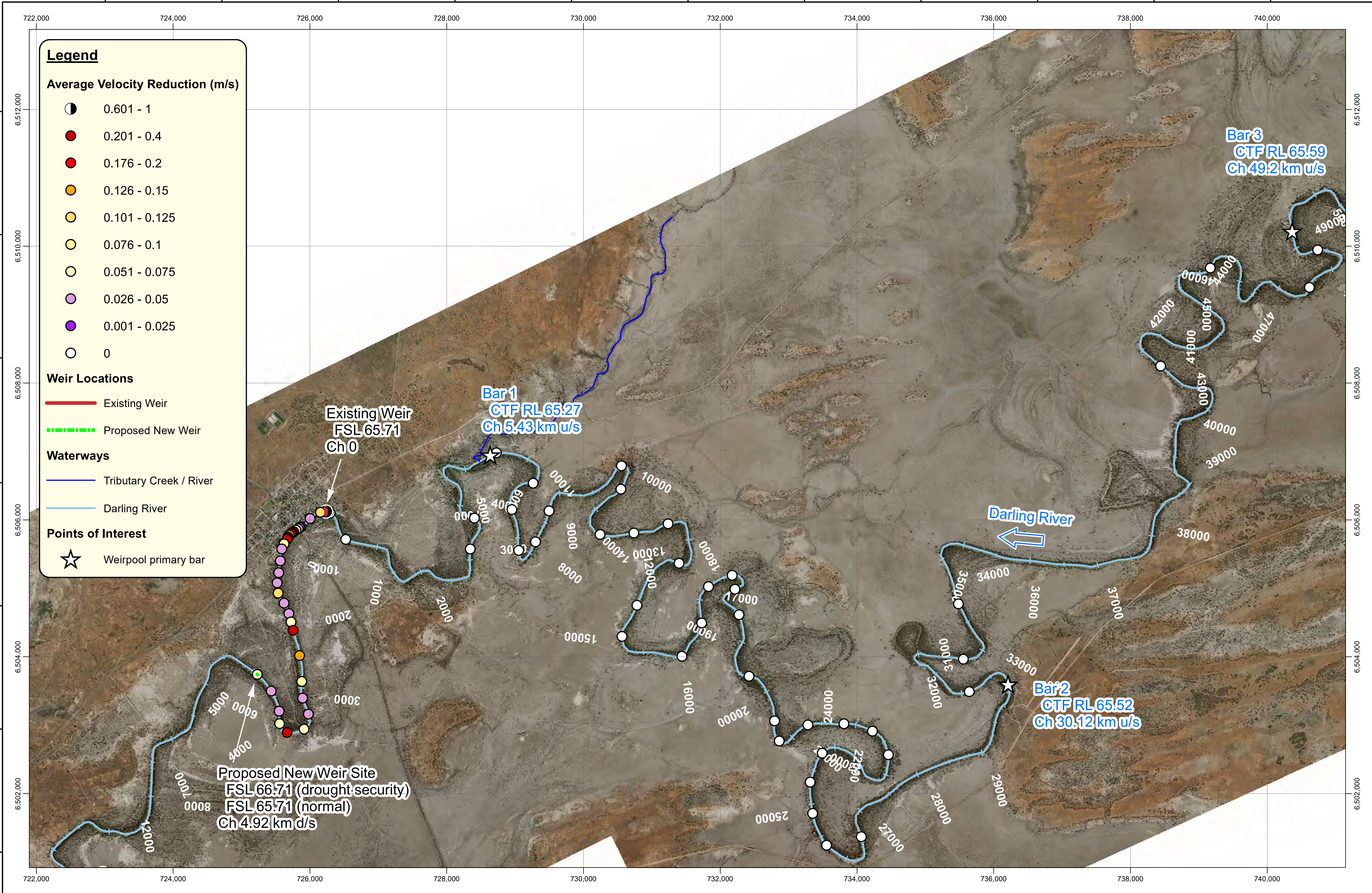
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
100 ML/d - SHEET 3 of 3

FIGURE NO.
VR100-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

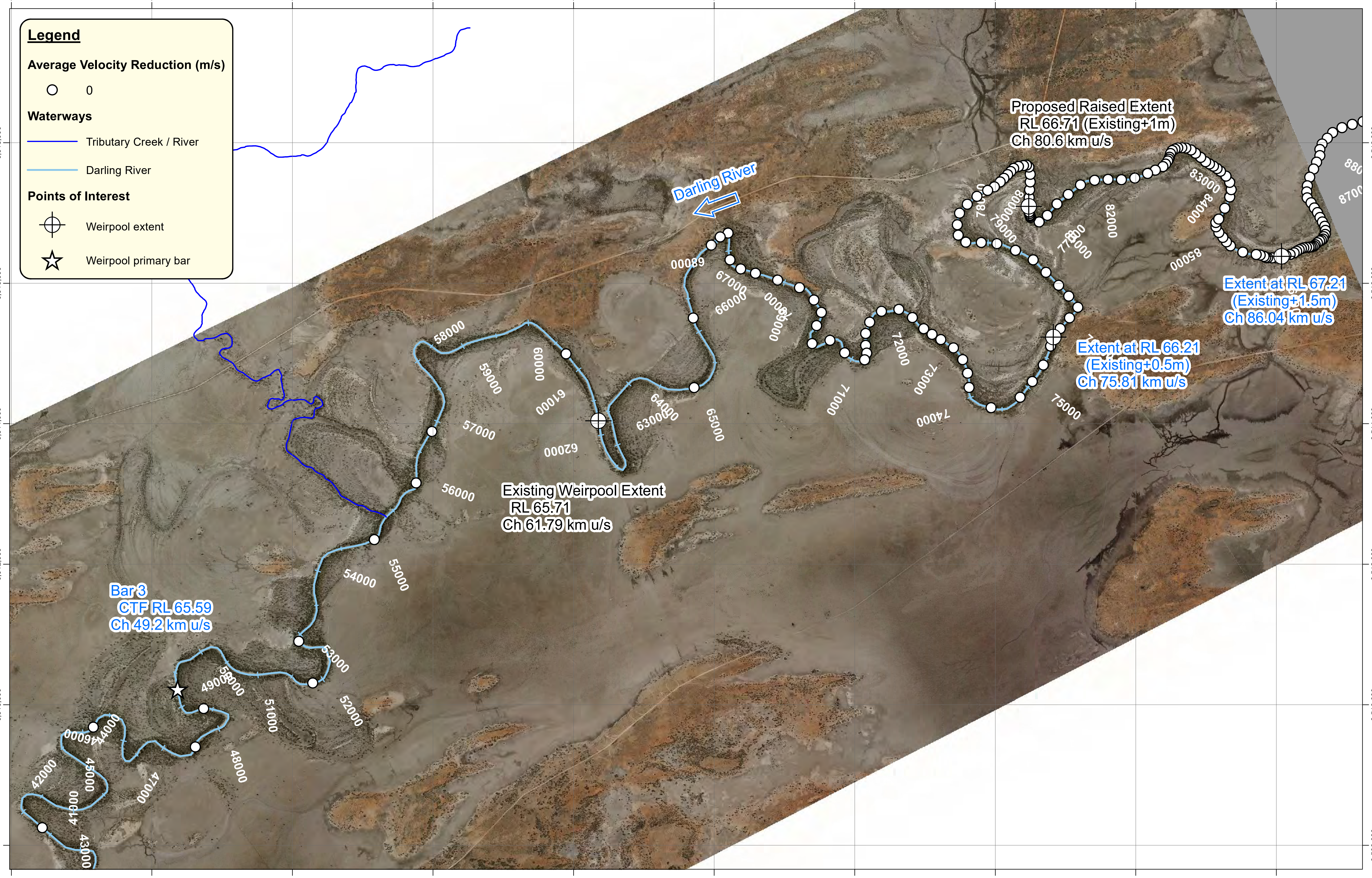
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
200 ML/d - SHEET 1 of 3

FIGURE NO.
VR200-1
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

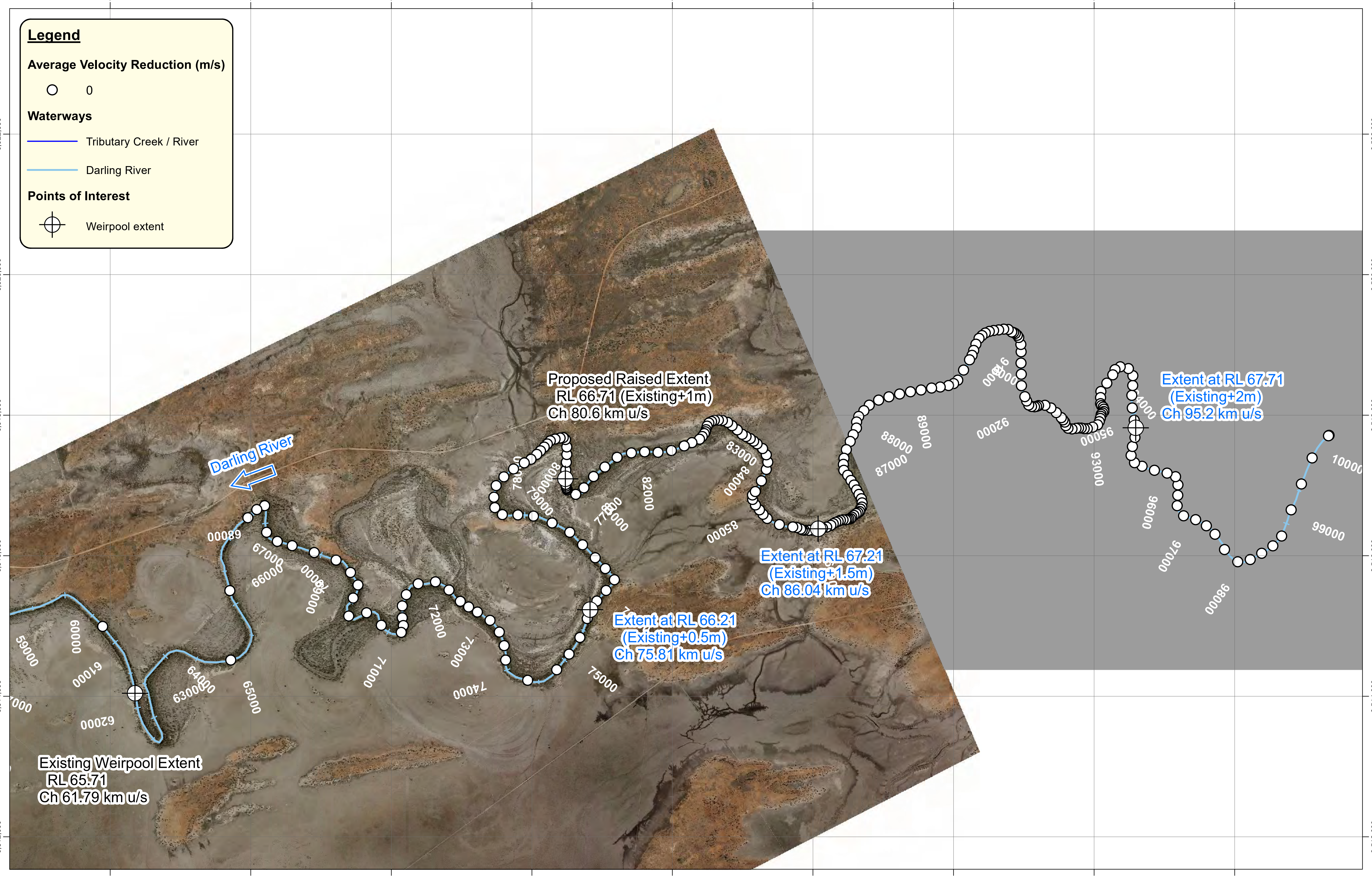
1:50,000
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
200 ML/d - SHEET 2 of 3

