Wilcannia Weir Replacement

Hydrology, Geomorphology, Groundwater, Surface Water and Flooding Impact Assessment

Final

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Water Infrastructure NSW

Wilcannia Weir Replacement

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Glossary of terms and abbreviations

Term	Definition
ADWG	*Australian Drinking Water Guidelines* (National Health and Medical Research Council and Natural Resource Management Ministerial Council, 2011)
AEP	Annual exceedance probability The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a flood event has an AEP of 5 per cent (one in 20 chance), then there is a 5 per cent chance of that flood event (or larger event) occurring in any one year.
AHD	Australian Height Datum (in metres)
ANZECC	Australia and New Zealand Environment and Conservation Council
ANZG (2018) Water Quality Guidelines	*Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, an online resource released in 2018.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARI	Average recurrence interval The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as big as, or larger than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Cease-to-flow	The absence of flowing water in a river channel. Partial or total drying of the river channel. Streams contract to a series of isolated pools.
Barwon-Darling WSP	Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012
Basin State	New South Wales, Victoria, Queensland, South Australia and the Australian Capital Territory.
CEMP	Construction environment management plan
cfu	Colony forming unit. CFU is a measure of viable colonogenic cell numbers in CFU/mL. These are an indication of the number of cells that remain viable enough to proliferate and form small colonies.
CN Act	*Water Supply (Critical Needs) Act 2019*
Darling Alluvial WSP	Water Sharing Plan for the Darling Alluvial Groundwater Sources 2020
DPE	Department of Planning and Environment
DPIE	Department of Planning, Industry and Environment (former)
Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but to communities, industry and society. It includes water held in reservoirs (held environmental water) or protected from extraction from waterways (planned environmental water) for meeting the water requirements of water-dependent ecosystems.
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FSL	Full supply level The water level when the water storage is full and at the weir crest.
GL	Gigalitre (1 x 10^9 litres)

Term	Definition
GMA	Groundwater management area
HWL	Headwater level (upper pool or storage level)
Left and right bank	Reference to ‘left’ and ‘right’ banks is with respect to the view in the downstream direction, in accordance with industry practice.
LGA	Local government area
MDBA	Murray-Darling Basin Authority
mg/L	Milligrams per litre
ML, ML/day	Megalitres, megalitres per day
m^3/s	Cubic metres per second
μS/cm	Microsiemens per centimetre
Afflux	In the context of a weir, afflux is the maximum increase in the water level upstream of a weir above what the water level would have been were the weir not there.
Operating rules	Rules which the operating authority has to follow for raising and lowering the weir gates.
The proposal	The Wilcannia Weir replacement project.
SEARs	Secretary’s environmental assessment requirements
Weir crest	The highest surface over which water flows.
Weir pool	The amount of water that collects behind the weir structure.
Weir pool extent	How far upstream the weir pool extends from the weir location when at the full supply level.
WM Act	*Water Management Act 2000*
WRPA	Water resource plan area

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 Shire 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 hydrology, geomorphology, groundwater, surface water and flooding impact assessment has been prepared on behalf of Water Infrastructure NSW to assess the potential impacts of constructing and operating the proposal in accordance with the SEARs.

Existing environment

The Darling River (Baaka) at Wilcannia forms part of the Barwon-Darling catchment area in the Murray-Darling Basin. The Barwon–Darling corridor connects all the rivers, lakes and wetlands in the northern Basin; and then provides a connection to the southern Basin through the lower Darling River.

The Barwon–Darling river system is unregulated, however, it is highly impacted by headwater dams, water extraction and numerous low-level weirs. Wilcannia Weir is located at the township of Wilcannia, about halfway between Bourke and the River Murray and about 50 kilometres downstream of the confluence with the Paroo River. There are 14 weirs on the Darling (Baaka) and Barwon rivers upstream of Wilcannia Weir that, together with weirs located downstream of Wilcannia, result in variable river flow, with some reaches flowing (lotic) and others non-flowing (lentic) at any one time. During low flows, weir pools can result in about 1000 river kilometres of artificial lentic conditions, or about 40 per cent of the length of the Barwon-Darling river system (Mallen-Cooper, M. and Zampatti, B., 2020).

Wilcannia weir pool

During dry periods, when the water level in Wilcannia weir pool drops below full supply level, the weir pool can reduce to four pools. Pool 1 extends about 5.43 river kilometres upstream from the existing weir and includes the water extraction infrastructure for the town. Pool 2, pool 3 and the end pool are delineated by bars located about 30.12 river kilometres and 49.20 river kilometres upstream of the existing weir.

Cease-to-flow events

A recently completed analysis of historical cease-to-flow and low-flow events in the Barwon-Darling (Baaka) system identified that a constantly flowing river is not normal for the region and that the Barwon-Darling River stopped flowing for extended periods even before there were large dams and significant agricultural water use upstream (Department of Planning, Infrastructure and Environment (DPIE), 2021). However, while low-flow periods are normal in the region, the frequency of extended low-flow periods has increased over the last 20 to 30 years. These extended periods of low- and no-flow place significant stress on the environment. The increasing frequency of cease-to-flow events in the Barwon-Darling (Baaka) system is attributed to climate change, although it is also acknowledged that water management rules and development may also be contributing factors and that it is difficult to be definitive about the role and impacts of climate change (DPIE, 2021).

Proposal overview

The proposed new weir would be located about two kilometres south of the Wilcannia township. The new weir would comprise a fixed crest portion with remotely operated gates and a fishway, also with remotely operated gates.

The existing weir pool extends about 61.79 river kilometres along the Darling River (Baaka) upstream from the existing weir. 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, known as the 'new town pool', to extend the total weir pool to about 66.71 river kilometres when the new weir is at the full supply level of the existing weir.

The new weir would have dual modes of operation: a normal operation mode when the weir would operate at the existing full supply level, and a drought security operation mode, when it would operate at a 'drought' full supply level of 66.71 metres AHD. This temporary increase in the full supply level 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 total weir pool length of about 85.52 river kilometres.

Dynamic storage during normal operation mode

The primary objective for management of the new weir during normal operation mode would be to prioritise flow discharge via the fishway to promote upstream fish passage. The fishway gates would be fully opened (lowered) during normal operation mode and the weir gates would be operated in accordance with preliminary operating rules that 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) to achieve a maximum flow depth of 0.5 metres over the top of the weir gates, up to the drought full supply level, at which point further raising would not be possible and overflows greater than 0.5 metres would be permitted.

Transition phases and trigger levels

The new weir would transition from normal 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 subject to the following triggers:

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

Progressive gate closure during the filling phase

When the new weir enters the filling phase the weir and fishway gates would be closed progressively in accordance with the following gate closure logic to mitigate downstream flow impacts:

- The discharge is reduced by 50 per cent of the previous days discharge every day
- The discharge cannot exceed the inflow to the weir pool
- The weir gates would close (and discharges cease) when the discharge reduces to 30 megalitres per day.

Translucency discharges during drought security operation mode

The new weir would have an accessible storage volume of about 5,654 megalitres at the drought full supply level compared to about 2,173 megalitres for the existing weir at the normal full supply level. 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 full supply level (66.71 metres AHD) and 65.54 metres AHD (the drought full supply level minus 1.17 metres).

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 discharges would result in a dynamic storage that would be managed through operation of the fishway gates and weir gates.

Impact assessment

Hydrology

The operation of the proposal has been simulated by carrying out storage behaviour modelling and the outputs from this modelling have been used to assess the hydrological impacts of the proposal. Initially, a modified water balance model was used to assess the performance and filling reliability of the weir pool due to the two weir operation modes. The model was further modified to assist with assessment of storage behaviour based on the preliminary operating rules for the new weir. The Barwon-Darling Source River System Model was used to provide input time series data for simulated Wilcannia weir pool inflows and for trigger flows past Bourke Town Weir based on 119 years of flow data from 01 January 1900 to 20 August 2019. A low spell analysis of flows downstream of the proposed new weir was undertaken using the outputs of the storage behaviour modelling. The analysis of flow alternation 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* (DPIE, 2020b).

The key findings of the modelling are that the operation of the new weir would result in an increase in short duration (less than five days) cease-to-discharge events due to the new weir not discharging when it is in the weir filling phase. Due to the short duration of these events their effect on flows downstream of the new weir is likely to dissipate, which would limit their effect on downstream cease-to-flow characteristics.

The operation of the new weir proposal would also result in what would otherwise be long duration cease-to-flow spells being broken into two shorter duration cease-to-flow spells due to the application of the translucency operating rules when the new weir is in drought security operation mode. This results in a reduction in the mean duration of cease-to-flow spells, from 57 days to 36 days.

The modelling indicated similar changes for very-low-flow spells (flows of more than 30 megalitres per day), with the number of spells increasing but the duration of spells decreasing. This indicates that the new weir would result in the interruption of some very-low-flow spells due to the filling phase being triggered and the weir being in drought security operation mode for brief periods. However, the net result of the predicted increase in the number of very-low-flow spells but decrease in their duration is minor, with the total number of days of very-low-flow spells largely the same across the 119-year simulation period, reducing slightly from 35,915 days to 35,468 days.

The number of base flow 2 spells (flows of more than 350 megalitres per day between September and March) would increase by about one-third, but the mean duration of these events would only decrease by about 10 per cent, resulting in an increase in the total duration of base flow 2 spells across the 119-year simulation period, from 21,062 days to 25,598 days. This alteration in base flow behaviour is attributed to the application of the translucency rule during drought security operation mode, which would result in discharges from the new weir when there are inflows to the new town pool and Pool1, whereas some of these flows would not have passed the existing weir.

The operation of the new weir would have only a minor impact on larger flows as the weir would be in normal operation mode and would be operated to optimise downstream flows.

At high flows the new weir would have a more substantial backwater effect than the existing weir due to the operation of the weir gates, which would cause flows near the new weir to slow down and the water level to rise.

Hydrodynamic modelling of the new weir in normal operation mode has shown that the greatest impact of the new weir on upstream water velocities would occur nearest to the new weir. There would be a significant reduction in water velocity in the reach of the river between the new and existing weirs. However, the impact of the new weir on water velocity in this reach of the river would be greatly amplified by its change from a flowing water habitat to weir pool. Upstream of the existing weir, the new weir would have a greater impact on water velocity at the downstream end of the existing weir pool, although this impact would mostly be at higher flow velocities, with very little change in water velocity at low flows. Further upstream, the new weir would result in a negligible decrease in water velocities at low flows and only a small decrease at higher flows.

During construction of the proposal there would be only minor impacts to hydrology associated with the diversion of flows around instream work sites for the new weir.

Geomorphology

A desktop assessment of the potential geomorphology impacts of the proposal was carried out and included consideration of RiverStyles mapping of the Darling River (Baaka) at Wilcannia. The operation of the new weir would result in an extension of the existing weir pool and these new sections of weir pool are expected to be subject to the same geomorphological impacts as are observed at the existing weir pool. Undercutting/notching of the riverbanks is expected to occur in the new town pool and within the about 18.81 river kilometres of temporary new weir pool upstream of the existing weir pool. Similar to the existing weir, this impact is expected to be relatively minor. The temporary nature of the inundation upstream of the existing weir pool is expected to result in a lesser impact than currently occurs at the upstream extent of the existing weir.

It is likely that sedimentation would occur in the 18.81 river kilometre section of additional weir pool at the upstream end of the existing weir pool when it is inundated. It is also expected that these sediments may be remobilised and transported further downstream into the existing weir pool. As a large proportion of the sediment is fine grained and forms 'wash load' it is expected that mobilised sediment may still be transferred beyond the extent of the new weir, particularly during larger flood events. This would reduce the potential for sediment starvation downstream of the new weir.

Fluctuations in the level of stored water in the weir pool associated with the operation of the new weir are not expected to impact the stability of the riverbanks. Fluctuations in the level of stored water in the weir pool are not expected to induce changes in pore water pressures that would weaken bank materials and promote bank failure.

Changes to flows downstream of the replacement weir are expected to have minimal impact on the geomorphology of the river downstream of the weir.

The construction of the new weir would require the right riverbank alongside the fishway and the left riverbank alongside the weir crest to be cut to construct the new infrastructure. These works to the riverbanks would create the potential for riverbank erosion and a loss of bank stability. The riverbanks at the new weir site would be reinstated at the conclusion of construction so as to tie-in with the undisturbed riverbanks upstream and downstream. The reinstated banks would be stabilised to reduce the risk of bank erosion occurring during high flow events that overtop the weir.

Groundwater

The operation of the new weir would result in a long-term local groundwater level increase near the new town pool to a level similar to the normal full supply level in the weir pool of 65.71 metres AHD and the groundwater level near Pool 1 upstream of the existing weir. For comparison, existing groundwater levels in the vicinity of the new town pool are known from two groundwater monitoring bores at Union Bend and have fluctuated between 61 to 66 metres AHD (or between seven and 10 metres below ground level).

Shallow groundwater (less than three metres below ground level) has the potential to become saline through evapo-concentration over time. Groundwater mounding in the new town pool is likely to occur up to 100 metres away from the banks of this section of the Darling River (Baaka). Long-term groundwater salinisation in low-lying areas next to the new town pool would be similar to that which has already occurred upstream of the existing weir in low-lying areas.

The new town pool is expected to contribute to aquifer recharge of the shallow alluvium aquifer, however, it is unlikely to contribute to the deeper alluvium aquifer due to a 20-metre-thick clay aquitard. Emergency town water supply bores are located at Union Bend in the vicinity of the new town pool and screen the deep alluvium and, although the overlaying clay aquitard is likely to leak, it will limit the direct connection to the Darling River (Baaka). Currently the salinity of groundwater pumped from the town water supply boreholes, while acceptable, is higher than that of good quality river water. Any increased salinisation in the upper aquifer is unlikely to impact the deeper aquifer quality.

As the emergency town water supply bores are not directly connected to the Darling River (Baaka), the risk to the town water supply bores from the construction of the weir is considered low.

Equilibrium groundwater levels near the new town pool are expected to rise to within five metres of the ground surface during operation of the proposal and this would be supportive of groundwater dependent ecosystems in these areas. An exception is low-lying areas near the new town pool that are less than three metre below ground level which would experience salinisation similar to that which is already occurring upstream of the existing weir. Any salinisation impact to groundwater dependent ecosystems in low lying areas near the new town pool would be similar to that which is already occurring upstream of the existing weir.

Surface water

A desktop assessment of the potential surface water impacts of the proposal was carried out together with some water quality monitoring to support and enhance the findings of the desktop analysis. The assessment considered the water quality objectives for the Barwon-Darling Watercourse water resource plan area.

Construction of the new weir and partial removal and decommissioning of the existing weir would involve works within the Darling River (Baaka), which presents several risks to surface water quality from erosion and sedimentation, release of tannin leachate, dewatering, disturbance of saline soils, release of oils and fuels, release of concrete waste, and dust and litter. A comprehensive range of management and mitigation measures are proposed to address these risks to surface water quality, including rehabilitation of disturbed areas of the riverbed and riverbanks.

The operation of the proposal would also present risks to water quality during the initial filling of the weir pool when there would be inundation of previously exposed land, hydrological changes, normal weir pool operations, and erosion downstream of the new weir. These operational risks are similar to those experienced at the existing weir and weirs across the State and would be managed by WaterNSW in accordance with its existing operating procedures.

Flooding

A flooding impact assessment of the proposal was prepared by carrying out a hydraulic analysis to estimate the indicative weir drown-out flow and assess the underlying potential for upstream impacts. The assessment identified an indicative weir 'drowns-out' flow of 12,070 megalitres per day (140 m^3/s), at which the water level difference across the initially assessed fixed crest weir (with crest level of 66.65 metres AHD) was estimated to be about 0.16 to 0.20 metres higher than existing river levels. The drown-out flow water level would be substantially below the top of low riverbank level, which indicates that the new weir is unlikely to produce any apparent significant upstream flooding impacts as flows increase and approach top of low bank level. Additionally, the afflux values at weir drown-out would diminish moving away from the weir site in the upstream direction due to backwater effects.

Furthermore, once drown-out of the weir occurs for larger flood events such as the one per cent annual exceedance probability event and the probable maximum flood the new weir would not produce any incremental impact in terms of affluxes than the existing weir.

The increase in flow rate needed to reduce afflux to 50 millimetres results in only a relatively minor increase in headwater levels that is estimated to be about 0.87 metres higher than those for weir drown-out conditions. These additional figures reaffirm the expectation that the proposed new weir is unlikely to produce any apparent upstream flooding impacts out of the main river channel.

The flow associated with a 50 millimetre afflux is 16,200 megalitres per day (187.5 m^3/s) past the weir obstruction. This provides an indicative river flow above which the potential for upstream impacts is anticipated to be insignificant before becoming negligible with further flow increases. The above flow corresponds to a headwater level of 68.96 metres AHD, which is 2.31 metres above the assessed one-metre raised fixed crest level of 66.65 metres AHD and 3.15 metres below the top of low (left) riverbank level.

Management and mitigation measures

Management and mitigation measures are proposed to avoid or reduce the potential impacts of the proposal. A key mitigation measure (number HY02) is the proposed investigation 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 will consider flows in tributaries downstream of Bourke Town Weir, including inflows from the Warrego River and Paroo River, anticipated flows from upstream of Bourke Town Weir and climatic conditions and prevailing weather. If successful this measure would reduce the hydrological impacts of the proposal from those identified in this assessment.

Other recommended management and mitigation measures include monitoring groundwater levels in the vicinity of the new town pool, surface water quality monitoring during the construction phase and at the commencement of operation and a range of measures to prevent surface water pollution including during flooding.

1. Introduction

Water Infrastructure NSW proposes to replace the existing Wilcannia Weir on the Darling River (Baaka) at Wilcannia, with a new weir located about five kilometres downstream of the existing weir (the proposal). The existing weir would also be partially removed and decommissioned 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 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* (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.

During planning for the proposal, approval as critical State significant infrastructure in accordance with Schedule 3 of the *Water Supply (Critical Needs) Act 2019* was proposed, however the expiry of this Act on 21 November 2021 meant that this is no longer a viable planning approval pathway. Water Infrastructure NSW has advised the DPE of this change to the planning approval pathway for the proposal and its intention to submit a State significant infrastructure application.

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 consolidated water impact assessment responds to SEAR nos. 2 and 3 (refer to **Table 1-1**).The proposal was originally proposed by WaterNSW as the proponent. The proposal's proponent changed to Water Infrastructure NSW as of 1 September 2021. This report includes the work undertaken for the proposal by WaterNSW prior to this change, that informs the preparation of this document.

1.2 Overview of the proposal

The proposed new weir would be located about two kilometres south of the Wilcannia township. The key design features of the proposal are listed below and shown in **Figure 1-2** 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
- Remotely operated 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 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, 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
- Partial removal and decommissioning of the existing weir on the Darling River (Baaka) in the Wilcannia township, located between Victory Park Caravan Park (left riverbank) and Field Street (right riverbank).

The existing weir pool extends about 61.79 river kilometres along the Darling River (Baaka) upstream from the existing weir. 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, to extend the total weir pool to about 66.71 river kilometres when the new weir is at the existing full supply level of 65.71 metres Australian Height Datum (AHD).

The new weir would have dual modes of operation: a normal operation mode when the weir would operate at the existing full supply level (65.71 metres AHD), and a drought security operation mode, when it would operate at a new full supply level of 66.71 metres AHD. This temporary increase in the full supply level 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 total weir pool length of about 85.52 river kilometres (refer to **Figure 1-1**).

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

- Construction compounds 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 at both the new and existing weir sites.

The key construction features proposed at the new weir and existing weir are shown in **Figure 1-2** and **Figure 1-3** respectively.

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

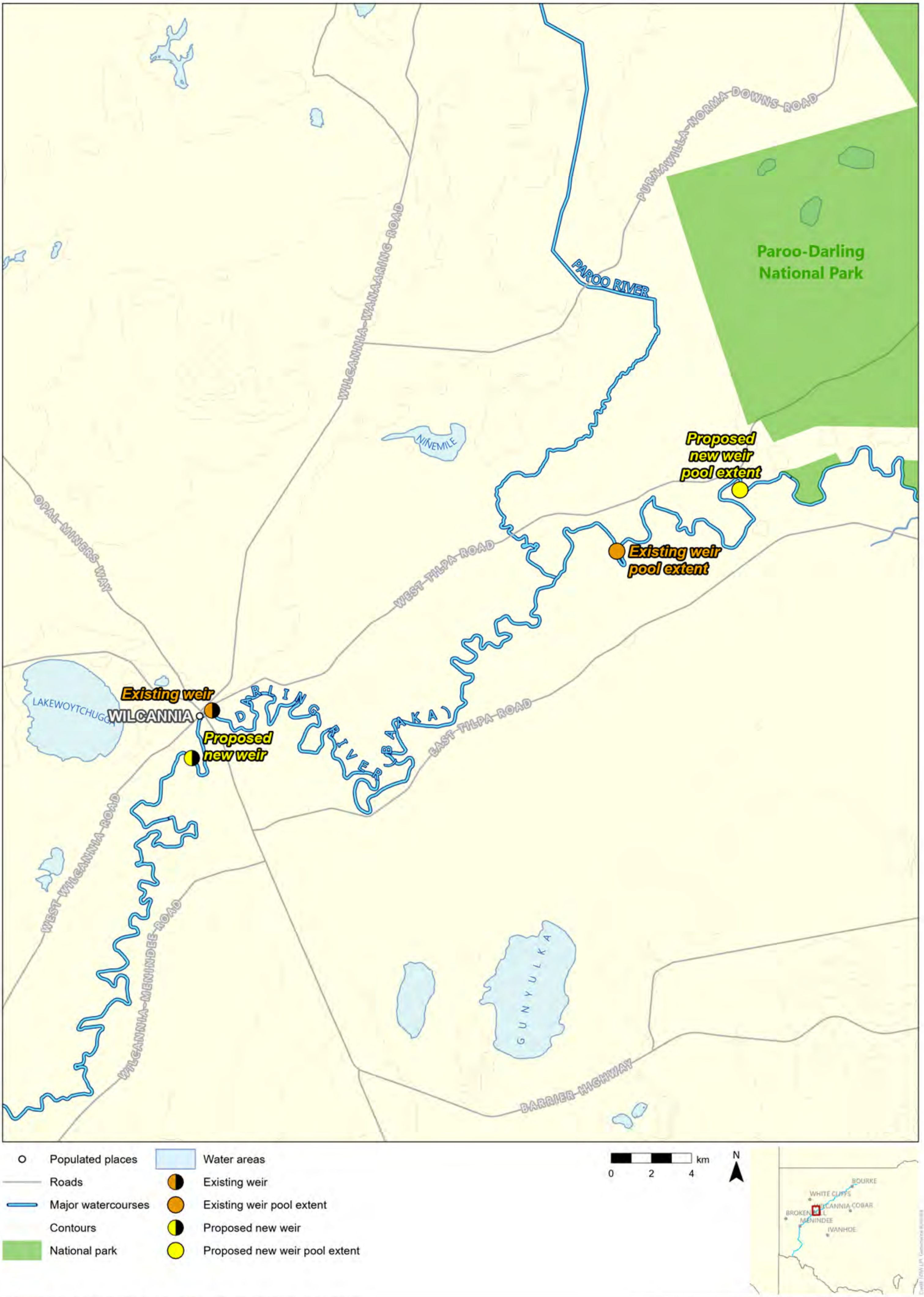

Figure 1-1: Proposal location and regional context

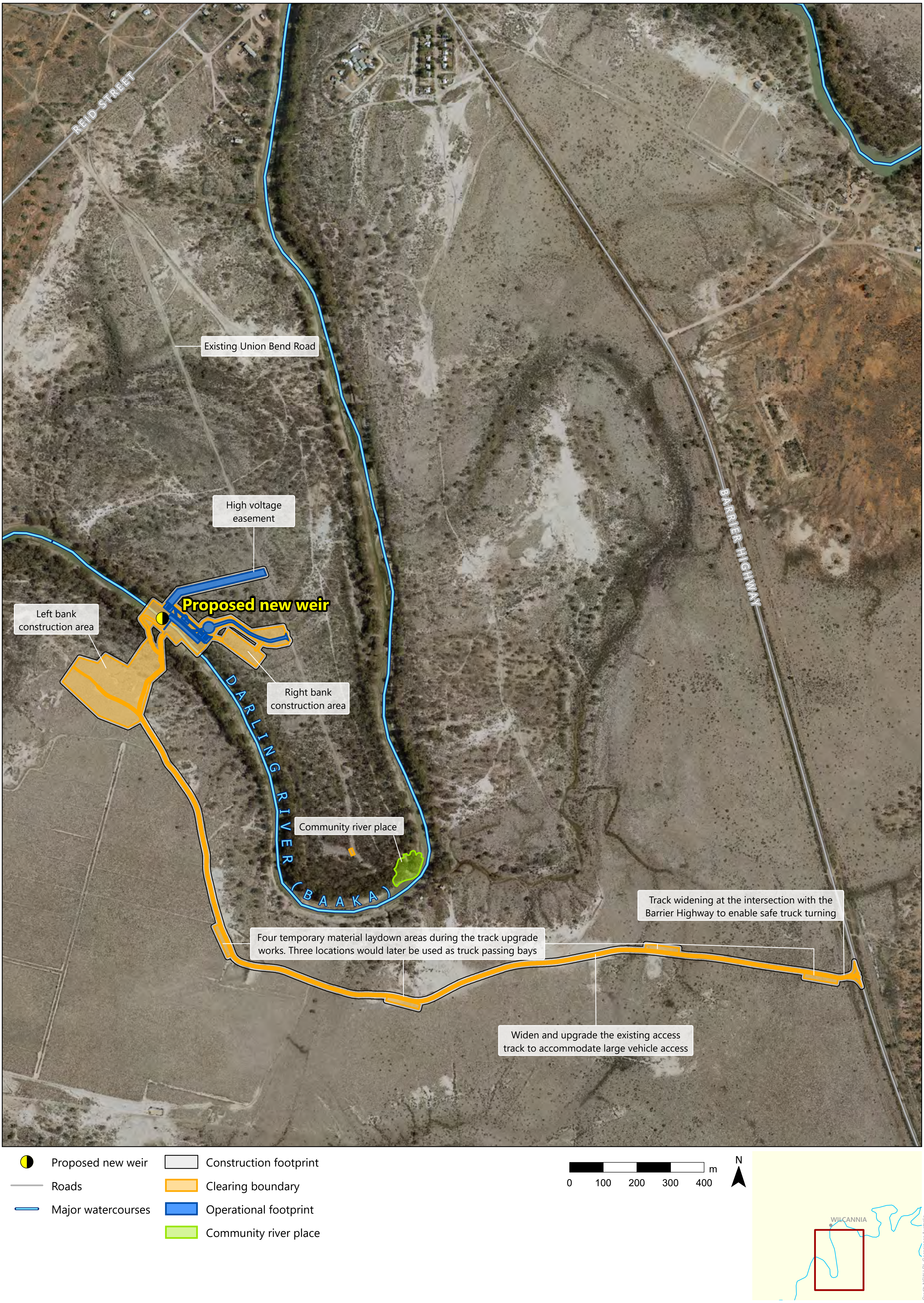

Figure 1-2: Key design features of the proposal – new weir site (overview)

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

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

1.3 Role of the proponent and its relationship with water authorities

Water Infrastructure NSW is the proponent of the proposal. Water Infrastructure NSW is responsible for leading the development and delivery of key State government water infrastructure projects and programs across NSW.