FIGURE NO.
VR200-2
Rev. 0



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

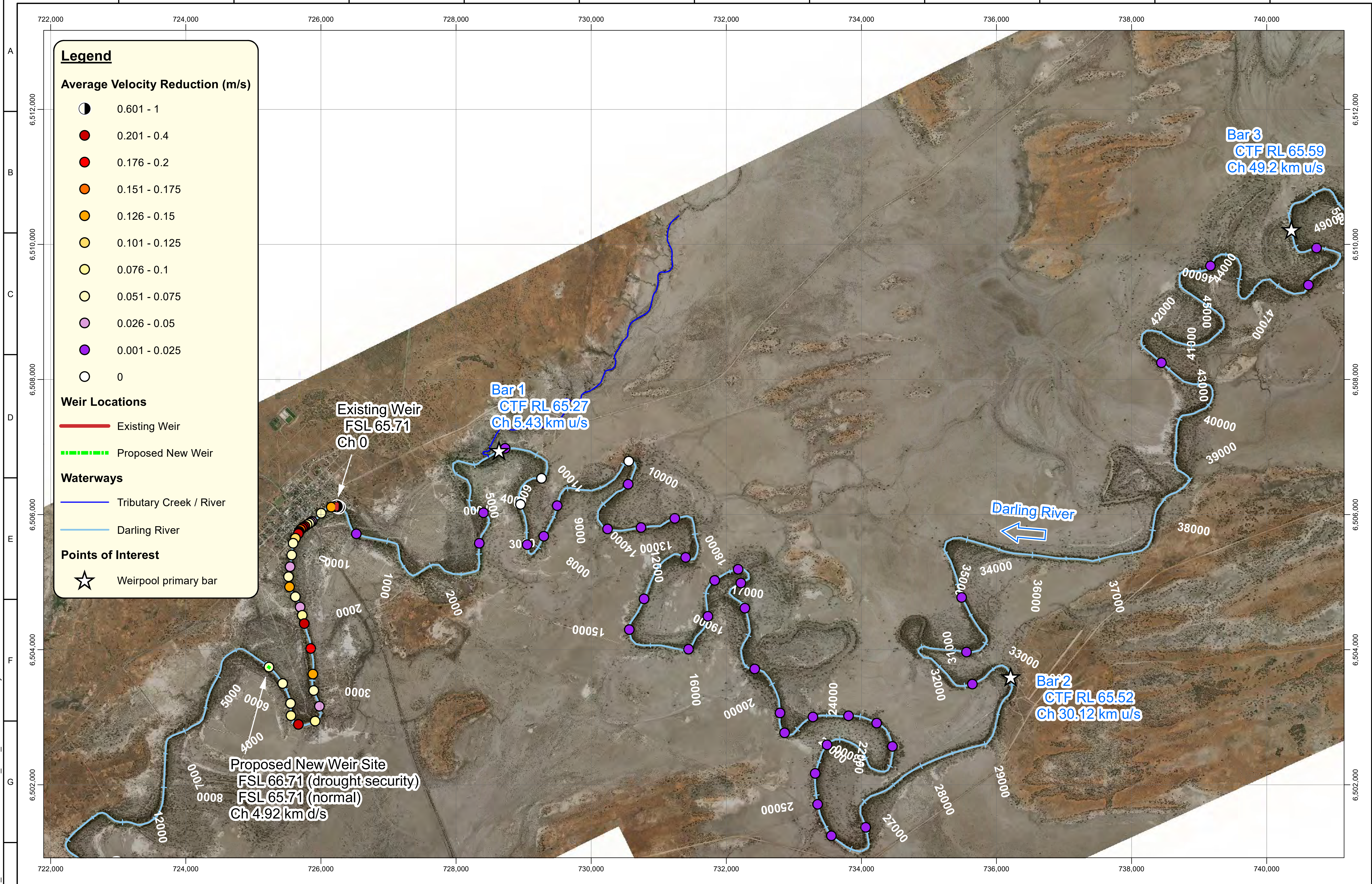
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
200 ML/d - SHEET 3 of 3

FIGURE NO.
VR200-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

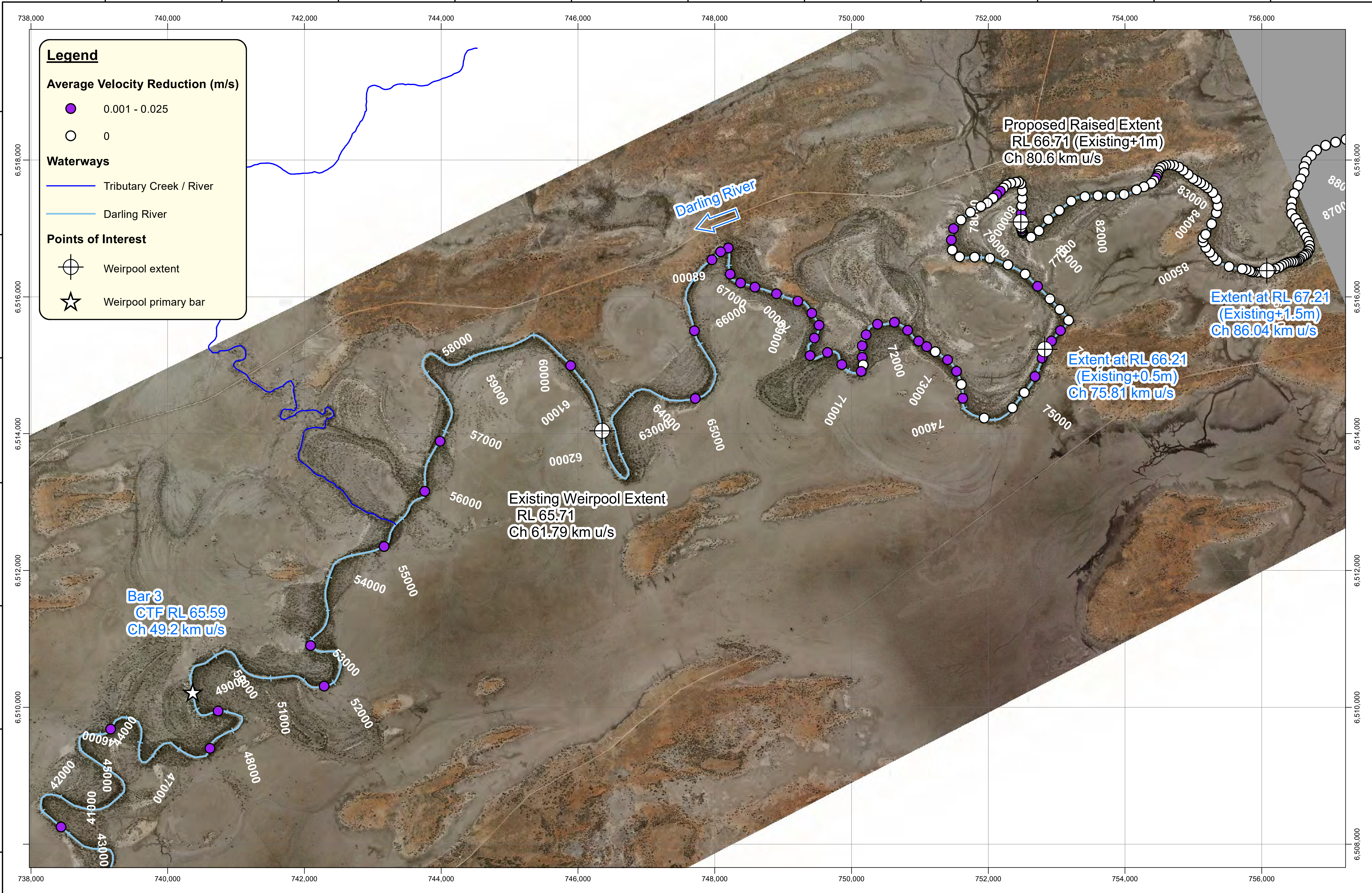
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
350 ML/d - SHEET 1 of 3

FIGURE NO.
VR350-1
Rev. 0



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

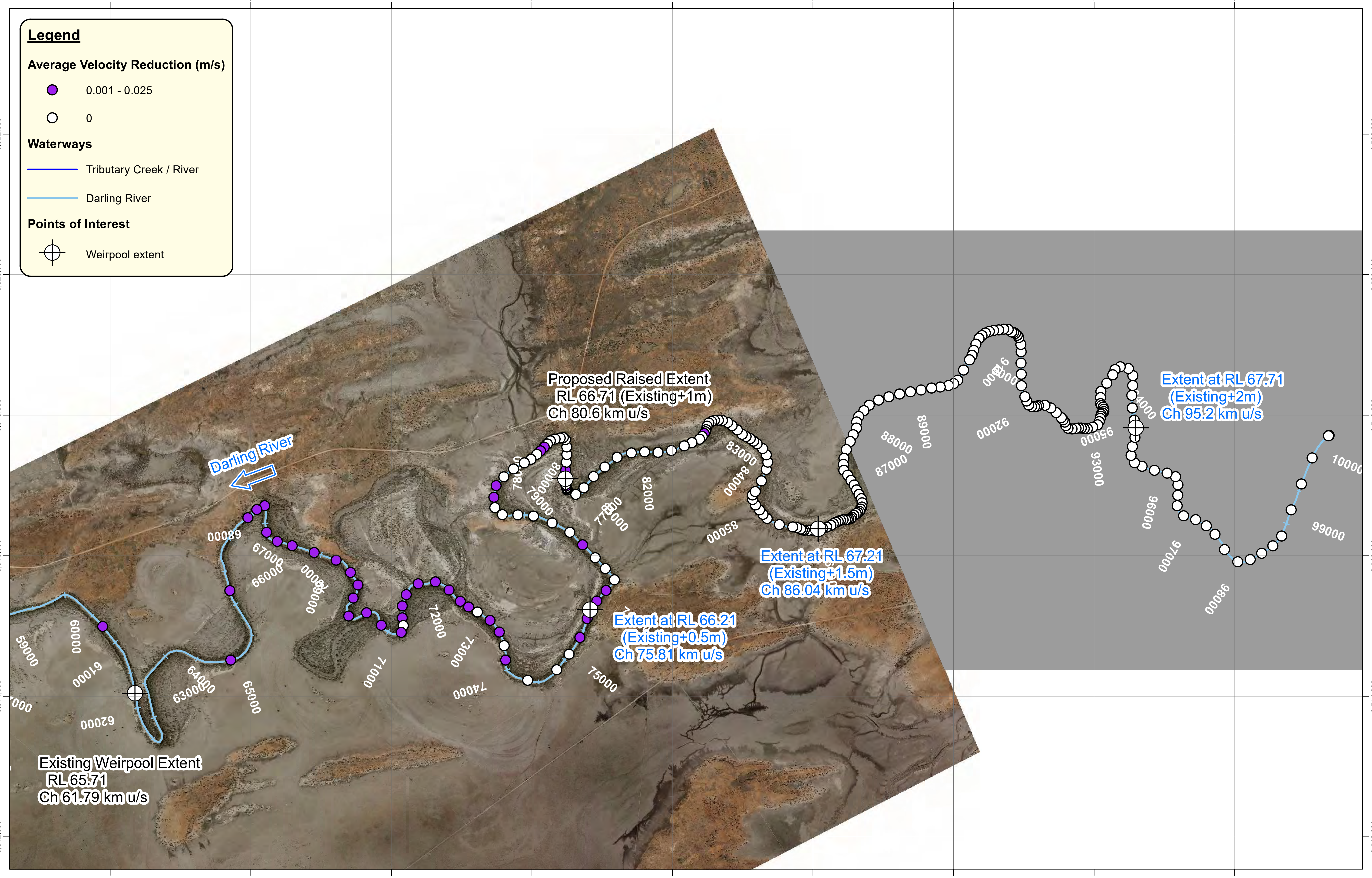
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
350 ML/d - SHEET 2 of 3