Water Infrastructure NSW would be responsible for the detailed design and construction of the proposal. Once construction and commissioning of the new weir is complete, it is proposed that ownership of the new weir would be transferred to WaterNSW, which would operate and maintain the new weir. WaterNSW is a NSW Government State-owned corporation established under the *Water NSW Act 2014*. It operates the State's rivers and water supply systems in accordance with the rules set by regulators. It supplies two-thirds of water used in NSW and its customers include regional towns and local water utilities.

Water Infrastructure NSW will consult with WaterNSW throughout the detailed design phase of the proposal, during which a final design for the new weir would be developed prior to construction starting.

The water authority in Wilcannia is Central Darling Shire Council. The council owns the town's water treatment plant. Council also owns the existing weir and emergency water supply bores at Union Bend that are used when the weir pool level is low. When the new weir is operational, WaterNSW would supply Central Darling Shire Council with water from the weir pool to council's water treatment plant.

1.4 Purpose and scope of this report

The purpose of this report is to assess the potential hydrology, geomorphology, groundwater, surface water, and flooding impacts from constructing and operating the proposal. The report:

- Addresses the relevant SEARs listed in **Table 1-1**
- Describes the existing environment with respect to hydrology, geomorphology, groundwater, surface water, and flooding
- Assesses the impacts of constructing and operating the proposal on hydrology, geomorphology, groundwater, surface water, and flooding
- Recommends measures to mitigate and manage the impacts identified.

The methodologies for the assessment of the proposal's potential impacts to hydrology, geomorphology, groundwater, surface water, and flooding are described in **Sections 8** to **9** for each respective environmental factor.

Table 1-1 How this assessment addresses SEAR nos. 2 and 3

Requirement	Location where this is addressed
Key issue 2: Water	
Include a thorough description of the existing environmental conditions and hydrological regime, including: ▪ Existing hydrology and river operations.	Existing hydrology and river operations are described in **Sections 3.1** and **3.2**.
▪ River channel form, relevant River Styles and alteration of channel form and geomorphic processes including sediment transmission rates, storage and reworking, and in-channel sediment features.	Existing geomorphology including River Styles is described in **Section 3.2.3**. Descriptions of features of the river channel at selected locations in the proposal area are provided in **Appendix E**.

Requirement	Location where this is addressed
▪ Mapping of rivers, streams, wetlands, estuaries, and groundwater potentially impacted by the project.	Mapping and schematics of the Darling River (Baaka) at a regional level and in the vicinity of the proposal is provided in **Figure 1-1**, **Figure** 3-3, **Figure 3-4**, **Figure 3-6**, **Figure 3-16** and **Figure 3-17**.
▪ Geomorphic features and energy transmission through the proposed weir pool upper extent and downstream along the river.	Existing geomorphology including River Styles is described in **Section 3.2.3**. Descriptions of geomorphic features of the river channel at selected locations in the proposal area are provided in **Appendix E**.
▪ In-channel geomorphic features, persistence and resilience of these features.	Descriptions of geomorphic features of the river channel at selected locations in the proposal area are provided in **Appendix E**.
▪ Relationships between the channel and adjacent floodplains, including a description of the frequency and duration of overbank flows, sediment trapping and sediment features on the floodplain and any river levees.	The relationship between the river channel and the adjacent floodplain is described in **Section 9.4.1.** Overbank flows since 1972 are shown in **Figure 9-3**. There are no river levees in the proposal area.
▪ Instream assets and functions associated with all upstream and downstream river that will see altered flow.	Instream assets in the proposal area include: ▪ the existing weir ▪ the town water intake ▪ a boat launching point at Steamers Point, about two kilometres upstream of the existing weir ▪ some private extraction pumps upstream of the existing weir ▪ some stormwater discharge points where the river passes through Wilcannia township. The existing weir would be partially removed and decommissioned as part of the proposal so the impact of any change in flows is not relevant to this structure. The stormwater discharge points are located at the top of the riverbanks and would not be impacted by the proposal. The other assets listed above would also not be adversely impacted by the proposal. Existing water users in the proposal area are discussed in **Section 3.2.4**.
▪ Water quality baseline data for the water resource likely to be impacted by the development.	Baseline water quality data is provided in **Section 3.3.**
▪ Highly connected alluvial aquifers and their responses to river flows.	The aquifer in the proposal area is described in **Section 3.5**.
Include a thorough assessment of the hydrological impacts of the proposed weir, including:	

Requirement	Location where this is addressed
▪ The extent of the proposed weir pool.	The extent of the proposed weir pool is shown in **Figure 4-1**.
▪ Geomorphic criteria to inform measures to arrest and prevent deterioration of channel condition, address sediment starvation downstream of the weir, and promote geomorphic recovery in regulated rivers impacted by changed flow regime.	The potential geomorphological impacts of the proposal are assessed in **Section 6**.
▪ Catchment scale water balance and projected alterations in water supply and demand management.	Storage behaviour modelling of the proposal has been carried out using the Barwon-Darling Source River System Model operated by WaterNSW, which is a water balance model. This modelling is summarised in **Section 5.1.1** and described in detail in **Appendix B**. This modelling incorporates the predicted future demand for water in Wilcannia, which is discussed in **Section 4.1.1**.
▪ Means to provide adequate volumetric limits, timing, inundation, flow velocities and associated stream power or shear stress in channel and on adjacent floodplains.	Hydrodynamic modelling of the proposal has been carried out and is summarised in **Section 5.1.4** and described in detail in **Appendix C**. This modelling only considers water velocities within the river channel, noting that the proposal would have a negligible impact on flooding and discussed in **Section 9**.
▪ Impacts during construction and operation of the Wilcannia Weir replacement on the region's surface and groundwater sources and adjacent water users, ensuring compliance with the Water Sharing Plan for the Barwon-Darling Unregulated and Alluvial Water Sources 2012, the Barwon-Darling Watercourse Water Resource Plan (including any amendments that may be required to accommodate the new weir), and sustainable diversion limits of the Murray-Darling Basin Plan.	The amendments proposed to update the Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012 to include the proposal are discussed in **Section 2.2.3**. The impact of the proposal on flows in the Darling River (Baaka) and on groundwater are assessed in **Sections 5.4.3** and **7.4** respectively. Surface water and groundwater users are discussed in **Sections 3.2.4** and **3.6.3** respectively. Potential impacts to surface water and groundwater users are discussed in **Sections 5.4.4** and **7.4.3** respectively.
▪ An assessment of the impacts of the project to the Environmental Flow Requirements downstream as stated in the relevant Long-Term Watering Plan (LTWP) prepared by DPIE EES as part of basin plan requirements.	The environmental water requirements of the Barwon-Darling Long-Term Watering Plan relevant to the proposal are discussed in **Section 2.3.5**. The impact of the proposal on flows in the Darling River (Baaka) are assessed in **Section 5.4.3**.
▪ Design criteria relating to flow hydrographs, release rules, any proposed translucency measures and other alteration of riverine hydrology, flow energy and sediment transport in the process of regulating a currently unregulated river.	Preliminary operating rules for the operation of the new weir including releases of flow downstream are described in **Section 4.2.** The preliminary operating rules include a translucency rule when the new weir is in drought security operation mode, as described in **Section 4.2.6**.

Requirement	Location where this is addressed
▪ Predicted impacts on licensed water users, including any impact to water quality and availability, and the potential for land salinisation adjacent to the extended weir pool.	Potential impacts to surface water and groundwater users are discussed in **Sections 5.4.4** and **7.4.3** respectively. Potential salinisation impacts near the extended weir pool are discussed in **Section 7.4.2**.
▪ An assessment of the potential impact on groundwater and surface water users and details of how existing water rights will be protected.	Surface water and groundwater users are discussed in **Sections 3.2.4** and **3.6.3** respectively. Potential impacts to surface water and groundwater users are discussed in **Sections 5.4.4** and **7.4.3** respectively.
▪ Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water, specifically: - assessment of the impacts on environmental water availability and flows to downstream receiving waters. - assessment of impacts to the volume, reliability and effectiveness of Planned Environmental Water in the catchment downstream of the work. - assessment of impact to volume, reliability, effectiveness or deliverability of Held Environmental Water assets in the catchment downstream of the works. - any water substitution effects of the removal of surplus or tributary flows from the catchment that may then require held or discretionary planned environmental water to make up the shortfall.	The impact of the proposal on flows downstream of Wilcannia is described in **Section 5.4.3**. The proposed new weir includes weir gates that would enable planned environmental water inflows to the weir pool to be released downstream, as discussed in **Section 4.2.7**.
▪ Include a thorough assessment of the water quality impacts of the proposed weir, including:	.
▪ The ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the river, including the indicators and associated trigger values or criteria for the identified environmental values.	The *NSW Water Quality and River Flow Objectives* (Department of Environment, Climate Change and Water, 2006) are discussed in **Section 2.3.3**.
▪ The significance of any identified impacts including consideration of the relevant ambient water quality outcomes.	Potential impacts to surface water quality are assessed in **Section 8.4**.
▪ How construction and operation of the project will, to the extent that the project can influence, ensure that: - where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and	Potential impacts to surface water quality during construction and operation of the proposal are assessed in **Section 8.4.1** and **8.4.2** respectively.

Requirement	Location where this is addressed
- where the NSW WQOs are not currently being met, activities will work toward their achievement over time.	
▪ Identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Proposed water quality monitoring during construction and operation of the proposal is outlined in environmental mitigation and management measures SW09 and SW10 respectively in **Table 8-4**.
▪ Assess changes to thermal stratification in the weir pool.	Potential changes to thermal stratification in the weir pool are addressed in **Section 8.4.2**.
Relevant Policies and Guidelines	
▪ NSW Water Quality and River Flow Objectives at http://www.environment.nsw.gov.au/ieo/	The *NSW Water Quality and River Flow Objectives* (Department of Environment, Climate Change and Water, 2006) are discussed in **Section 2.3.3**.
▪ Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006)	The booklet *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (Department of Environment and Conservation, 2006) is discussed in **Section 2.3.3**.
▪ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)	The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) are discussed in **Section 2.3.2**.
▪ Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DECC, 2004).	The *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (Environment Protection Authority, 2003) is discussed in **Section 2.3.10**.
Key issue 3: Flooding	
Identify flood risk on-site (detailing the most recent flood studies for the project area) and consideration of any relevant provisions of the NSW Floodplain Development Manual (DIPNR, 2005), including the potential effects of climate change, sea level rise and an increase in rainfall intensity. If there is a material flood risk, include design solutions for mitigation.	The proposal would have a negligible impact on flooding as discussed in **Section 9**. There is no recent flood study for the proposal area. Given that the proposal would have a negligible impact on flooding, consideration of factors that may worsen flooding such as climate change is not relevant.
Map features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government, 2005), including: ▪ Flood prone land. ▪ Flood planning area, the area below the flood planning level. ▪ Hydraulic categorisation (floodways and flood storage areas). ▪ Flood hazard.	The proposal would have a negligible impact on flooding as discussed in **Section 9**. There is no local mapping of flood prone land, a flood planning area, flood storage areas or flood hazards. However, given that the proposal would have a negligible impact on flooding, consideration of these matters is not relevant.
Describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% Annual Exceedance Probability (AEP), 1% AEP, flood levels and the	Weir drown-out would occur at a flow of 12,070 ML/day, which is equivalent to about a 57% AEP flood event, as noted in **Section 9.4.4.** Afflux would diminish as the new weir becomes

Requirement	Location where this is addressed
probable maximum flood, or an equivalent extreme event.	more submerged in lower probability events. For flood events equal to or greater than the 10% AEP, the afflux due to the new weir would be insignificant.
Model the effect of the proposed project (including fill) on current flood behaviour for a range of design events. This includes the 0.5% and 0.2% AEP year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	As noted above, for flood events equal to or greater than the 10% AEP, the afflux due to the new weir would be insignificant. Given that the proposal would have an insignificant impact on flooding no flood modelling has been carried out.
Provide flood modelling which considers and documents: ▪ Existing council flood studies in the area and examine consistency to the flood behaviour documented in these studies. ▪ The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood, or an equivalent extreme flood. ▪ Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affectation of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazard categories and hydraulic categories. ▪ Relevant provisions of the NSW Floodplain Development Manual 2005.	There is no existing council flood study for the proposal area. The proposal would have a negligible impact on flooding as discussed in **Section 9**. As noted above, for flood events equal to or greater than the 10% AEP, the afflux due to the new weir would be insignificant. Given that the proposal would have an insignificant impact on flooding no flood modelling has been carried out.
Assess the impacts on the proposed project on flood behaviour, including: ▪ Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure. ▪ Consistency with Council floodplain risk management plans. ▪ Consistency with any Rural Floodplain Management Plans. ▪ Compatibility with the flood hazard of the land. ▪ Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. ▪ Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site. ▪ Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river-banks or watercourses.	There is no existing council flood study for the proposal area, The proposal would have a negligible impact on flooding as discussed in **Section 9**.

Requirement	Location where this is addressed
▪ Any impacts the development may have upon existing community emergency management arrangements for flooding. ▪ Whether the proposal incorporates specific measures to manage risk to life from flood. ▪ Emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). ▪ Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	

1.5 Report structure

The structure of the report is outlined below:

- **Section 1 –** provides an introduction to the report
- **Section 2 –** provides an overview of legislation, policies and guidelines applicable to this assessment
- **Section 3 –** describes the existing environment
- **Section 4 –** describes the proposal
- **Section 5 –** provides an assessment of the proposal's potential impacts to hydrology
- **Section 6–** provides an assessment of the proposal's potential impacts to geomorphology
- **Section 7 –** provides an assessment of the proposal's potential impacts to groundwater
- **Section 8 –** provides an assessment of the proposal's potential impacts to surface water
- **Section 9 –** provides an assessment of the proposal's potential impacts on flooding
- **Section 10 –** provides a summary of the key findings of this report.

2. Legislative and policy context

This section provides an overview of legislation, policies and guidelines applicable to this assessment.

2.1 Commonwealth legislation

2.1.1 Water Act 2007

The *Water Act 2007* (Cwlth) provides a legislative framework for the management of the Murray-Darling Basin in the national interest. The Act establishes the Murray-Darling Basin Authority (MDBA) as an independent authority that has functions and powers, including enforcement powers, to ensure that Murray-Darling Basin water resources are managed in an integrated and sustainable way. The Act requires the MDBA to prepare the Murray-Darling Basin Plan, which is a strategic plan for the integrated and sustainable management of water resources in the basin. As part of the plan, the MDBA is required to set limits on the amount of water (both surface and groundwater) that can be taken from basin water resources on a sustainable basis, known as long-term average sustainable diversion limits.

2.2 State legislation

2.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act and Environmental Planning and Assessment Regulation 2021 establish the framework for development assessment in NSW. The EP&A 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.

Part 5 Division 5.2 of the EP&A Act sets out environmental assessment provisions for State significant infrastructure. In accordance with section 5.14, Minister's approval is required for State significant infrastructure.

2.2.2 Water Management Act 2000 and Water Act 1912

The *Water Act 1912* and the *Water Management Act 2000* (WM Act) are the two key pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. The *Water Act 1912* is being progressively phased out and replaced by the WM Act.

The aims of the WM Act are to provide for the sustainable and integrated management of the State's water sources for the benefit of both present and future generations. The WM Act implicitly recognises the need to allocate and provide water for the environmental health of rivers and groundwater systems, while also providing license holders with more secure access to water and greater opportunities to trade water through the separation of water licenses from land.

Section 50 of the WM Act allows for the preparation of water sharing plans, which establish rules for the sharing of water in a particular water source between water users and the environment, and rules for the trading of water in a particular water source.

The WM Act provides protection for basic landholder rights, which include domestic and stock rights, harvestable rights and native title rights. Sections 52 to 55 of the Act allow for extraction under these rights without the need for water access licences. The Act requires water sharing plans to protect basic landholder rights by taking these rights into consideration before designing rules for licenced water extractions.

Section 89 of the WM Act requires a water use approval for the use of water for a particular purpose at a particular location. However, as the proposal is State significant infrastructure a water use approval is not required in accordance with section 5.23 of the EP&A Act. Therefore, Water Infrastructure NSW would not be required to obtain a water use approval to extract water for use during construction of the proposal.

Section 90 of the WM Act requires an approval to undertake a water management work, which includes a water supply work. The definition of a water supply work includes any work that has, or could have, the effect of impounding water in a water source. However, as the proposal is State significant infrastructure a water management work approval is not required in accordance with section 5.23 of the EP&A Act.

Section 91 of the WM Act requires an 'activity approval' to carry out a 'controlled activity' in, on or under waterfront land or to carry out an aquifer interference activity. The definition of a controlled activity includes the carrying out of work, the removal of material or vegetation from land, the deposition of material on land and the carrying out of any other activity that affects the quality or flow of water in a water source. Waterfront land is defined as including the bed and banks of rivers as well as land that is 40 metres inland of the highest bank of the river. As the proposal would involve construction of a new weir and fishway within the river channel and ancillary road/facility within 40 metres of the riverbanks, the proposal would meet the definition of a controlled activity under the WM Act.

Section 41 of the Water Management (General) Regulation 2018 provides that a public authority is exempt from requiring a controlled activity approval to carry out a controlled activity in, on or under waterfront land. Furthermore, in accordance with section 5.23 of the EP&A Act, an activity approval (other than an aquifer interference approval) under section 91 of the WM Act is not required for State significant infrastructure.

2.2.3 Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012

The Darling River (Baaka) is subject to the Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012 (Barwon-Darling WSP). The key elements of the Barwon-Darling WSP that are relevant to the proposal are described in this section based on the statutory instrument itself and also a background document prepared by the former NSW Office of Water (2012).

The Barwon-Darling WSP has several objectives; the objectives that are most relevant to the proposal include:

- To protect, and contribute to the enhancement of, the ecological condition of the water source and its water-dependent ecosystems
- To maintain, and where possible improve, the spiritual, social, customary and economic values and uses of water by Aboriginal people
- To provide access to surface water to support surface water-dependent social and cultural values.

In accordance with sections 20 and 21 of the WM Act, the Barwon-Darling WSP applies a range of strategies to achieve these objectives including establishing and maintaining compliance with a long-term average annual extraction limit and a long-term average sustainable diversion limit, restricting the take of water to protect 'active environmental water' and to restore connectivity within and between water sources following an extended dry period, and providing access to water for basic landholder rights, town water supply, and for licensed domestic and stock purposes.

The Barwon-Darling WSP divides the water source into four sections and 14 management zones. The proposal is located in River Section 4, which extends from Bourke to Upstream Lake Wetherell. Two management zones are relevant to the proposal: the Tilpa to Wilcannia Management Zone and the Wilcannia to Upstream Lake Wetherell Management Zone.

Water availability

The availability of water in the water sources was investigated by CSIRO as part of the Murray-Darling Basin Sustainable Yields Project. CSIRO (2008) identifies that the then current average surface water availability (assessed at Bourke) is 3,515 gigalitres per year.

Planned environmental water

Planned environmental water is water that is committed by management plans for fundamental ecosystem health or other specified environmental purposes, either generally or at specified times or in specified circumstances and that cannot, to the extent committed, be taken or used for any other purpose. Part 4 of the Barwon-Darling WSP contains rules for the commitment, identification, establishment and maintenance of planned environmental water in the water source.

Requirements for water

Requirements for water in the water sources are identified in Part 5 of the Barwon-Darling WSP for basic landholder rights and for extraction under access licences.

The total estimated water requirements of persons entitled to domestic and stock rights in the water source is 824 megalitres per year.

Limits to the availability of water

Limits to the availability of water that can be extracted from the water source are identified in Part 6 of the WSP. The limit is expressed as a cap that is agreed under the Murray-Darling Basin Agreement in Schedule 1 of the *Water Act 2007* (Commonwealth). The cap is assessed using the Barwon-Darling IQQM computer model. When the WSP commenced in 2012, the cap for the water source was 223 gigalitres per year.

Town water supply

Towns have a higher priority for access to water than commercial licences. Water sharing plans recognise this priority by ensuring that a full share of water is allocated for annual town water supplies except where exceptional drought conditions prevent this. The annual share for every town water supply is specified on the town's licence (NSW Office of Water, 2012).

Resumption of flows

The first flow of water after a dry period has important social, cultural and environmental outcomes. The *Managing Resumption of Flow Fact Sheet* (Department of Planning, Industry and Environment (DPIE), 2019d), identifies first flows as providing:

- Cultural benefits to Aboriginal communities who have an association with the river
- Social benefits to local communities who rely on water in the river for human needs and their livestock
- Economic benefits to townships that are affected by the limited recreational and social opportunities
- Environmental benefits to aquatic biota that are restricted to isolated pools during low flow periods, where poor water quality can cause significant stress
- Water efficiency benefits by wetting the river channel, which reduces water losses from any larger flows that follow.

A resumption of flows rule was introduced in changes to the Barwon-Darling WSP that commenced on 1 July 2020. Clause 50 of the Barwon-Darling WSP contains a resumption of flows rule that is designed to ensure that flows that follow a prolonged low or no flow period are able to pass through the system to achieve connectivity from the Queensland border to Menindee Lakes. The resumption of flows rule is applied in four river sections, measured at Walgett, Brewarrina, Bourke and Wilcannia. Extraction of water is prohibited when the flow in that river section has been less than the flow equivalent of 200 megalitres per day at Wilcannia for greater than 90 consecutive days. Standard access conditions resume when a flow event is forecast to be received in that section and all downstream sections of at least the flow equivalent of 400 megalitres per day at Wilcannia for a minimum of 10 days, or if a total flow of 30,000 megalitres is forecast to pass Bourke since the commencement of the suspension. If access is suspended in a river section, access in all sections upstream is also suspended to ensure that flows that could contribute to the downstream section are protected. If access is reinstated (rule relaxed) in a lower river section due to a tributary inflow to that section, upper sections remain suspended if they still meet the conditions to suspend access for that section.

The resumption of flows rule was first triggered on 12 January 2021 after flows at Wilcannia dropped below 200 megalitres per day on 15 October 2020 and remained below this level for 90 consecutive days. This resulted in access being suspended for A, B and C Class licence holders until flows were forecast to reach the requirements specified in clause 50 of the WSP (WaterNSW, 2021).

Extraction of water for town water supply is exempt from the resumption of flows rule in accordance with clause 49 of the Barwon-Darling WSP.

Proposed updates to the Barwon-Darling WSP

Amendments are required to the Barwon-Darling WSP to reflect the proposed operation of the proposal as well as changes to gauging locations (including upgrades). The Department of Planning and Environment – Water (DPE Water) is responsible for water sharing plans including their amendment.

Water Infrastructure NSW has engaged DPE Water as a key stakeholder to inform them of the proposed amendments to the Barwon-Darling WSP and to receive advice on the process for amending the Barwon-Darling WSP including timeframes. The consultation has also involved DPE EES, DPI Fisheries, WaterNSW and the MDBA at strategic points in the proposal's program to communicate the intent to amend the WSP and obtain feedback from these agency stakeholders.

DPE Water has advised Water Infrastructure NSW that a new Barwon-Darling WSP is being developed to replace the 2012 WSP and is expected to be placed on public exhibition in about April/May 2022. The amendments required to the Barwon-Darling WSP for the proposal would only be made after the public exhibition of the environmental impact statement for the proposal is completed. DPE Water would carry out targeted consultation on the amendments to the Barwon-Darling WSP.

The proposal represents a significant shift away from fixed crest weirs, which have been constructed in the Barwon-Darling River system since the 1900s. The proposal has varying gate operational parameters that need to be implemented based on modes of operation and their transition phases to maximise the passing of flows and fish passage in balance with providing town water security.

An operations plan is being developed to document how the new weir would be managed and maintained by the river operator, WaterNSW. A high level outline of the proposed operations plan which has been informed by WaterNSW and agency stakeholders is provided as Appendix I to the environmental impact statement for information purposes. The outline operations plan will be refined into a detailed operations plan in collaboration with WaterNSW, and DPE Water will extrapolate the relevant information to be inserted into the new WSP.

The operations plan will:

- Outline governance arrangements for operating the new weir including roles, responsibilities, accountabilities, risk management, and reporting requirements
- Define the operating rules for the normal and drought security operation modes and filling and reset phases
- Document the approvals process for any future amendments and updates to the operations plan, which will involve a consideration of the consistency of the proposed changes with the Barwon-Darling WSP, planning approval conditions of consent, and requirement for additional consultation with relevant stakeholder agencies.

It is intended that the operations plan will be finalised prior to the approval of the proposal by the Minister for4 Planning.

The proposal does not require any change to the sustainable diversion limits of the Murray-Darling Basin Plan.

2.2.4 Water Sharing Plan for the Darling Alluvial Water Groundwater Sources 2020

Groundwater at Wilcannia is subject to the Water Sharing Plan for the Darling Alluvial Groundwater Sources 2020 (Darling Alluvial WSP). The Darling Alluvial WSP covers the Warrego, Upper Darling, Paroo and Lower Darling alluvial groundwater sources. The proposal is located within the Upper Darling alluvial groundwater source.