FIGURE NO. VR350-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

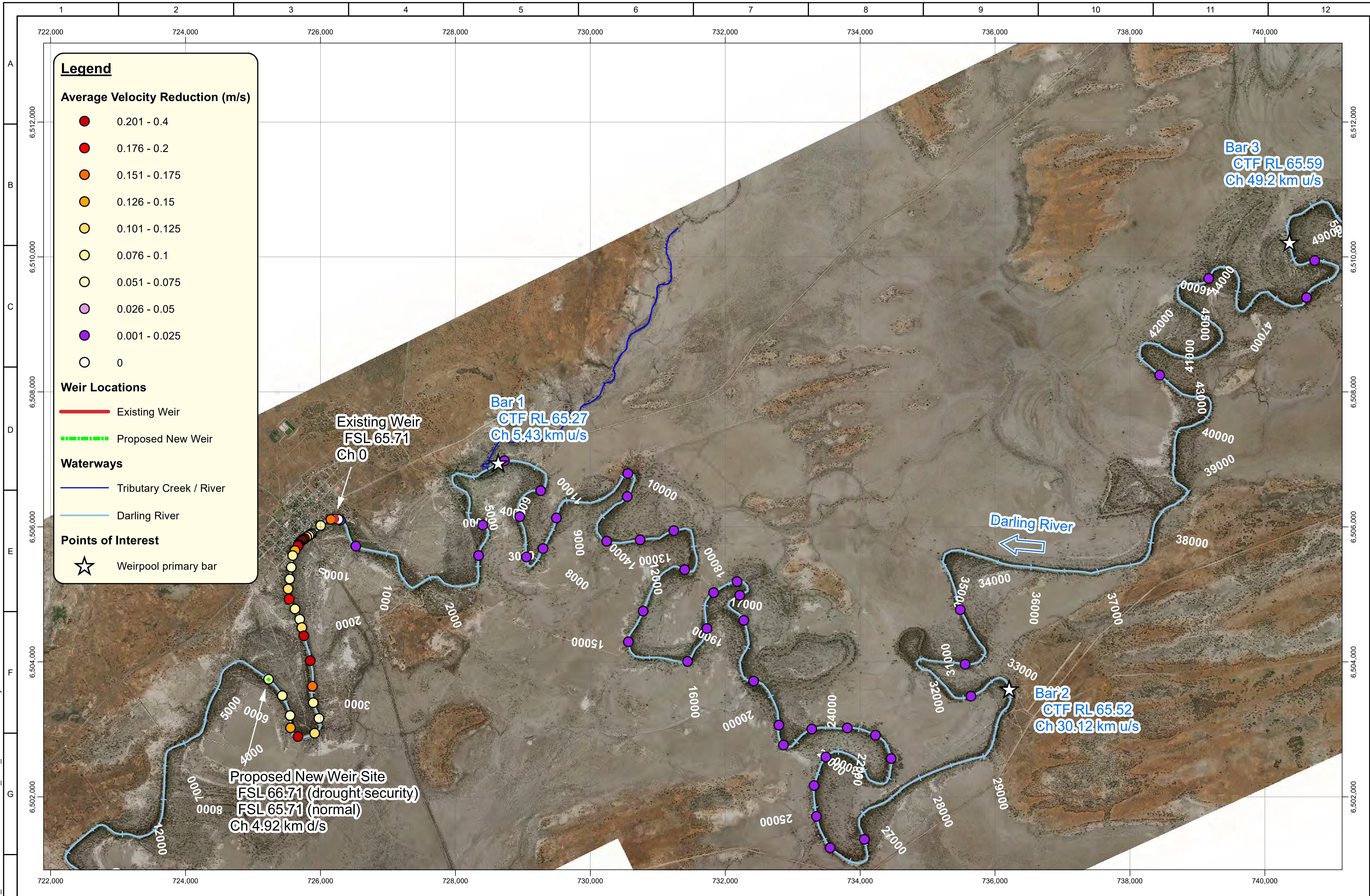
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
350 ML/d - SHEET 3 of 3

FIGURE NO.
VR350-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd

Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

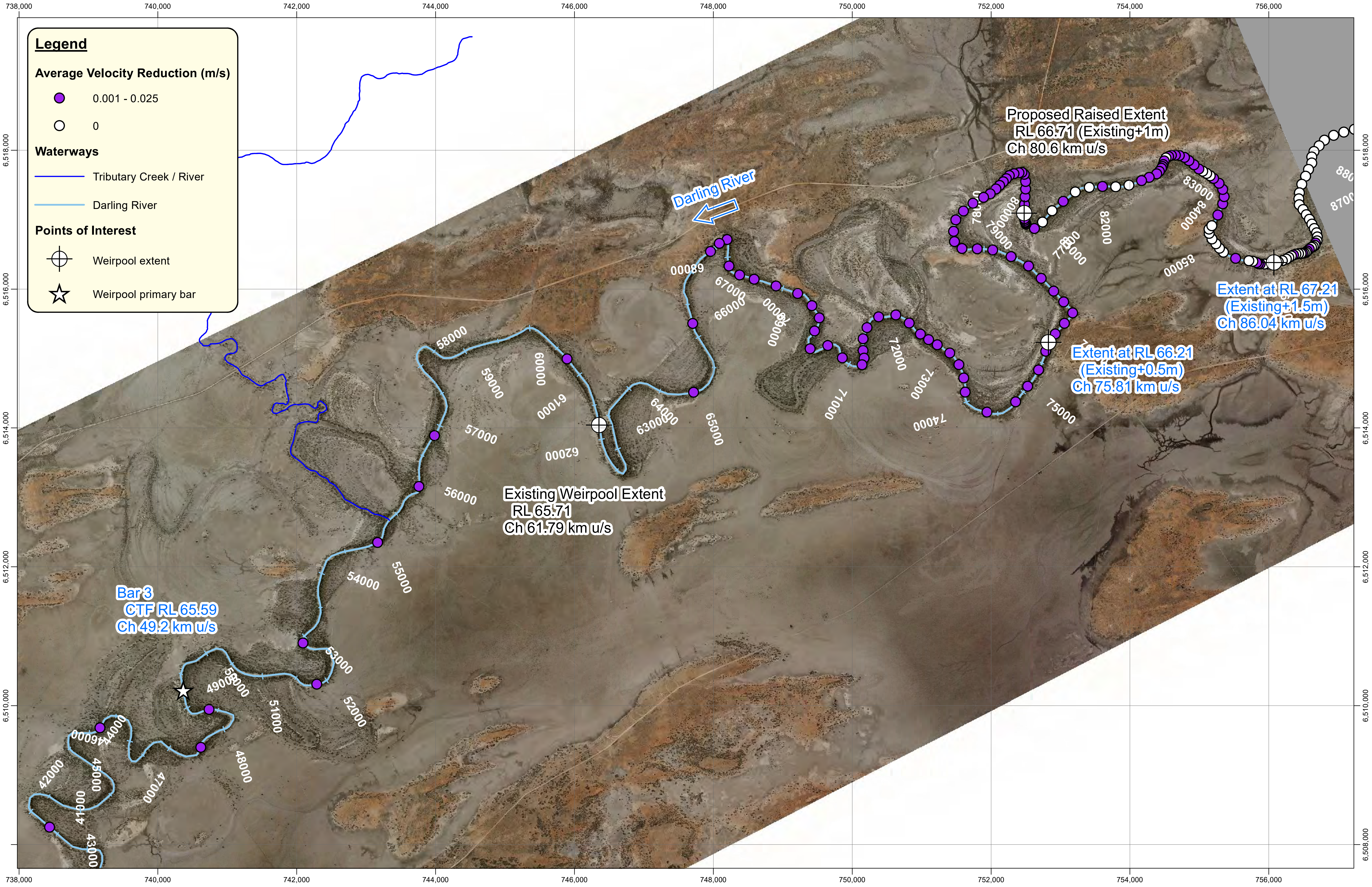
1:50,000
1,000 0 1,000 2,000 3,000
Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
600 ML/d - SHEET 1 of 3

FIGURE NO.
VR600-1
Rev. 0



Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd

Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

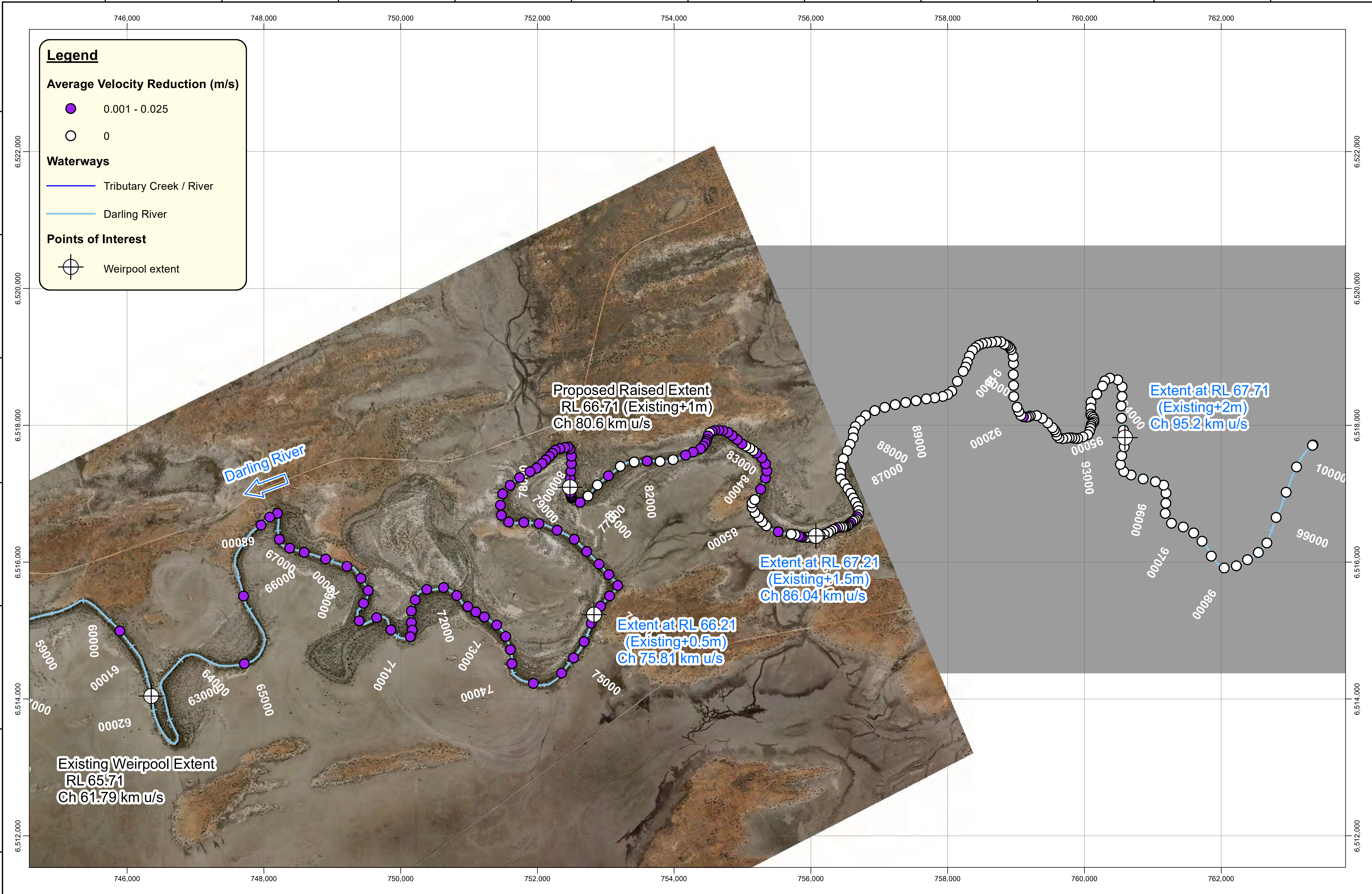
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
600 ML/d - SHEET 2 of 3

FIGURE NO.
VR600-2
Rev. 0



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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