The key elements of the Darling Alluvial WSP that are relevant to the proposal are described in this section based on the statutory instrument itself and also a background document prepared by the former NSW Office of Water (2012).

The Daring Alluvial WSP has several objectives; the objectives that are most relevant to the proposal include:

- To protect the condition of the groundwater sources and their groundwater dependent ecosystems
- To maintain the spiritual, social, customary and economic values and uses of groundwater by Aboriginal people
- To provide access to groundwater to support groundwater-dependent social and cultural values.

In accordance with sections 20 and 21 of the WM Act, the Darling Alluvial WSP applies a range of strategies to achieve these objectives including:

- Providing groundwater for basic landholder rights, town water supply, and for licensed domestic and stock purposes
- Managing extractions under access licences and basic landholder rights within the limits to the availability of water
- Managing the construction and use of water supply works to minimise impacts on high priority groundwater dependent ecosystems, groundwater quality, groundwater-dependent culturally significant areas, basic landholder rights and town water supply.

Planned environmental water

Part 4 of the Darling Alluvial WSP contains rules for the commitment, identification, establishment and maintenance of planned environmental water in the water sources.

Requirements for water

Requirements for water in the water sources are identified in Part 5 of the Darling Alluvial WSP for basic landholder rights and for extraction under access licences.

The water requirements of persons entitled to domestic and stock rights in the Upper Darling Alluvial Groundwater Source is estimated at 2,281 megalitres per year when the plan commenced in 2020.

Limits to the availability of water

Limits on the availability of water that can be extracted from the water sources are identified in Part 6 of the Darling Alluvial WSP. The long-term average annual extraction limit for the Upper Darling Alluvial Groundwater Source is 2,230 megalitres per year.

2.2.5 Protection of the Environment and Operations Act 1997

The NSW *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the Environment Protection Authority. The POEO Act regulates air and water pollution, noise control and waste management.

The Act contains pollution controls and requirements for granting environment protection licences. Schedule 1 of the Act lists activities that require an environment protection licence. The proposal is not of a kind listed in Schedule 1 of the POEO Act and would not require an environment protection licence under this schedule. In accordance with section 43(d) of the POEO Act, an environment protection licence may also be issued to control the carrying out of a non-scheduled activity for the purpose of regulating water pollution.

2.3 Regulatory policies/documents

2.3.1 National Water Quality Management Strategy

The National Water Quality Management Strategy is an Australian Government initiative in partnership with state and territory governments to protect the nation's water resources by maintaining and improving water quality, while supporting dependent aquatic and terrestrial ecosystems, agricultural and urban communities, and industry.

Channels for delivery of the National Water Quality Management Strategy include policy, process and guidelines. There are currently nine guidelines prepared as part of the National Water Quality Management Strategy. Of these guidelines, the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council (ANZECC) is the most relevant to the proposal.

2.3.2 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The current *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG (2018) Water Quality Guidelines), also referred to as the 'revised Water Quality Guidelines', were released in 2018 as an online resource. They provide high-level guidance on the management context, ecological descriptions, biological indicator selection, regional default guideline values for physical and chemical stressors and other advice for three of Australia's 12 inland water drainage divisions. For ecoregions where regional physical and chemical stressor default guideline values are not yet provided and local jurisdictions have not yet derived finer scale (e.g. catchment, basin or physiographic level) guideline values, the regional default guideline values provided in the superseded *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australia and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000) (ANZG (2000) Water Quality Guidelines) apply.

The ANZG (2018) Water Quality Guidelines do not contain default guideline values relevant to the proposal. The water quality targets relevant to the proposal are set out in the Murray-Darling Basin Plan, the Murray-Darling Basin Agreement and the ANZG (2000) Water Quality Guidelines.

2.3.3 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (Department of Environment, Climate Change and Water, 2006) are the agreed environmental values and long-term goals for NSW's surface waters. The objectives set out the community's values and uses (i.e. healthy aquatic ecosystems, water suitable for recreation and drinking water) for watercourses (e.g. rivers, creeks, estuaries and lakes) and contain a range of water quality indicators to assess whether the current condition of a watercourse supports these values and uses. The objectives are consistent with the agreed national framework for assessing water quality set out in the ANZG (2000) Water Quality Guidelines.

Water quality and river flow objectives have been developed for each catchment in the State; the proposal is located within the Barwon Darling and Far Western Catchment (Department of Environment, Climate Change and Water, 2006). Different water quality and river flow objectives have been set for areas within this catchment based on land use and the nature of its watercourses and their flows. The Darling River (Baaka) from Mungindi to the top of Lake Wetherell, which includes Wilcannia, is categorised as a 'controlled river with reduced flow', for which there are 10 water quality objectives and no river flow objectives.

The booklet *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (Department of Environment and Conservation, 2006) provides technical practitioners with a concise summary of the NSW water quality objectives.

2.3.4 Murray-Darling Basin Plan

The Murray-Darling Basin Plan (MDBA, 2012) provides a coordinated approach to managing Basin water resources across Queensland, NSW, ACT, Victoria and South Australia. In NSW, the plan came into effect following the signing of Inter-governmental and National Partnership Agreements in 2014. As lead agency, DPE Water is working across government with Biodiversity and Conservation Division and Department of Primary Industries (Fisheries) and other agencies to implement the plan.

2.3.5 Barwon-Darling Long-Term Water Plan

The *Barwon–Darling Long-Term Water Plan Part A* (Department of Planning, Industry and Environment, 2020a) identifies strategies for maintaining and improving the long-term health of the Barwon–Darling riverine and floodplain environmental assets and the ecological functions they perform. It identifies strategies for maintaining and improving the long-term health of the Barwon–Darling riverine and floodplain environmental assets and the ecological functions they perform. This includes detailed descriptions of ecologically important river flows and risks to water for the environment.

The Long Term Water Plan does not prescribe how environmental water should be managed in the future, rather it aims to help water managers make decisions about where, when and how available water can be used to achieve agreed long-term ecological objectives. The Long Term Water Plan considers all sources of water and how these can be managed to help support environmental outcomes in the catchment. This recognises that the Murray–Darling Basin Plan specifically requires environmental water managers to act adaptively by making timely decisions based on the best-available knowledge, and from monitoring and evaluating the outcomes from water use.

To address variation along the Barwon–Darling River (Baaka), the Barwon–Darling Long-Term Water Plan divides the river into 14 planning units, which correspond to the 14 management zones in the Barwon-Darling WSP. The proposal is located at the boundary between two planning units: the Tilpa to Wilcannia planning unit (PU13) and the Wilcannia to Upstream Lake Wetherill planning unit (PU14). The existing Wilcannia Weir is within PU13.

The Long Term Water Plan comprises two parts:

- Part A provides a catchment-scale description of the flow regimes required to maintain or improve environmental outcomes in the Barwon-Darling (Baaka)
- Part B describes the flow regimes required to maintain or improve environmental outcomes in the Barwon-Darling at a planning unit scale.

Environmental water requirements for the Tilpa to Wilcannia and Wilcannia to Upstream Lake Wetherill planning units are provided in Table 17 and Table 18 respectively of Part B of the Long Term Water Plan. The environmental water requirements for these two planning units are the same and are reproduced in **Table 2-1.** The potential impact of the proposal on the environmental water requirements is assessed in **Section 5.4**.

Table 2-1 Environmental water requirements for the Tilpa to Wilcannia and Wilcannia to Upstream Lake Wetherell planning units

Flow category and EWR code		Flow rate	Timing	Duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
Cease-to-flow	CtF	<1 ML/day	Can occur anytime of year, but most 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.	Cease-to-flow events should occur in no more than 50% of years	Not applicable	When managing water to restart flows, avoid harmful water quality impacts, such as de-oxygenation of refuge pools.
Very-low-flow	VLF	>30 ML/day	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 (Baaka). Waterhole persistence can also be supported by groundwater.
Baseflows	BF1	>350 ML/day	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 metres to allow fish passage. Also to manage water quality, prevent destratification and reduce risk of blue-green algal blooms.
	BF2	>350 ML/day	September to March	In typical years, at least 185 days per year (within timing window). In very dry years, at least 60 days per	Every year	200 days	Aiming to provide a depth of 0.3 metres to allow fish passage.

Flow category and EWR code		Flow rate	Timing	Duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
				year (within timing window).			
Small fresh	SF1	>1,400 ML/day	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 – greater than 20°C for most native fish and greater than 18°C for Murrray 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 metres per second (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/day	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 – greater than 20°C for most native species and greater than 18°C for Murray Cod.

Flow category and EWR code		Flow rate	Timing	Duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
							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 metres per second (depending on channel form).
Large fresh	LF1	> 14,000 ML/day	Anytime, but ideally July to September	15 days minimum	5-10 years in 10 (75% of years)	2 years	This flow in July to September will improve pre-spawning fish conditions. Aiming to provide a depth of two metres to cover in-stream features and trigger a response from fish. Flow velocity ideally 0.3 to 0.4 metres per second(depending on channel form).
	LF2	> 14,000 ML/day	October to April	15 days minimum	3-5 years in 10 (42% of years)	2 years	Aiming to provide a depth of two metres to cover in-stream features and trigger a response from fish. Flow velocity ideally 0.3 to 0.4 metres per second (depending on channel form).

Flow category and EWR code		Flow rate	Timing	Duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
							Temperature preferably greater than 17°C to maximise spawning outcomes. Ideally shortly before SF1.
Bankfull	BK1	> 25,000 ML/day	Anytime	15 days minimum	5 in 10 years (50% of years)	4 years	
Overbank	OB1	> 30,000 ML/day	Anytime	15 days minimum	2 to 4 years in 10 (30% of years)	5 years	Clustered events (i.e. multiple events over two to three years) will provide improved conditions for native vegetation recruitment. Multiple events in close proximity will also improve the condition of native vegetation communities.
	OB2	>31,000 ML/day	Anytime	15 days minimum	1 to 3 years in 10 (20% of years)	10 years	
	OB3	>43,000 ML/day	Anytime	15 days minimum	0.5 to 1 years in 10 (10% of years)	15 years	

Source: Table 17 of the *Barwon-Darling Long-Term Water Plan Part B* (Department of Planning, Industry and Environment, 2020b)

2.3.6 Basin Salinity Management 2030

Basin Salinity Management 2030 (Murray-Darling Basin Ministerial Council, 2015) provides a 15-year strategy for the coordination of efforts by state governments to manage salinity in the Murray-Darling Basin during the period 2015-2030. It builds upon the reductions in salinity achieved under the *Basin Salinity Management Strategy 2001–2015*.

The salt of the Murray–Darling Basin derives from millions of years of rainfall deposition and the weathering of rocks and ancient ocean sediments. The flat terrain, low rainfall and high evaporation rates that typify most of the Basin favour the accumulation of salt in the landscape while the groundwater and river systems only slowly return the salt to the ocean. Changes to the landscape since the clearing of native vegetation and development of agriculture means that more water now drains into groundwater systems where it can mobilise the salt into surface water systems. River regulation and increasing water extraction for irrigation and other uses has also changed river flow patterns and increased river salinities.

Basin Salinity Management 2030 is being implemented in the context of basin landscapes that will continue to export salt, with salinity forecast to gradually increase as the delayed salinity impacts of land clearing and historical irrigation development manifest, but also in a period when the Basin is being reset to a new sustainable state following the commencement of the Basin Plan in November 2012.

While the Basin Plan sets high-level objectives and targets for salinity, it has no mechanism for joint State action. This is addressed in *Basin Salinity Management 2030*, in which the partner governments agree to implement individual, collective and coordinated actions in the shared water resources and where necessary in their catchments. *Basin Salinity Management 2030* was established as an agreed program under the Murray–Darling Basin Agreement (Schedule 1 of the *Water Act 2007* (Cth)) and it is consistent with and complementary to the Basin Plan.

Basin Salinity Management 2030 comprises eight key elements. The core element is the continuation and refinement of the accountability framework that has been at the heart of Basin salinity management since 1988. The accountability framework commits the partner governments to maintain agreed salinity levels and ensure that their actions that increase river salinity are offset by investing in actions to reduce salinity. The framework includes the Basin Salinity Target to maintain modelled average daily salinity at the town of Morgan in South Australia at less than 800 EC for at least 95 per cent of the time over a benchmark period from May 1975 to April 2000 that encompassed the expected long-term range of climate variability.

Another of the key elements in *Basin Salinity Management 2030* is salinity accountability for environmental water management. Environmental watering provides long-term salinity dilution benefits, but it can also mobilise salt from floodplains into the river system. *Basin Salinity Management 2030* requires the positive and negative salinity impacts associated with environmental water management to be accountable actions.

2.3.7 Barwon-Darling Watercourse Resource Plan

Water resource plans are put in place to implement the Commonwealth Government's *Basin Plan 2012*. All NSW water resource plans were submitted in 2020 to the MDBA to assess the plan against accreditation requirements of the *Basin Plan 2012*. An outcome of this process is that further work is being done to the Barwon-Darling Watercourse Resource Plan to address accreditation requirements prior to it being resubmitted to the MDBA.