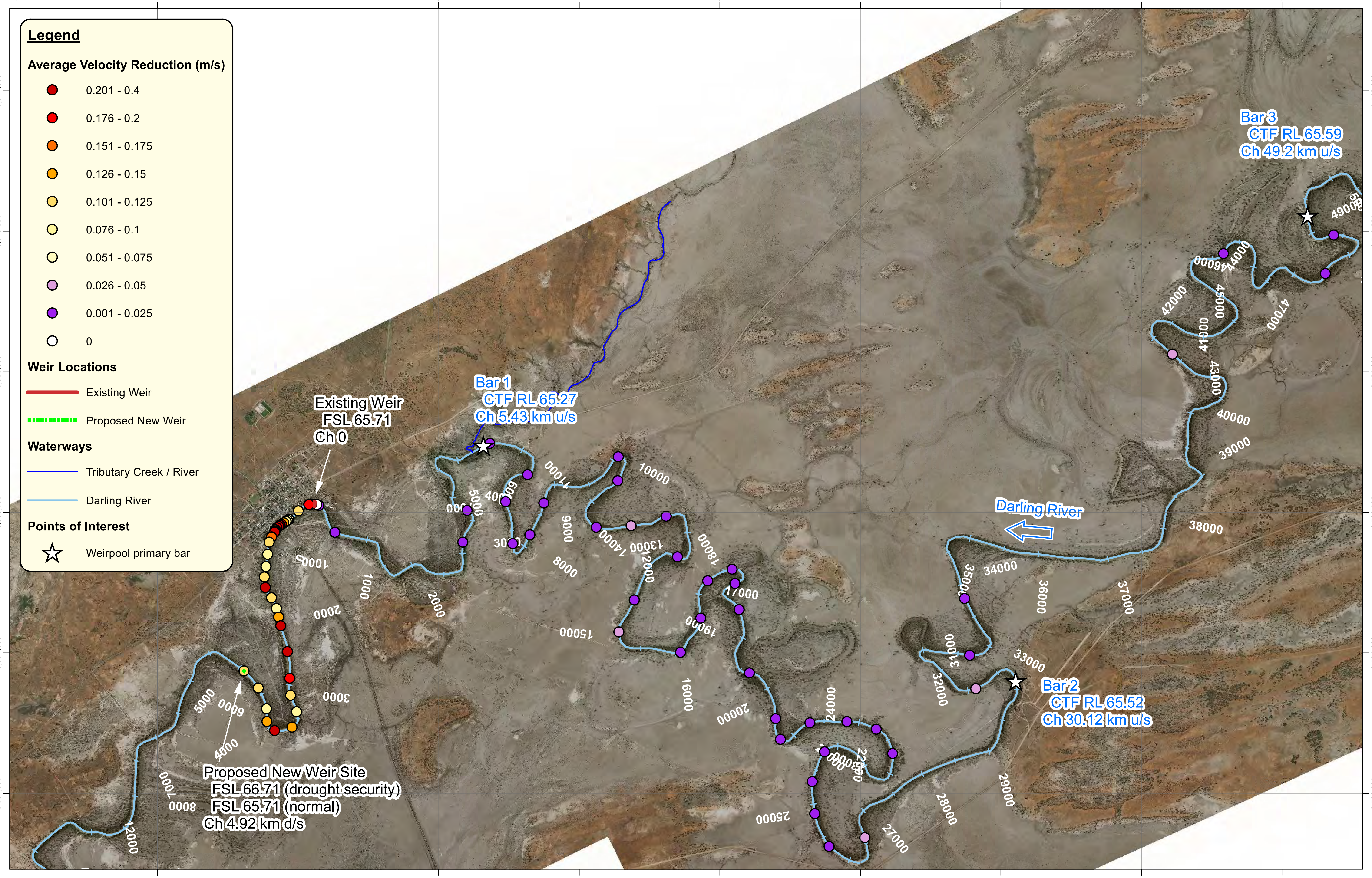
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
600 ML/d - SHEET 3 of 3

FIGURE NO.
VR600-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

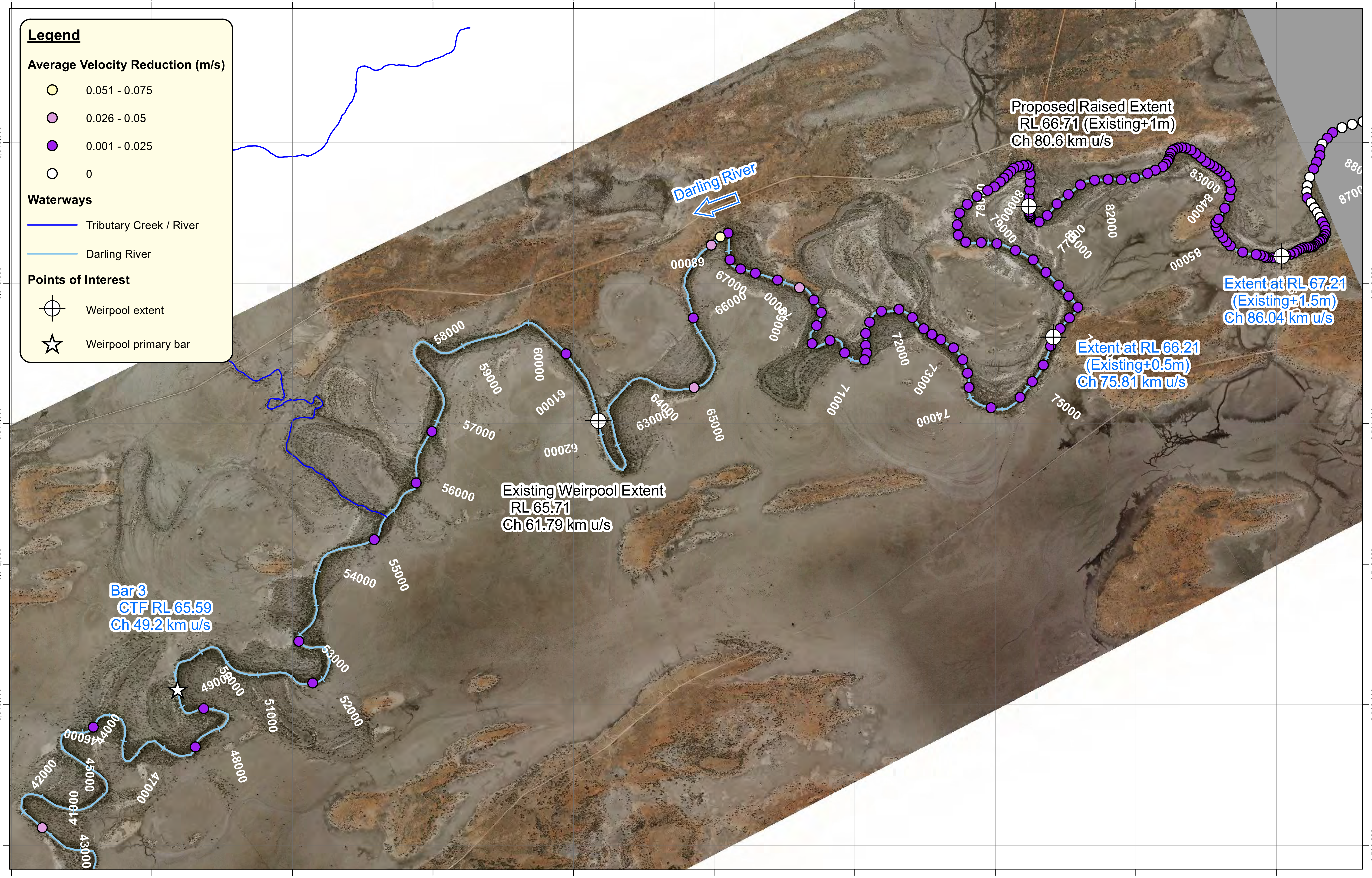
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
800 ML/d - SHEET 1 of 3

FIGURE NO.
VR800-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

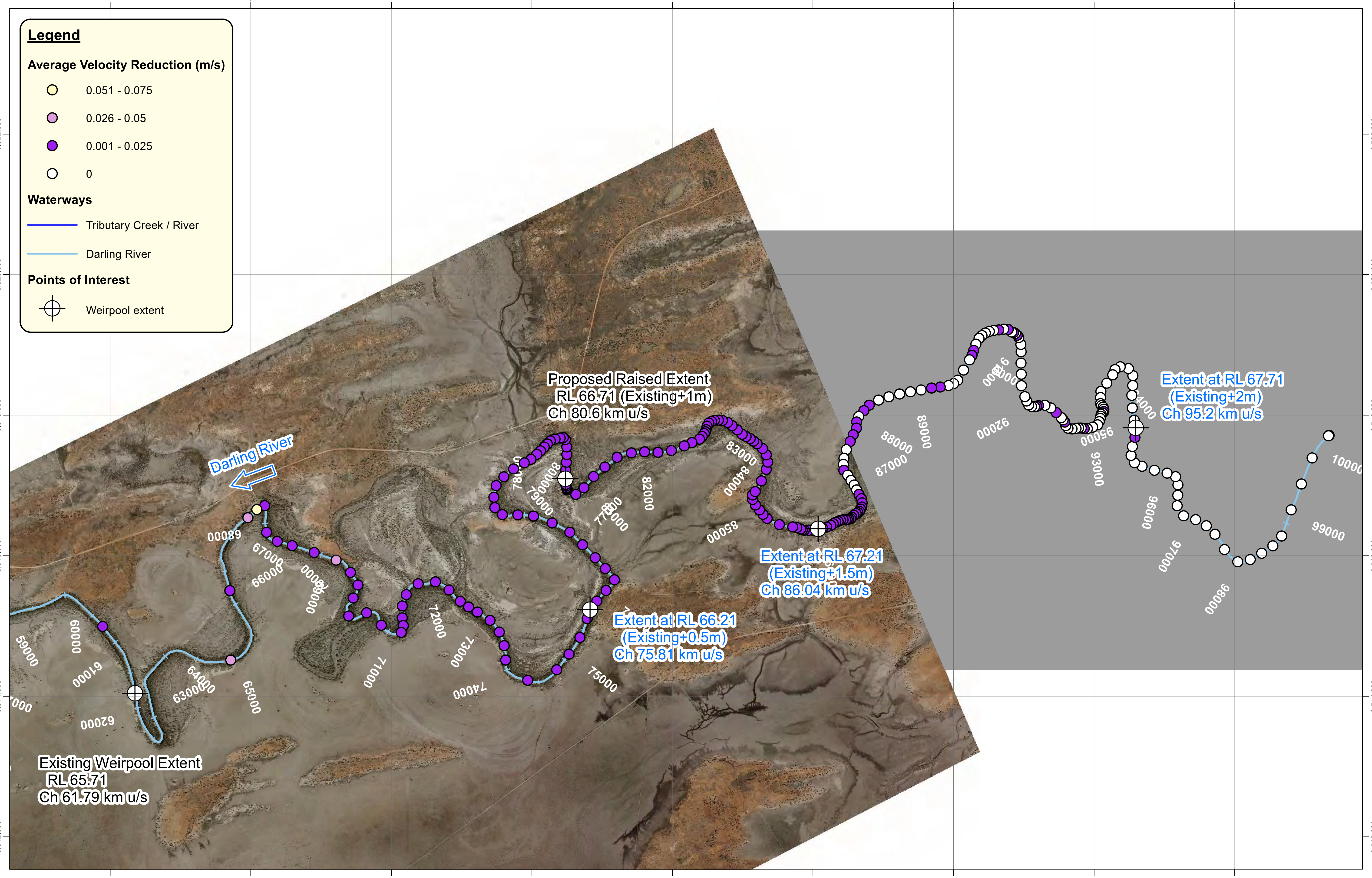
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
800 ML/d - SHEET 2 of 3

FIGURE NO.
VR800-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

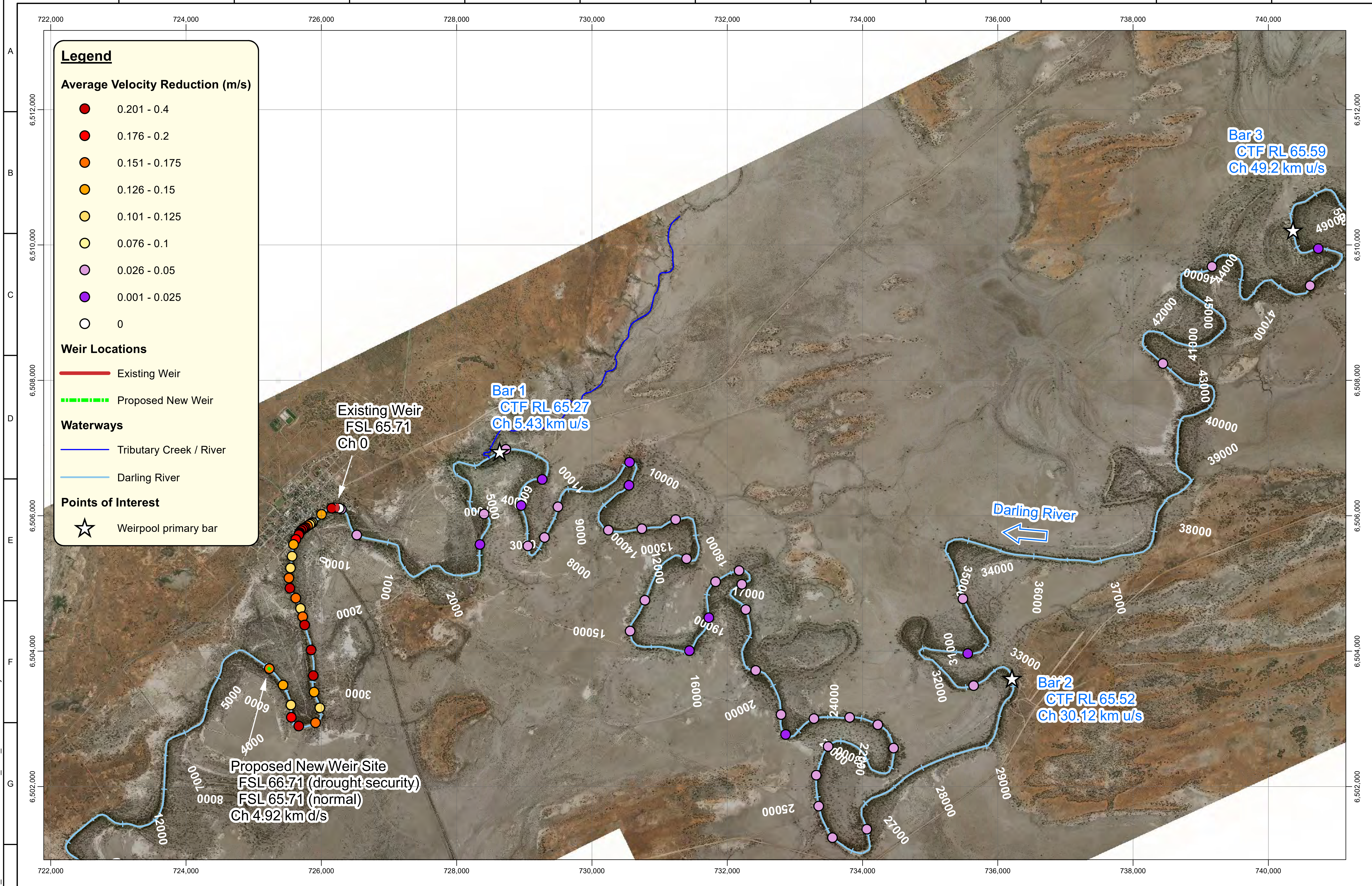
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
800 ML/d - SHEET 3 of 3

FIGURE NO.
VR800-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



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Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

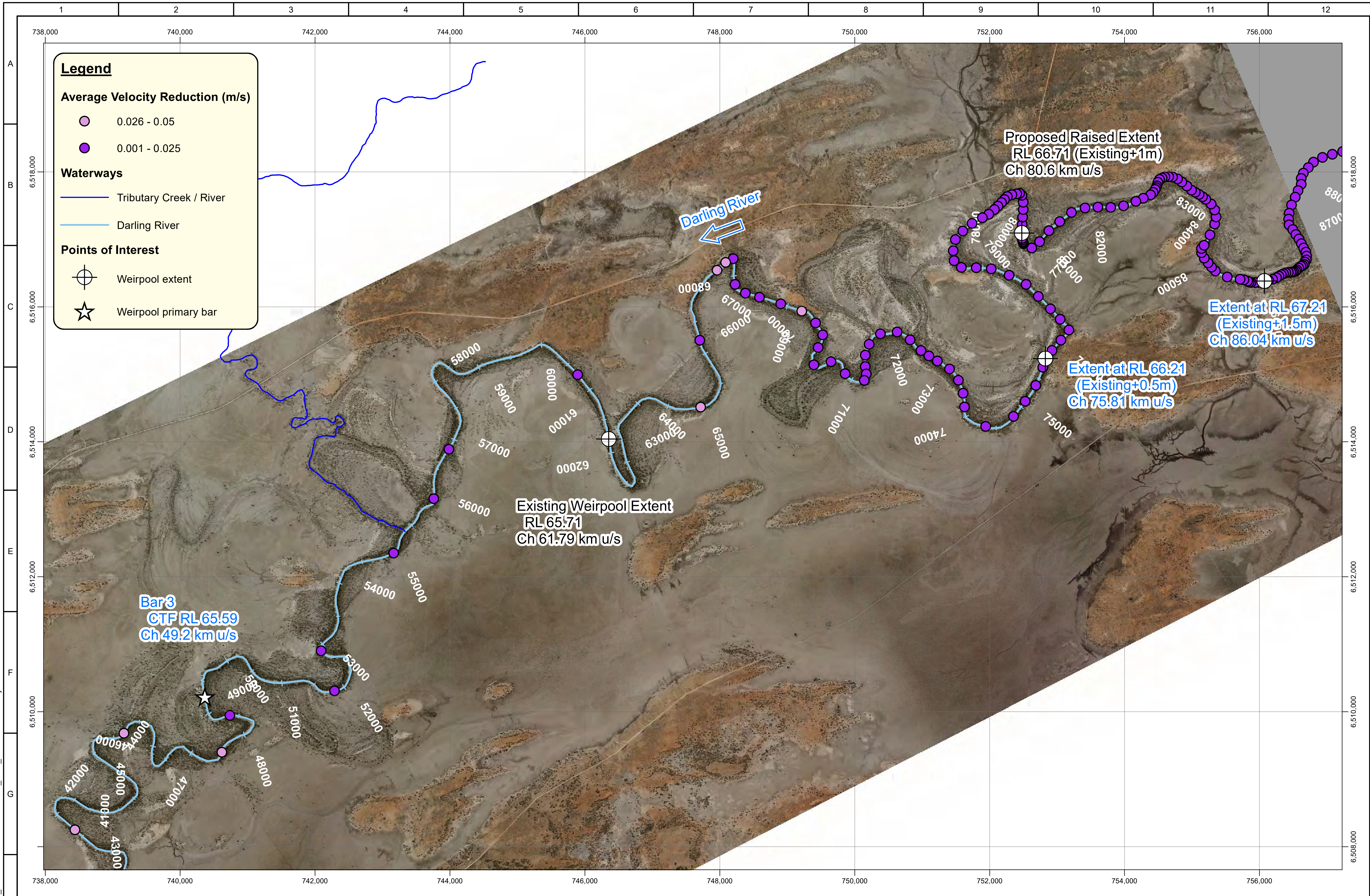
1:50,000
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
1400 ML/d - SHEET 1 of 3

FIGURE NO.
VR1400-1
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

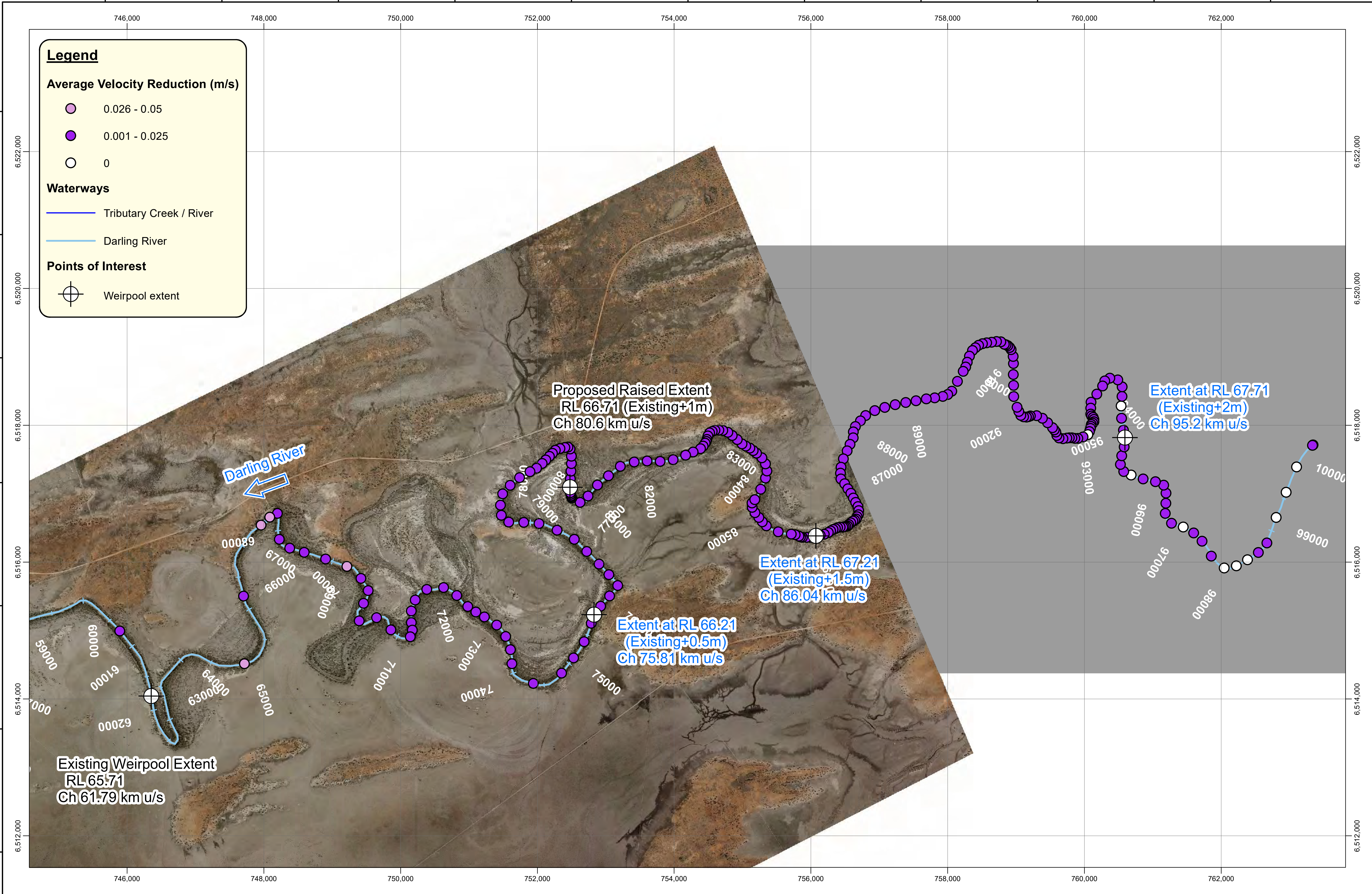
1:50,000
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
1400 ML/d - SHEET 2 of 3