Water Quality Management Plan

Under the Murray-Darling Basin Plan, there is a requirement to develop water quality management plans for each water resource plan area within the Murray-Darling Basin with the purpose of providing a framework to protect, enhance and restore water quality that is suitable for a range of outcomes. The *Water Quality Management Plan for the Barwon-Darling Watercourse Water Resource Plan* (DPIE, 2019b) identifies relevant water quality objectives for the Barwon-Darling (Baaka) watercourse and the water quality targets required to achieve these objectives.

The plan notes that water quality attributes in the Barwon-Darling (Baaka) are strongly correlated to flow. High flow from rainfall and runoff results in higher turbidity, nutrients and possibly pesticides and pathogens. There is also a general trend towards increasing turbidity and nutrient concentration with distance down the catchment as cumulative impacts increase. Poor water quality also occurs when the Barwon-Darling (Baaka) dries to a series of standing pools, which generally have poor water quality with high nutrients, suspended solids and salinity. Water arriving from upstream catchments can flush this poor quality water from these pools, possibly affecting the usability further downstream and impacting on the riverine environment. The plan notes the following risks to water quality when the river commences to flow after a period of no flow:

- As poor quality water is flushed downstream, it may be unusable for some activities
- Water with low or zero dissolved oxygen often sits on the bottom of stagnant pools. The flushing of this water can cause fish kills in pools and downstream
- Some elements are released at harmful concentrations from river sediments under zero oxygen conditions. These could have toxic effects on plants and soil if used for irrigation
- Denser saline water can flow along or sit on the bottom of pools, leaving the fresher water sitting on top
- The water in stagnant pools can have high nutrient concentrations, triggering potentially toxic blue-green algal blooms downstream.

2.3.8 Australian Drinking Water Guidelines

The *Australian Drinking Water Guidelines* (ADWG) are prepared by the National Health and Medical Research Council and Natural Resource Management Ministerial Council (2011) for the Australian Government and are:

"…intended to provide a framework for good management of drinking water supplies that, if implemented, will assure safety at point of use. The ADWG have been developed after consideration of the best available scientific evidence. They are designed to provide an authoritative reference on what defines safe, good quality water, how it can be achieved and how it can be assured. They are concerned both with safety from a health point of view and with aesthetic quality."

The ADWG are not mandatory standards, however, they provide a basis for determining the quality of water to be supplied to consumers in all parts of Australia. They are intended for use by the Australian community and all agencies with responsibilities associated with the supply of drinking water, including catchment and water resource managers, drinking water suppliers, water regulators and health authorities.

The Central Darling Shire Council is responsible for providing Wilcannia's raw water for drinking purposes. Water abstracted from the weir pool is treated at the Wilcannia Water Filtration Plant to a standard that compiles with the *Australian Drinking Water Guidelines*.

2.3.9 Guidelines for Managing Risks in Recreational Water

The *Guidelines for Managing Risks in Recreational Water* (National Health and Medical Research Council, 2008) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters.

The guidelines provide recommended values for indicators that may pose a risk to human health. These indicators are relevant for the Darling River (Baaka) which has "maintain the quality of surface water for recreational use" as a water quality objective in the *Water Quality Management Plan for the Barwon-Darling Watercourse Water Resource Plan* (DPIE, 2019b). Potential threats to the recreational use of the watercourse may arise as a result of the construction and operation of the proposal.

2.3.10 Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales

The *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (Environment Protection Authority, 2003) lists the sampling and analysis methods to be used when complying with a requirement by, or under, NSW environment protection legislation, or a licence or notice under that legislation, to test for the presence or concentration of matter in water and the volume, depth and flow of water or wastewater.

2.3.11 Floodplain Management Plan for the Barwon-Darling Valley Floodplain 2017

The *Floodplain Management Plan for the Barwon-Darling Valley Floodplain 2017* was prepared in accordance with section 50 of the *Water Management Act 2000*. The upstream limit of the floodplain is at Mungindi on the Barwon River, at the NSW-Queensland border and the downstream limit is about 20 kilometres downstream of Louth on the Darling River (Baaka). Wilcannia is about 220 kilometres downstream of Louth and the plan is therefore not directly applicable to the proposal.

An objective of the plan is to facilitate the orderly passage of floodwaters through the Barwon-Darling Valley Floodplain. The plan contains several strategies to achieve its objectives including establishing management zones for coordinating flood work development, identifying the existing and natural flooding regimes in the area, and delineating a floodway network that has adequate hydraulic capacity and continuity to effectively convey floodwaters.

2.3.12 Floodplain Development Manual

The *Floodplain Development Manual: The Management of Flood Liable Land* (Department of Planning, Infrastructure and Natural Resources, 2005) incorporates the NSW Government's Flood Prone Land Policy, the primary objectives of which are to reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods, whilst also recognising the benefits of use, occupation and development of flood prone land.

The *Floodplain Development Manual* forms the NSW Government's primary technical guidance for the development of sustainable strategies to support human occupation and use of the floodplain, and promotes strategic consideration of key issues including safety to people, management of potential damage to property and infrastructure and management of cumulative impacts of development. Importantly, the manual promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

Flood and floodplain risk management studies carried out by local councils as part of the NSW Government's Floodplain Management Program are carried out in accordance with the merits based approach promoted by the *Floodplain Development Manual*. A similar merits based approach has been adopted in the assessment of the impacts that the proposal would have on existing flood behaviour and also in the development of a range of potential measures which would be aimed at mitigating its impact on the existing environment. In accordance with the manual, the hydraulic and hazard categorisation of the floodplain was also considered when assessing the impact of the proposal on existing flood behaviour, as well as the impact of flooding to the proposal and its users.

2.3.13 Considering flooding in land use planning

In July 2021 the NSW Government issued Planning Circular PS 21-006 *Considering flooding in land use planning: guidance and statutory requirements* which provided advice on a package of changes regarding how land use planning considers flooding and flood-related constraints including an overview of its new guideline Considering Flooding in Land Use Planning (2021).

The guideline supports the principles of the *Floodplain Development Manual* and provides advice to councils on land use planning on flood-prone land. It provides councils with greater flexibility in defining the areas to which flood-related development controls apply, with consideration of defined flood events, freeboards, low-probability/high consequence flooding and emergency management considerations.

The manual states that a defined flood event of one per cent annual exceedance probability (1% AEP), or a historic flood of similar scale, plus a freeboard should generally be used as the minimum level for setting residential flood planning levels (FPL). Choosing different defined flood events and freeboards requires justification based on a merit assessment that is consistent with the floodplain risk management process and principles of the *Floodplain Development Manual*.

Special flood considerations apply to sensitive and hazardous development in areas between the flood planning area and the probable maximum flood and to land that may cause a particular risk to life and other safety considerations that require additional controls. These controls relate to the management of risk to life and the risk of hazardous industry/hazardous storage establishments to the community and the environment in the event of a flood.

3. Existing environment

This section provides a detailed description of the water catchment area in which the proposal is located and its relationship with the wider Murray-Darling Basin. The surface and groundwater resources within the catchment are described including their extent and usage, the quality of each water source and the factors affecting water quality. The characteristics of water flow in the Darling River (Baaka) are also described.

3.1 Water catchment overview

The Darling River (Baaka) at Wilcannia forms part of the Barwon-Darling catchment area in the Murray-Darling Basin. The Barwon–Darling corridor connects all the rivers, lakes and wetlands in the northern Basin; and then provides a connection to the southern Basin through the lower Darling River.

The Darling River (Baaka) between the Barwon River and River Murray covers a distance of 1,545 kilometres and spans two water catchment areas:

- *Barwon-Darling catchment* – The Barwon-Darling catchment takes in the Barwon River, from upstream of Mungindi at the confluence of the Macintyre and Weir rivers, to where the Barwon meets the Culgoa River, a distance of 577 kilometres. The Darling River (Baaka) is formed by the confluence of the Barwon River and the Culgoa River upstream of Bourke and flows in a westerly and southerly direction through semi -arid areas of Western NSW to join the Menindee Lakes at the artificial storage of Lake Wetherell. The catchment of the Barwon–Darling covers 699,500 square kilometres or about 13 per cent of the Murray-Darling Basin (Thoms, Sheldon and Crabb, 2004)
- Lower Darling catchment – Downstream of Menindee Lakes the Darling River (Baaka) enters the Lower Darling catchment and continues onwards to join the River Murray at Wentworth.

The Barwon–Darling river system is unregulated, however, it is highly impacted by headwater dams, water extraction and numerous low-level weirs. Wilcannia Weir is located at the township of Wilcannia, about halfway between Bourke and the River Murray and about 50 kilometres downstream of the confluence with the Paroo River. There are 14 weirs on the Darling (Baaka) and Barwon rivers upstream of Wilcannia Weir (refer to **Figure 3-3**) including weirs for town water supply at Mungindi, Collarenebri, Walgett, Brewarrina, Bourke, Louth and Tilpa. There are also four weirs on the Darling River (Baaka) downstream of Wilcannia at Menindee, Pooncarie and Burtundy:

- Menindee Main Weir forms Lake Wetherill, one of the four main lakes of the Menindee Lakes Storage
- Weir 32 is located about 39 river kilometres downstream of Menindee Main Weir and is associated with the Menindee Lakes Storages. Weir 32 provides a pumping pool for Essential Water, the provider of town water supplies to Broken Hill and Menindee
- Pooncarie Weir supplies water to the small town of Pooncarie
- Burtundy Weir is located about 500 metres downstream from Tulney Point homestead and about 50 kilometres north of Wentworth. Burtundy Weir is a privately owned and licensed structure that provides stock and domestic water supply to about seven properties from a 15 river kilometre weir pool. There are also a number of water licences servicing permanent planting enterprises both upstream and downstream of the weir (Department of Primary Industries, 2006).

The weirs along the Darling River (Baaka) result in variable river flow, with some reaches flowing (lotic) and others non-flowing (lentic) at any one time (refer to **Figure 3-4**). During low flows, weir pools can result in about 1,000 river kilometres of artificial lentic conditions, or about 40 per cent of the length of the Barwon-Darling river system (Mallen-Cooper, M. and Zampatti, B., 2020).

The Darling River (Baaka) at Wilcannia has an upstream catchment area of 569,000 square kilometres and a mean daily flow of 6,314 megalitres over the period 1913 to 2016 (DPIE, 2019e). The hydraulic gradient (change in water level per unit of distance) in this reach of the Darling River (Baaka) is very low, averaging 0.01 metre per kilometre. The mean annual flow at Wilcannia is 2,305 gigalitres, but the inter-annual variability is extreme, as shown on **Figure 3-1**. This is reflected in the daily flow variability and the large difference between the high and low flows, as shown in **Figure 3-2**. The median daily flow is significantly lower than the mean daily flow.

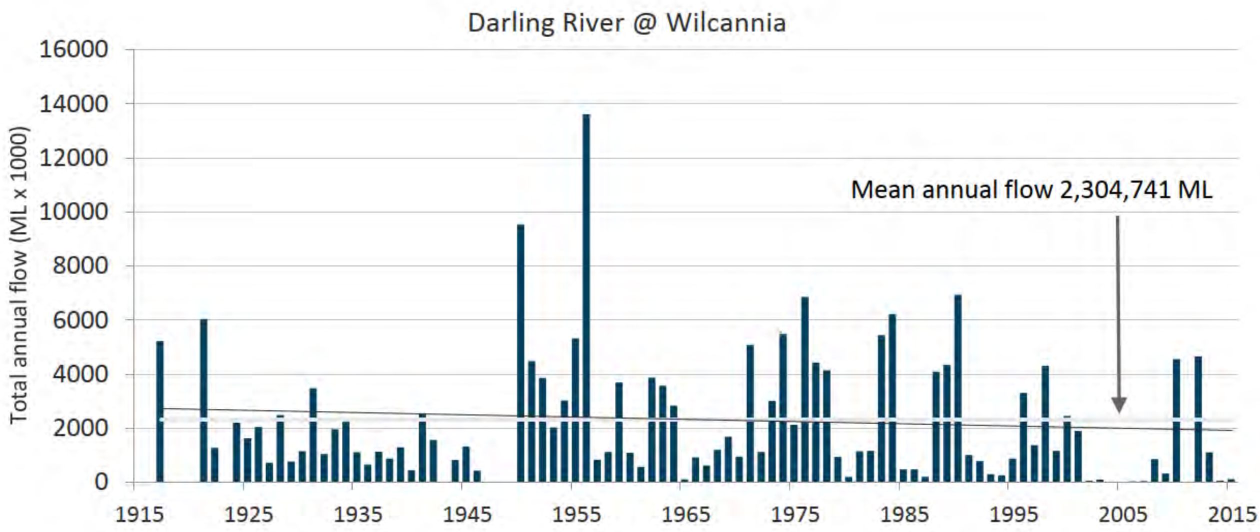


Figure 3-1 Inter-annual streamflow at Wilcannia, 1913 to 2016

Source: DPIE (2019e)