FIGURE NO.
VR1400-2
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

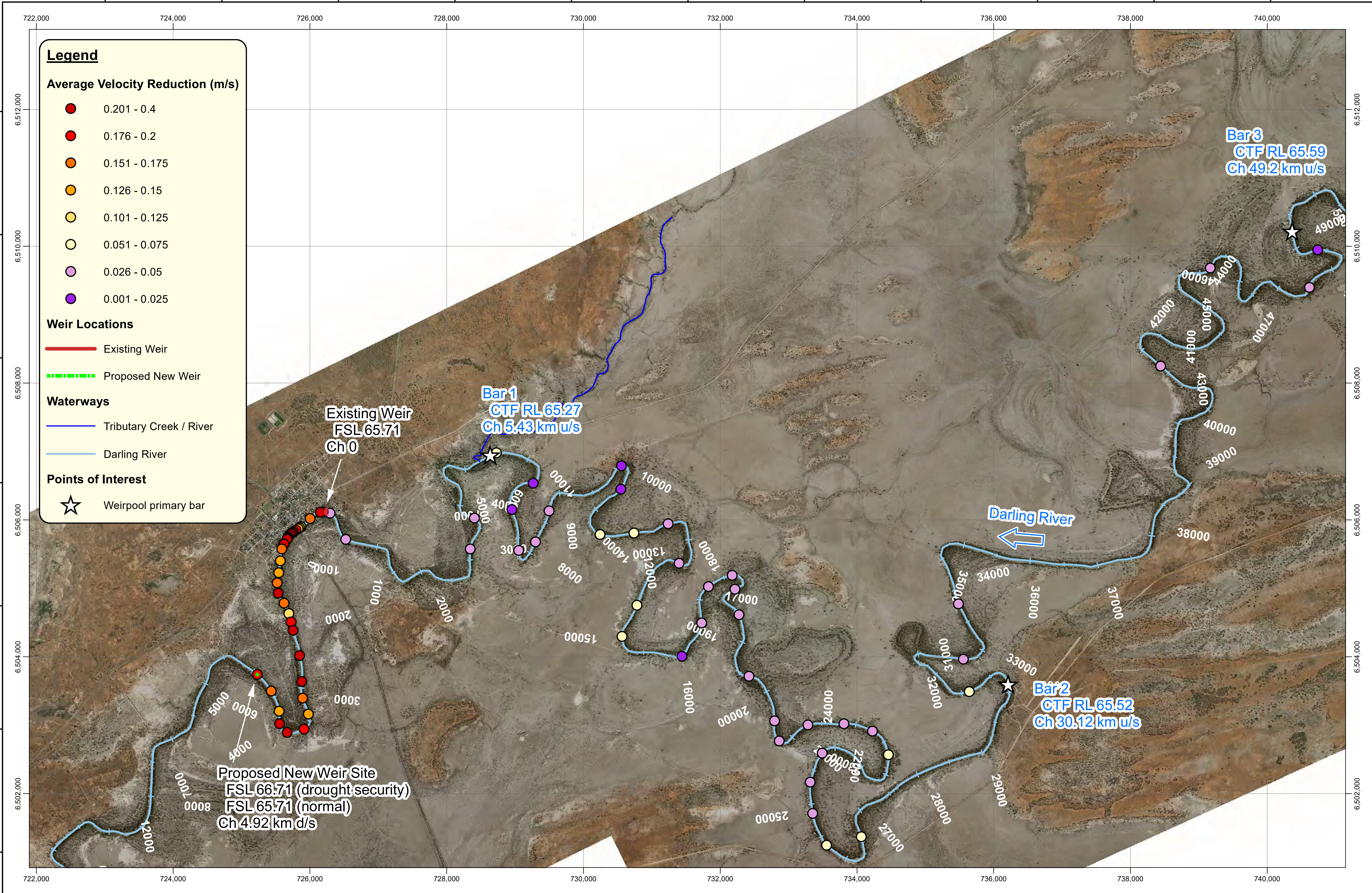
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
1400 ML/d - SHEET 3 of 3

FIGURE NO.
VR1400-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

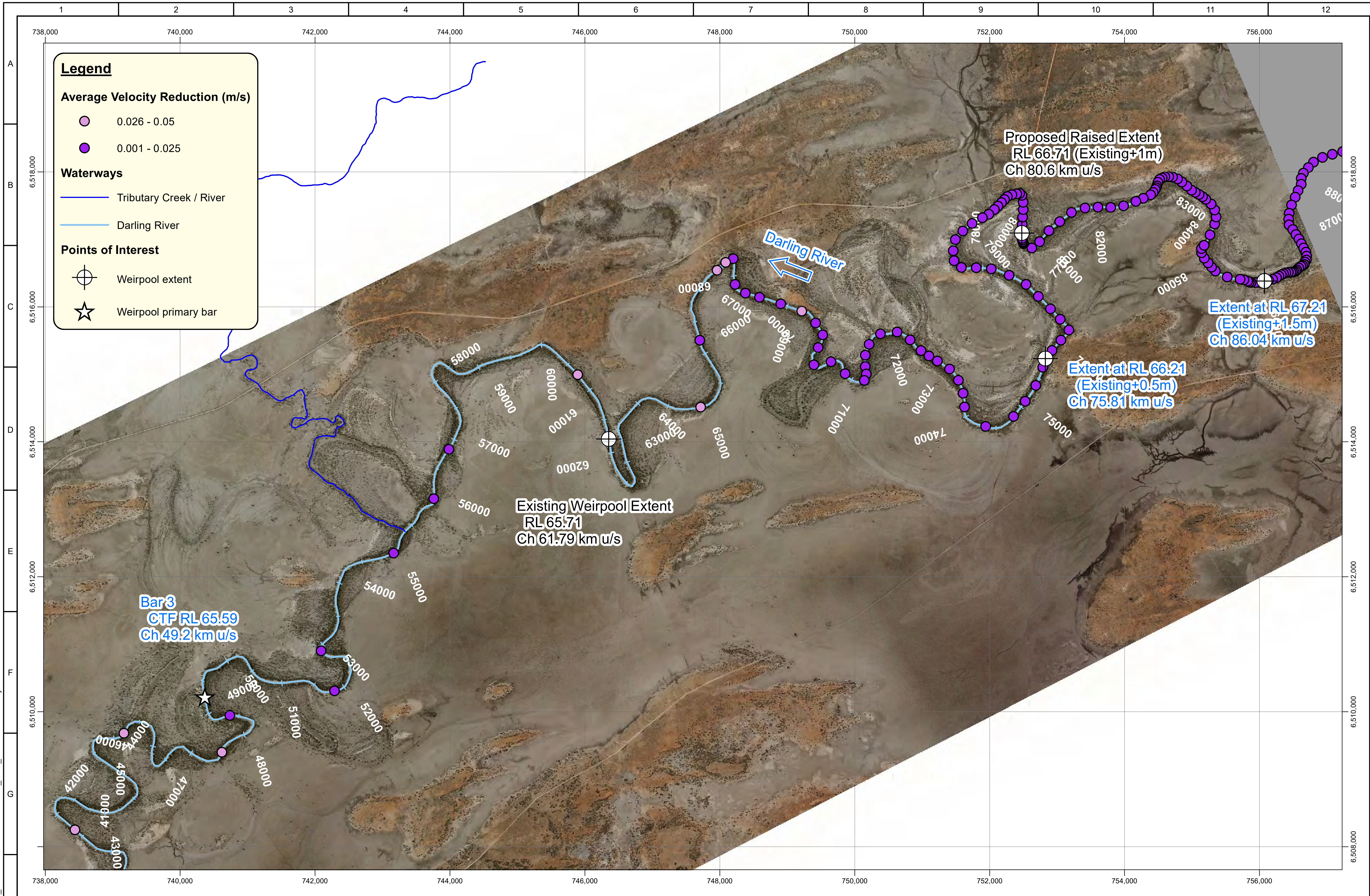
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
2000 ML/d - SHEET 1 of 3

FIGURE NO.
VR2000-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

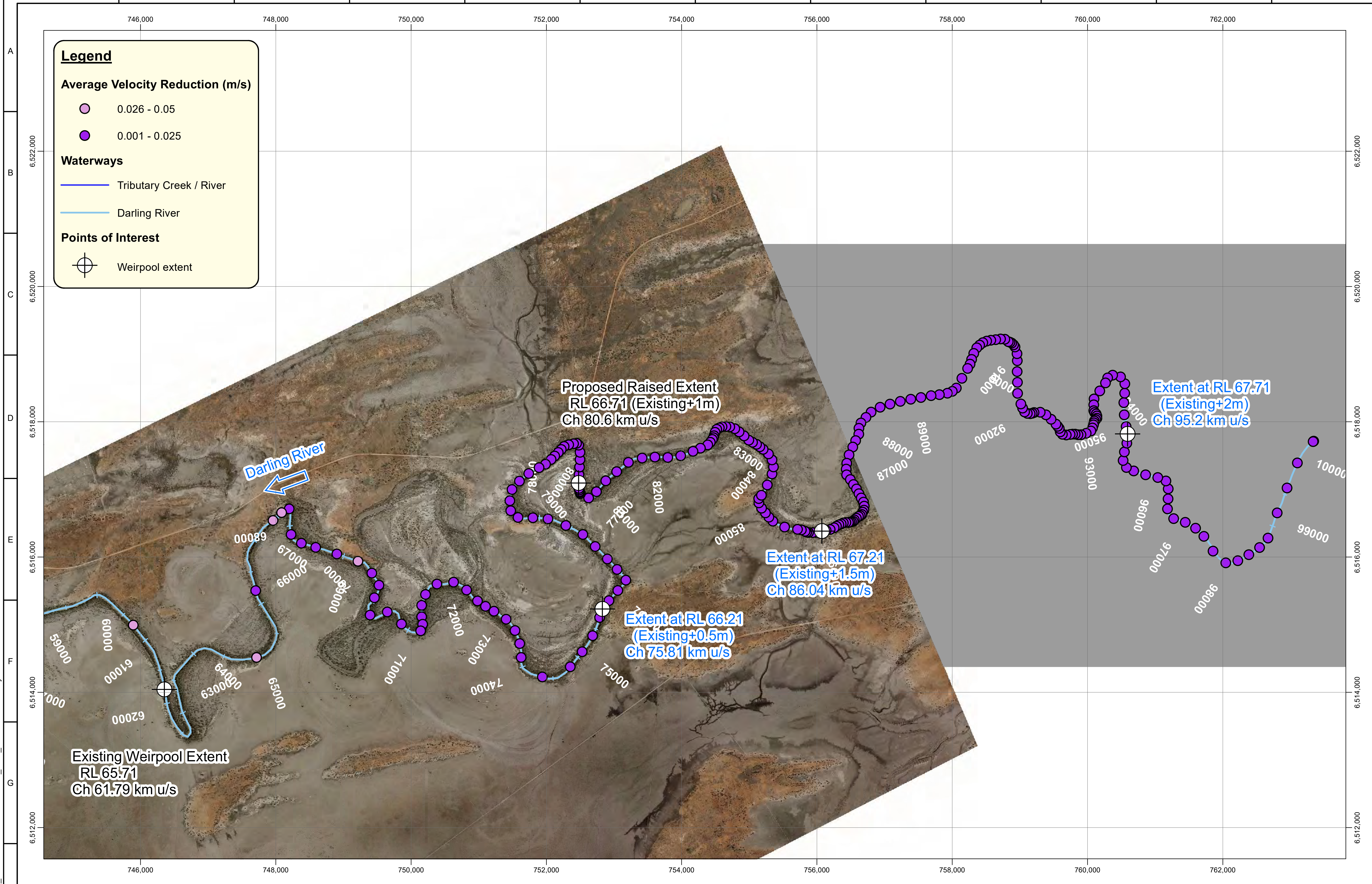
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
2000 ML/d - SHEET 2 of 3