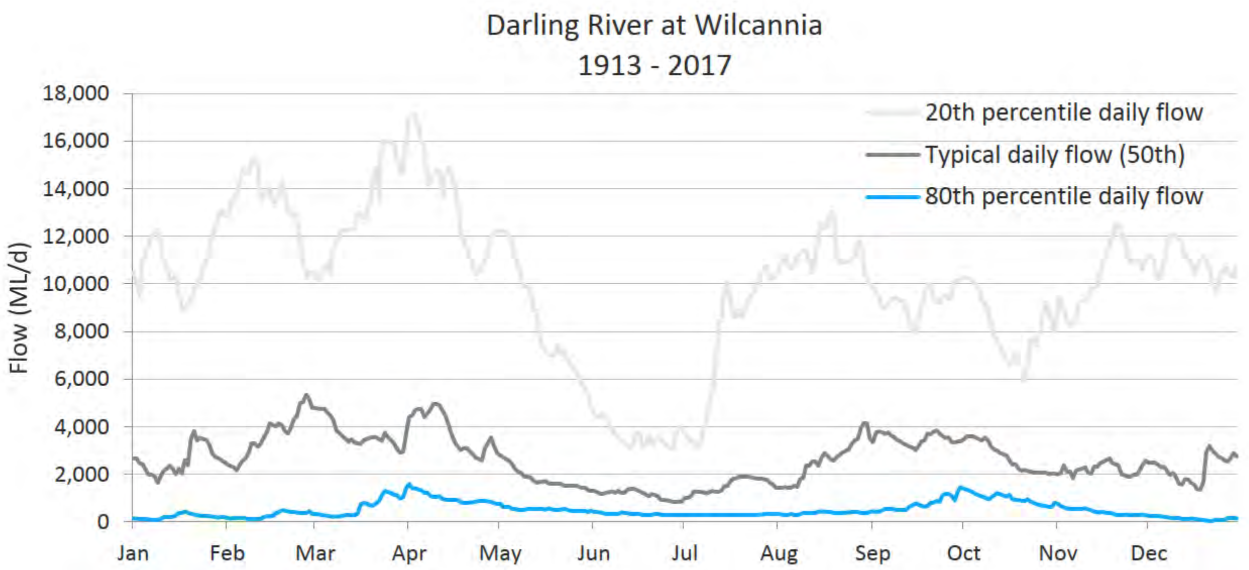


Figure 3-2 High (80th percentile), median (50th percentile) and low (20th percentile) daily flows at Wilcannia, 1913 to 2017

Source: DPIE (2019e)

The Barwon-Darling catchment only generates about 2.8 per cent of the flow in the Murray-Darling Basin, however much more water flows through the system, with 99 per cent of this flow generated in upstream catchments. The region only uses three per cent of the total surface water that is diverted for irrigation in the Basin and less than one per cent of the total volume of groundwater used across the Basin (MDBA, 2021).

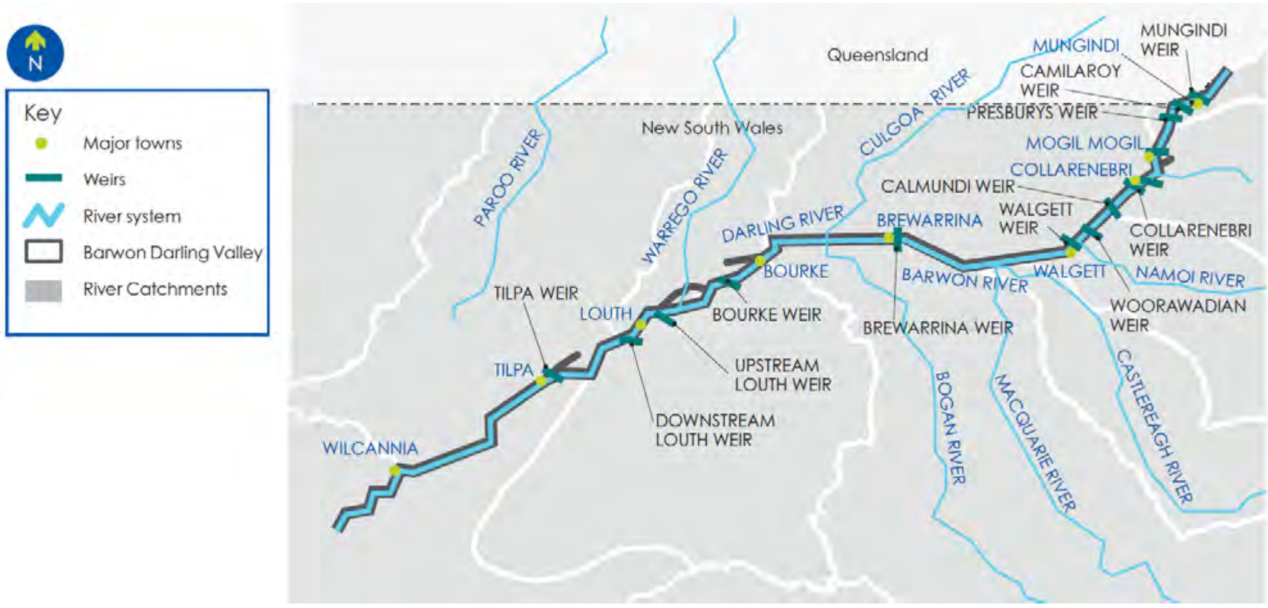


Figure 3-3 Weirs on the Barwon-Darling River upstream of Wilcannia

Source: WaterNSW (2019)

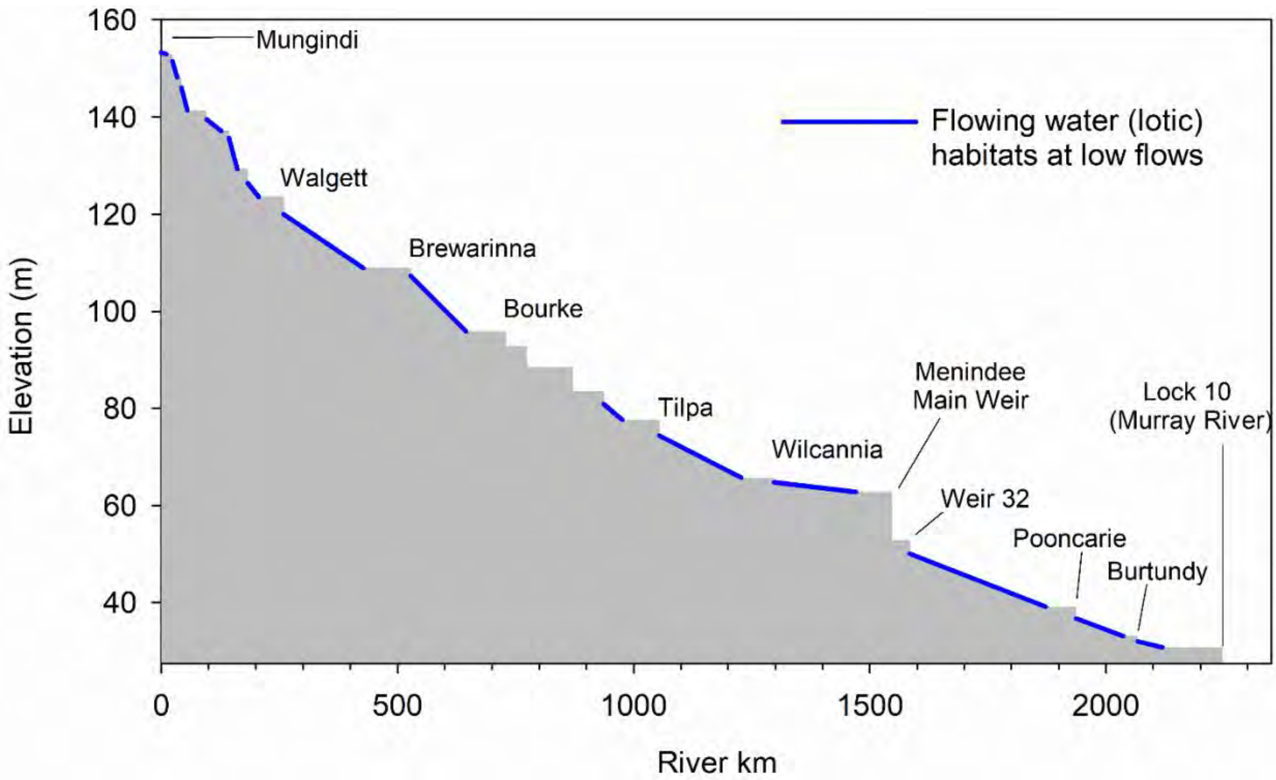


Figure 3-4 Profile of the Barwon-Darling River (Baaka), with blue lines showing flowing (lotic) reaches between weir pools at low flows

Source: Mallen-Cooper, M and Zampatti, B. (2020)

3.1.1 Land use

The major land use in the Barwon-Darling catchment is agriculture, mostly dryland grazing of cattle for beef and sheep for wool.

A small area of the catchment is irrigated and mostly comprises cotton production on the western plains near the river. Crops are irrigated by supplementary water from large on-farm storages, which is harvested from upstream tributary flows. While cotton is the dominant irrigated crop in the region, there are several other enterprises including fruit, nuts and grapes.

There is increasing development of land for grazing and intensive cropping in the eastern margin of the region. Almost one-third of the catchment area remains as native vegetation (MDBA, 2021).

3.1.2 Topography

Wilcannia and the surrounding floodplains are generally very flat, typically between 74 and 77 metres AHD with a shallow gradient to the south-west. The town sits at 81 metres AHD with a slight increase in elevation to the north (refer to **Figure 3-5**).

The crest of the existing Wilcannia Weir is 65.71 metres AHD with the Darling River (Baaka) channel about 10 metres below that of the floodplain elevation at 61 – 62 metres AHD. The proposed new weir would have a crest at 65.71 metres AHD which would be raised to 66.71 metres AHD when it is drought security operation mode.

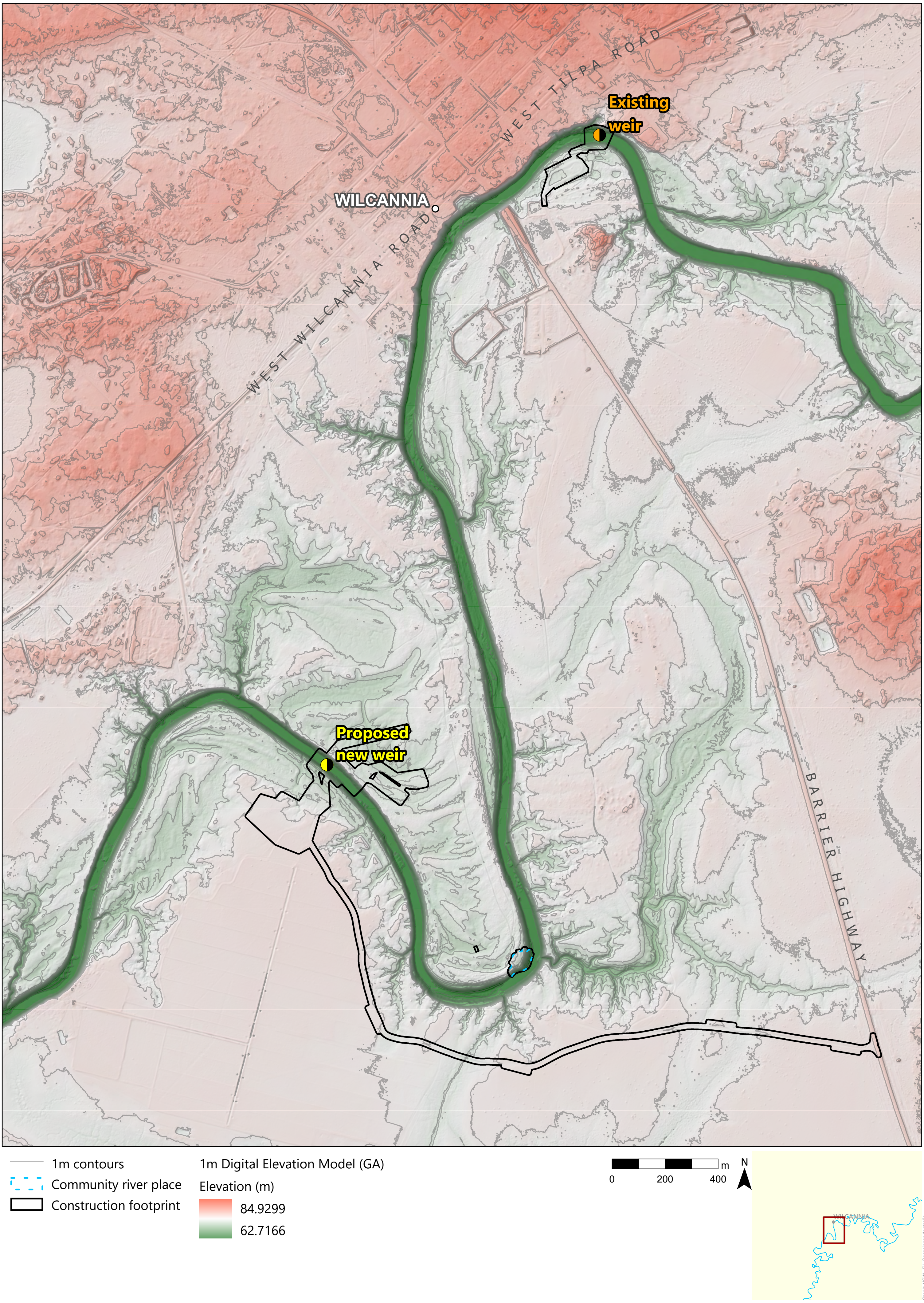


Figure 3-5 Site topography

3.1.3 Climate and rainfall

Average rainfall across the Barwon-Darling catchment is low, ranging from around 500 millimetres per year at Mungindi to 250 millimetres per year at Wilcannia (MDBA, 2016). Annual river flow may range from just one per cent to over 1,000 per cent of the annual mean, and periods of no flow can persist from months to years (Saintilan and Overton, 2010). Rainfall in the catchment is extremely variable, resulting in highly variable river flows. Typically, rain events are summer dominated with the largest events tending to be associated with ex-tropical cyclones that have moved inland (Thoms, Sheldon and Crabbe, 2004).