FIGURE NO.
VR2000-2
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

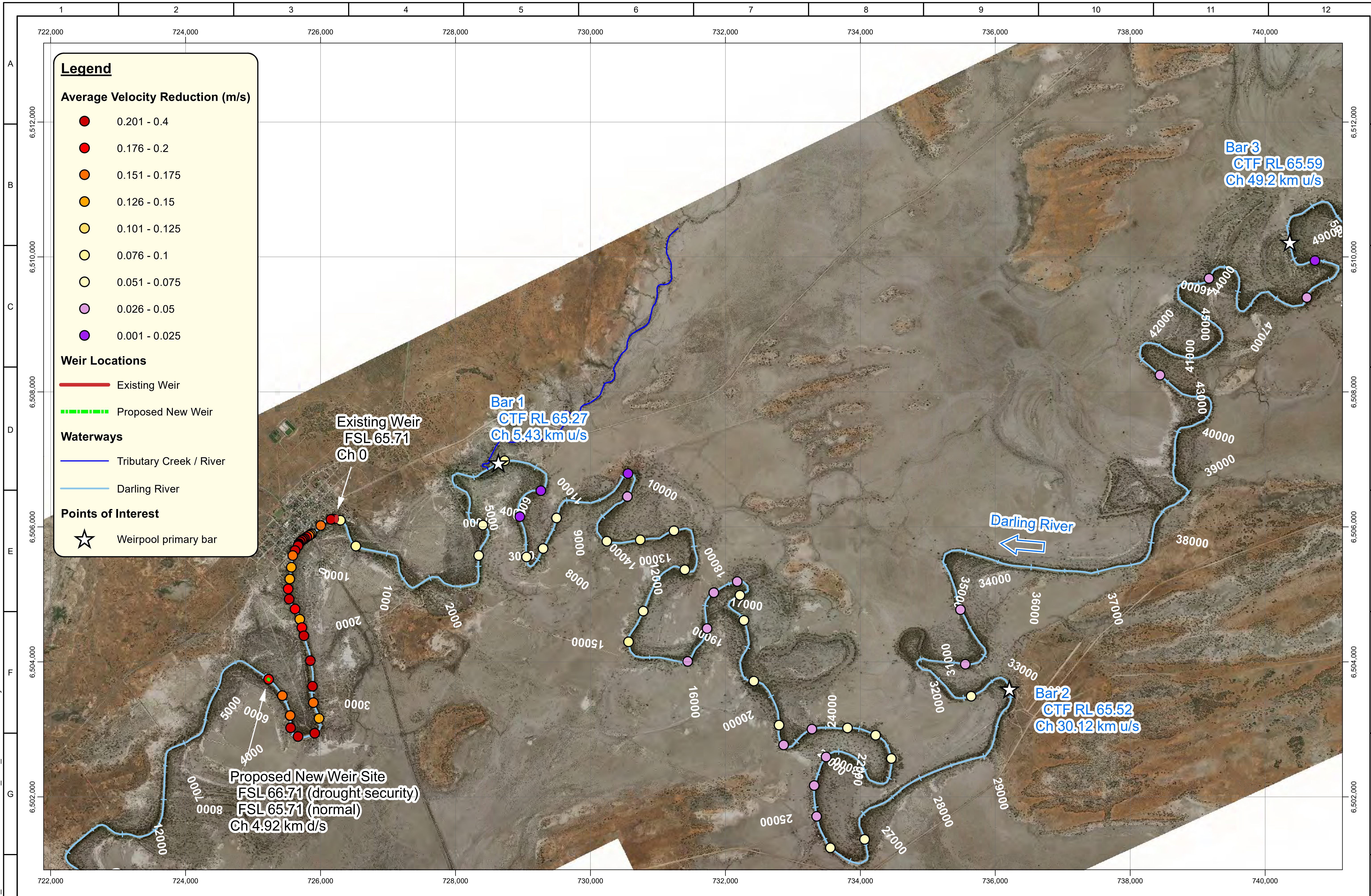
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
2000 ML/d - SHEET 3 of 3

FIGURE NO.
VR2000-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

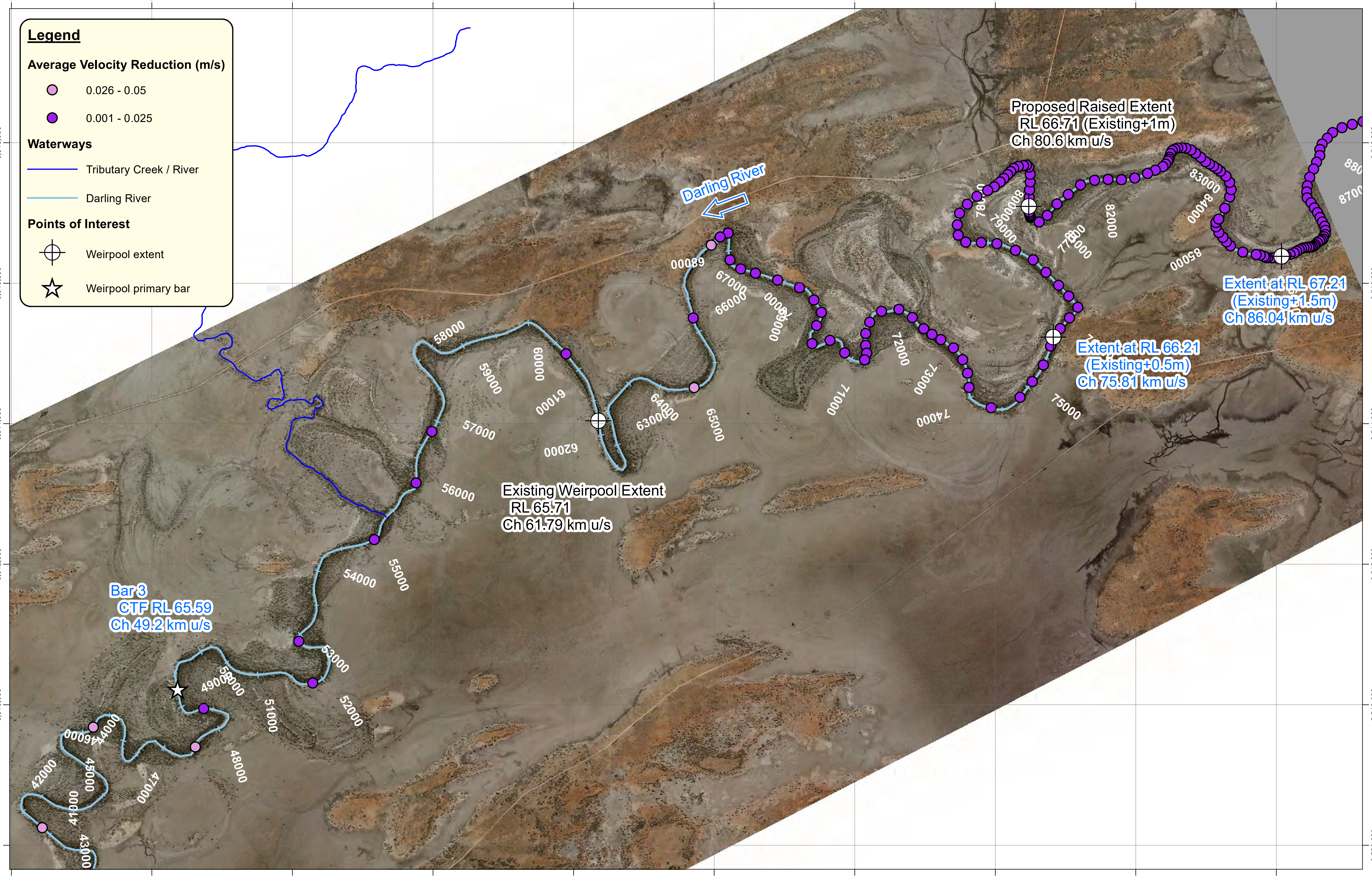
MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
3500 ML/d - SHEET 1 of 3

FIGURE NO.
VR3500-1
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
3500 ML/d - SHEET 2 of 3

FIGURE NO.
VR3500-2
Rev. 0

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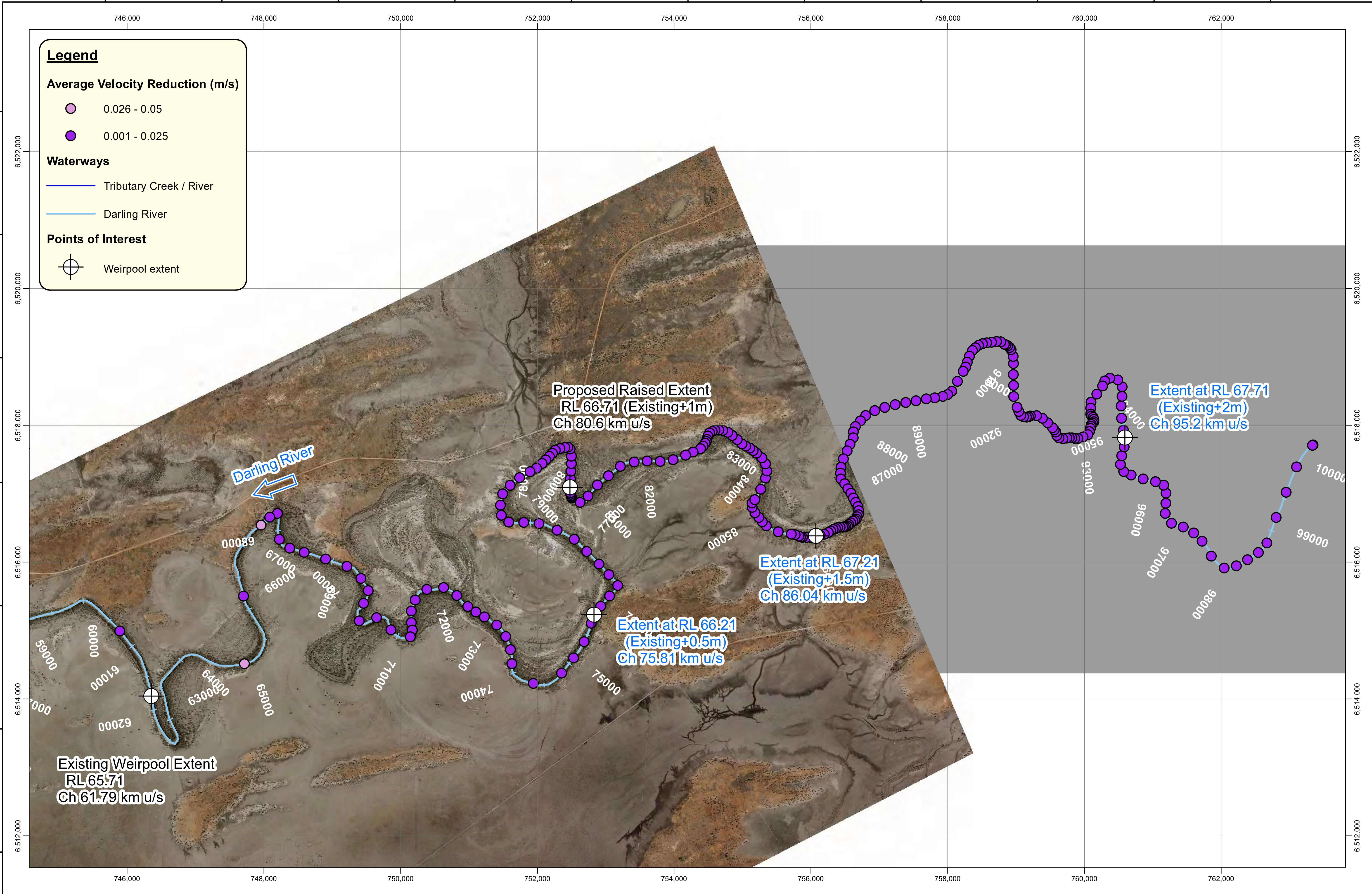


Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000
1,000 0 1,000 2,000 3,000 Metres

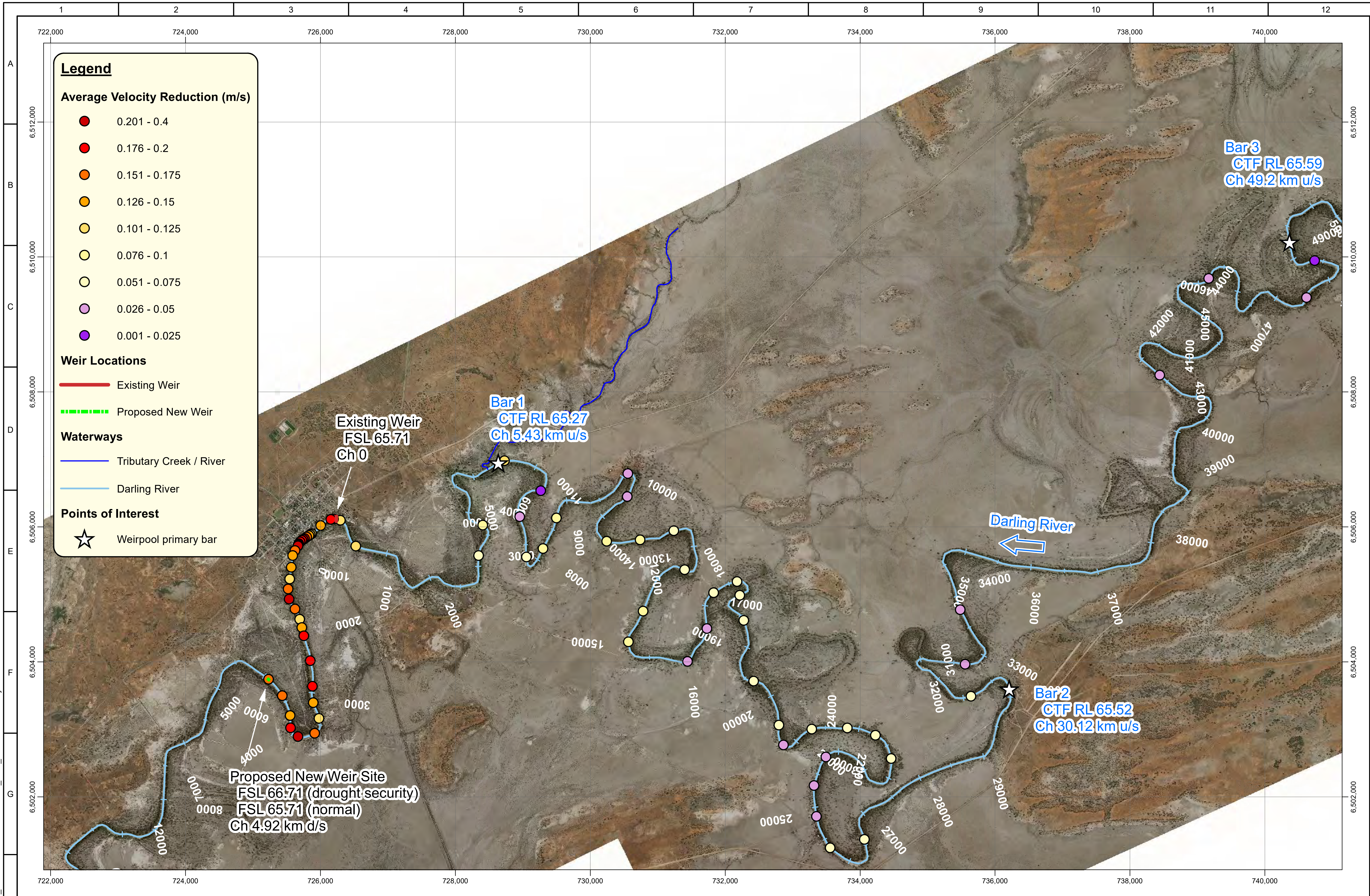
MGA94 ZONE 54

NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
3500 ML/d - SHEET 3 of 3

FIGURE NO.
VR3500-3
Rev. 0

Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd



Document Path: D:\My_Work\PROJECTS\Wilcannia_Weir_GIS\New Weir - Hydro.mxd

Notes:
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DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

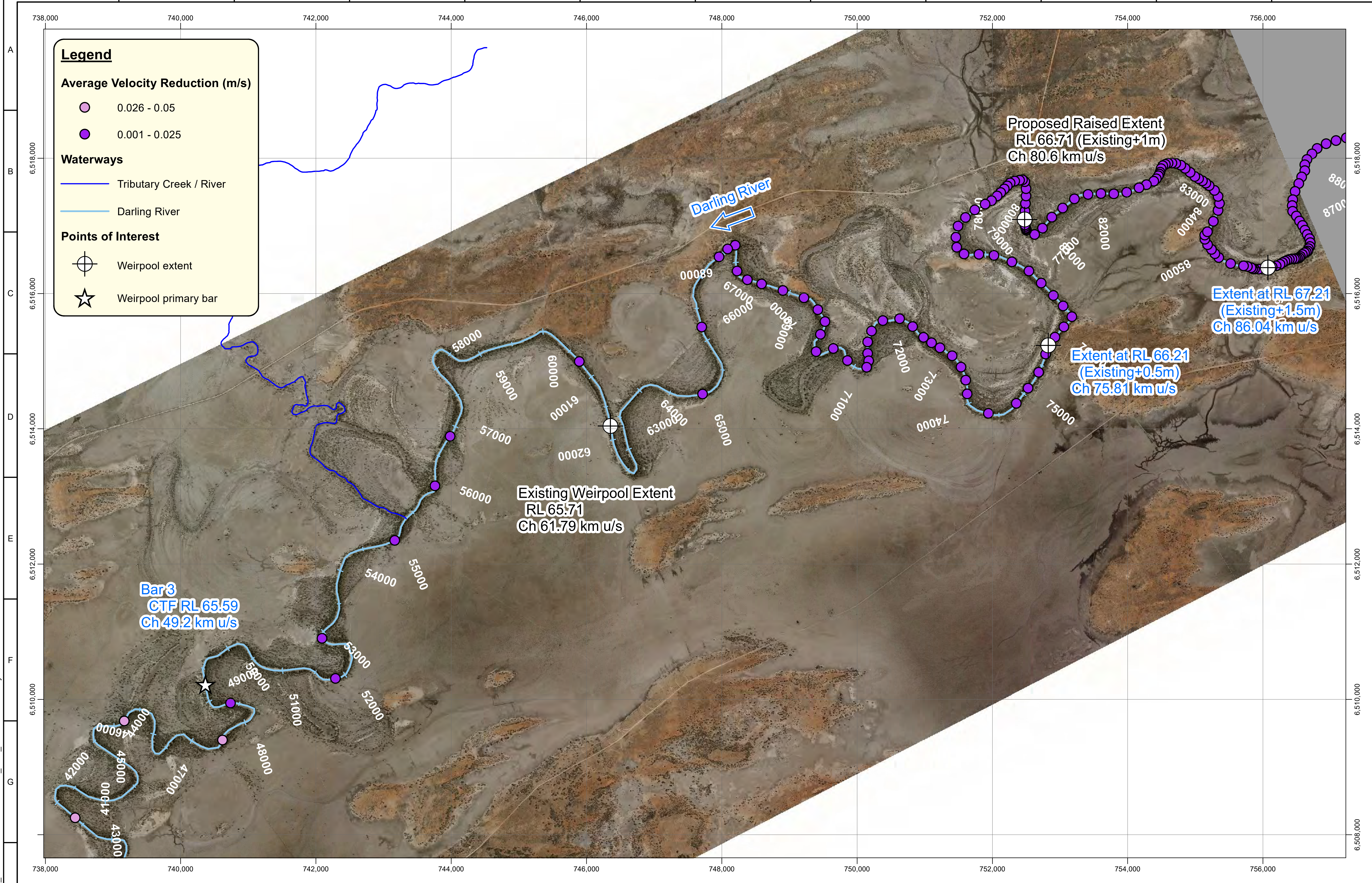
1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
5000 ML/d - SHEET 1 of 3

FIGURE NO.
VR5000-1
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

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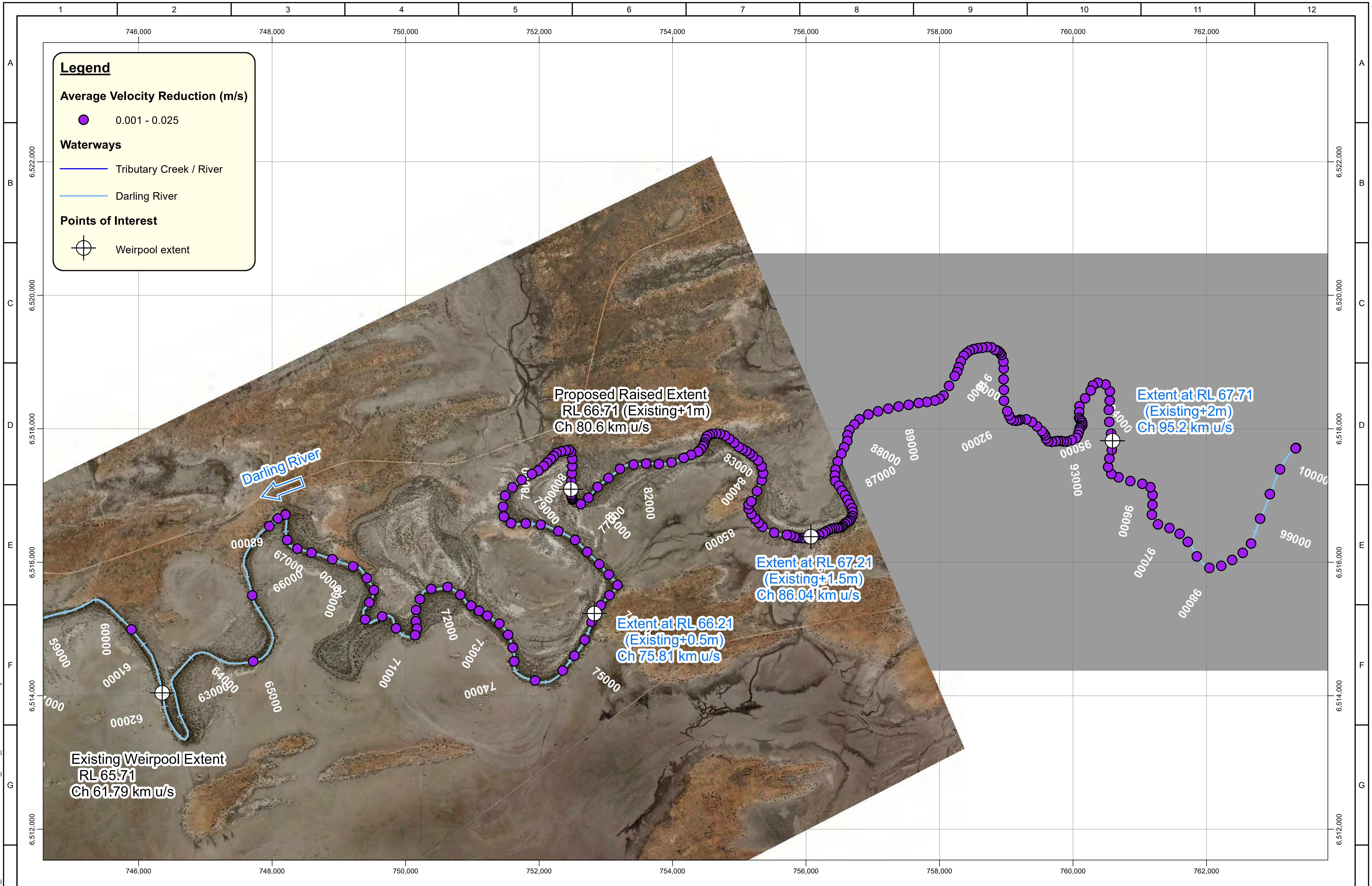
NSW GOVERNMENT | Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
5000 ML/d - SHEET 2 of 3

FIGURE NO.
VR5000-2
Rev. 0



Notes:
Aerial Imagery: Supplied by Jacobs Australia Pty Ltd
Imagery Date: 26/11/2020 | River flow at Wilcannia: <1 ML/day (incl 10 days prior).
DEM (1m): Supplied by Geoscience Aust. (Middle Darling 2014.)
Capture Date: 2/2 to 5/3/2014 | River flow: 0 ML/day (43-74 days).

1:50,000

1,000 0 1,000 2,000 3,000 Metres

MGA94 ZONE 54

NSW GOVERNMENT Public Works Advisory

WWR - PRELIM CONCEPT DESIGN
U/S FLOWING WATER HABITAT IMPACTS
VELOCITY REDUCTION
5000 ML/d - SHEET 3 of 3

FIGURE NO.
VR5000-3
Rev. 0

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