Daily rainfall data from 1897 to the present is available for the weather station operated by the Bureau of Meteorology at Reid Street in Wilcannia (weather station number 046043). Summary statistics for all years of collected rainfall data collected at this weather station are provided in **Table 3-1**.

Table 3-1 Daily rainfall data for Reid Street at Wilcannia (Bureau of Meteorology weather station number 046043)

Month	Average rainfall (millimetres)	Median rainfall (millimetres)	Highest daily rainfall (millimetres)
January	26.6	11.9	121.8
February	25.4	12.2	101.9
March	24.7	10.8	116.6
April	17.9	8.4	65.4
May	23.3	18.1	94.2
June	22.6	18.0	58.4
July	18.0	14.0	43.7
August	17.5	12.3	40.4
September	16.4	9.6	41.4
October	24.8	16.8	88.4
November	20.8	13.3	46.4
December	25.6	10.9	173.2

Source: Bureau of Meteorology (2022)

The rainfall data collected by the Bureau of Meteorology shows there is only a moderate level of seasonality to rainfall at Wilcannia, and that rainfall is typically low in every month. The period of the year with the lowest rainfall is from July to September, with this period characterised by slightly lower average and median monthly rainfall than other months. Average monthly rainfall is greatest from December to March, although median rainfall in each of these months is lower than the median rainfall in July, August and September. This indicates that rainfall in the December to March period is characterised by more intense but less regular daily rainfall events than the July to September period. This is reflected in highest daily rainfall ever recorded in each of July, August and September being substantially lower than that for July to September.

The rainfall data collected at the Bureau of Meteorology's weather station number 046043 has been analysed to identify the average, median and highest number of days of rainfall in each month. The results of this analysis are presented in **Table 3-6**.

Table 3-2 Number of days of rainfall at Wilcannia

Month	Average number of days of rainfall	Median number of days of rainfall	Highest number of days of rainfall
January	3.1	2	14
February	2.8	2	11
March	2.7	2	12
April	2.7	2	16
May	4.0	3	12
June	4.5	4	13
July	4.3	4	13
August	4.0	4	12
September	3.3	3	12
October	3.9	4	11
November	3.3	3	11
December	3.2	3	12

The analysis confirms that on average there are fewer days of rainfall between December and March compared to July to October, although the difference is minor.

3.2 Watercourses

The Barwon River flows south-west through a relatively narrow floodplain with a tightly meandering channel and a highly-variable flow pattern and capacity. Capacity is significantly increased downstream of Collarenebri, after the Little Weir, Boomi, Moonie, Gwydir and Mehi rivers have joined the Barwon River. Other tributaries in this section of the river system include the Namoi, Macquarie and Bogan rivers (MDBA, 2021).

In the section of the river system downstream of Bourke, the main tributaries are the Warrego and Paroo rivers.

A stylised map of the Barwon-Darling river system including its tributaries is provided in **Figure 3-6**.

Most reliable runoff to the Darling River comes from the eastern tributaries (Border Rivers, Gwydir, Namoi and Macquarie rivers) that drain the western slopes of the Great Dividing Range. The northern tributaries (Paroo, Warrego and Culgoa rivers) are arid and intermittent, providing only minor and more variable run-off (Mallen-Cooper and Zampatti 2020, Thoms et al. 2004).

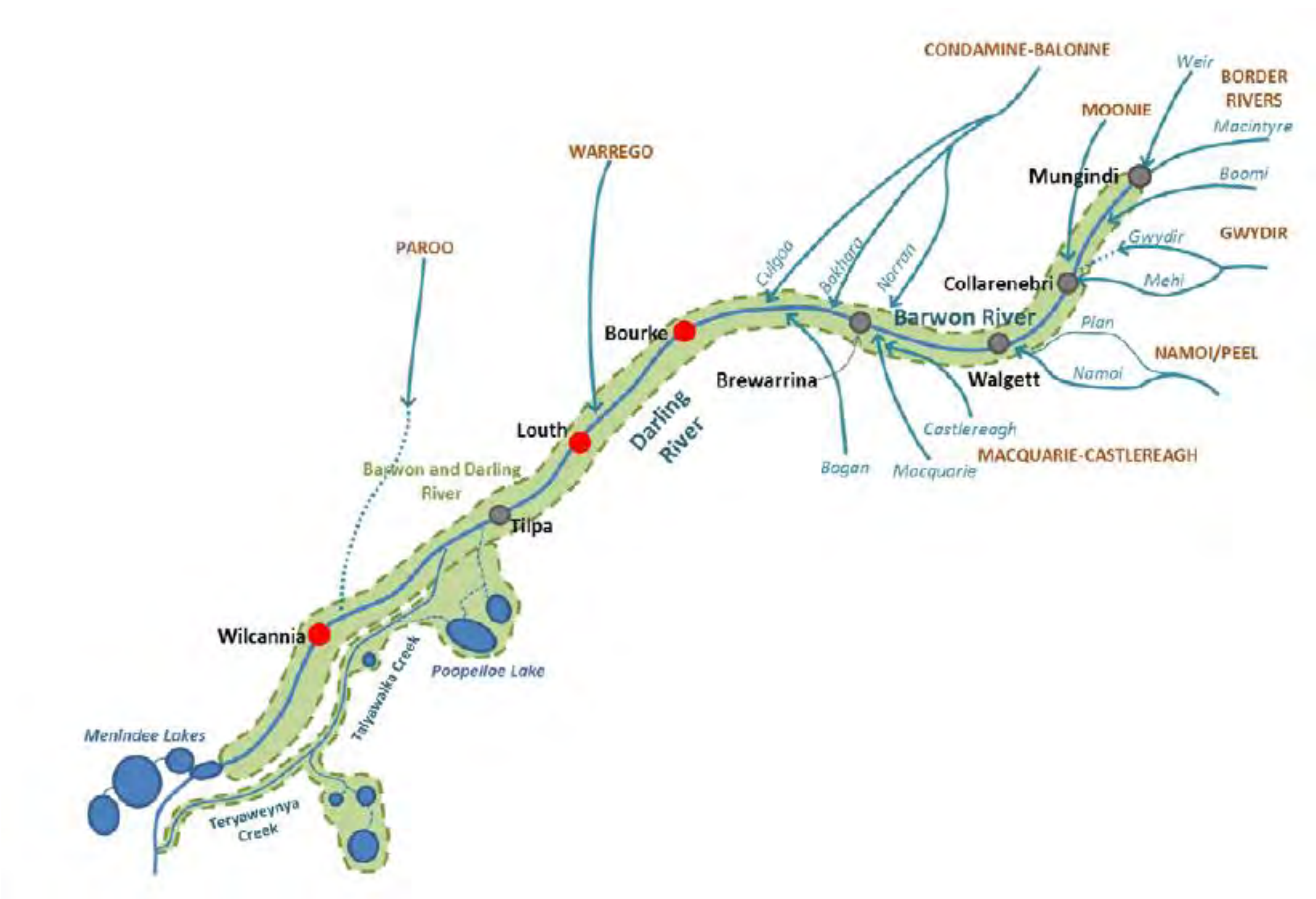


Figure 3-6 Stylised map of the Barwon-Darling river system

Source: MDBA (2016)

As noted in **Section 3.1.3**, rainfall in the Barwon–Darling catchment is extremely variable, resulting in highly variable river flows. Annual river flow may range from just one per cent to over 1,000 per cent of the annual mean, and periods of no-flow can persist from months to years (Saintilan & Overton, 2010). The variability in the flow is shown in the daily flow data recorded at the Wilcannia gauging station over the last 50 years, which is reproduced in **Figure 3-7**.

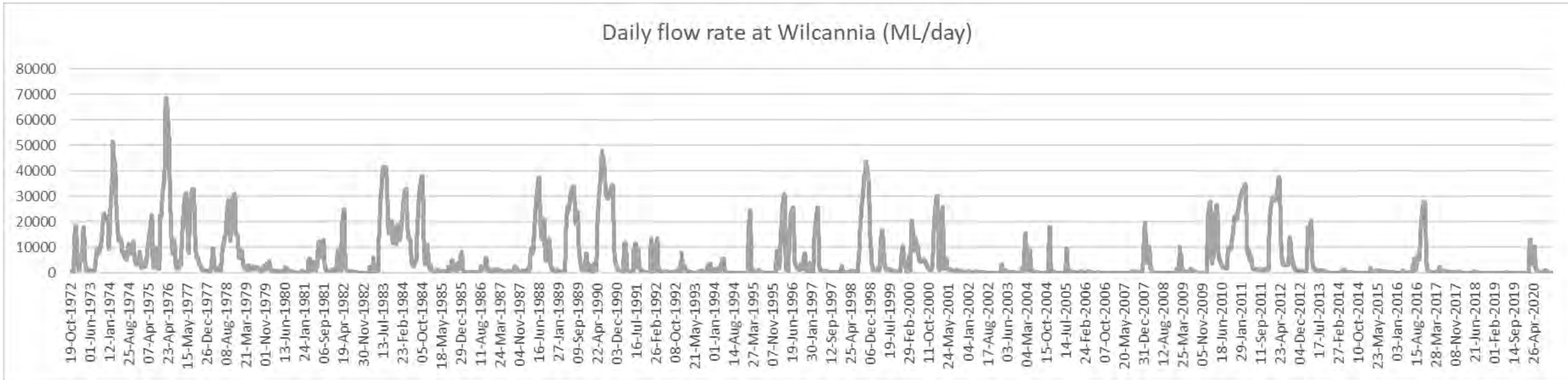


Figure 3-7 Daily flow data recorded at Wilcannia Main Channel gauging station (no. 425008), 1972 to 2020

Source: MDBA (2020a)

3.2.1 Wilcannia weir pool

The accessible storage of a weir is that portion of the weir pool that can be accessed for water supply purposes. It typically excludes upstream pools that becomes isolated from the point of extraction when the surface level of the weir pool drops below the level of upstream bars. It also excludes the portion of the weir pool that is below the level at which the intake pumping station can extract water.

A longitudinal schematic profile of the new and existing weir pools is provided in **Figure 4-2**. It shows that the existing weir pool comprises four pools. Pool 1 extends about 5.43 kilometres upstream from the existing weir and includes the water extraction infrastructure for the town. Water in Pool 1 is accessible down to the maximum operating depth of the intake pump i.e. 63.65 metres AHD. About 149 megalitres of water in Pool 1 is below the maximum operating depth of the intake pump would be inaccessible and is known as 'dead' storage as it cannot be used for the purpose of supplying water to Wilcannia.

Upstream of Pool 1, there are three river bars that isolate sections of the existing weir pool from the water extraction infrastructure for the town when the weir pool level is low:

- Bar 1 — Bar 1 is located about 5.43 river kilometres upstream of the existing weir. Bar 1 has an elevation of about 65.27 metres AHD, which is 44 centimetres below the existing full supply level. Immediately upstream of Bar 1 there is about 24.69 kilometres of river that is below the level of Bar 1, which is known as 'Pool 2'. Pool 2 extends upstream to Bar 2. Pool 2 can store an accessible volume of about 1,200 megalitres of water below 65.27 metres AHD. Pool 2 is 'dead' storage that cannot be accessed for the purpose of supplying water to Wilcannia unless the water extraction infrastructure for the town in Pool 1 is extended to this pool. If such an extension were developed it would reduce the dead storage in this pool to about 699 megalitres that is below the maximum operating depth of the intake pump.
- Bar 2 — Bar 2 is located about 30.12 river kilometres upstream of the existing weir. Bar 2 has an elevation of about 65.52 metres AHD, which is only 19 centimetres below the existing full supply level. Immediately upstream of Bar 2 there is about 19.08 kilometres of river that is below the level of Bar 2, which is known as 'Pool 3'. Pool 3 extends upstream to Bar 3. Pool 3 can store about 798 megalitres of water below 65.52 metres AHD. Pool 3 is 'dead' storage that cannot be accessed for the purpose of supplying water to Wilcannia.
- Bar 3 — Bar 3 is located about 49.20 river kilometres upstream of the existing weir. Bar 3 has an elevation of about 65.59 metres AHD, which is only 12 centimetres below the existing full supply level. Immediately upstream of Bar 3 there is about 12.59 kilometres of river that is below the level of the Bar 3, which is known as the 'end pool'. The end pool can store about 388 megalitres of water below 65.59 metres AHD. The end pool is 'dead' storage that cannot be accessed for the purpose of supplying water to Wilcannia.

3.2.2 Cease-to-flow events

DPIE (2021) has recently completed an analysis of historical cease-to-flow and low-flow events in the Barwon-Darling (Baaka) system. It identified that a constantly flowing river is not normal for the region and that the Barwon-Darling River stopped flowing for extended periods even before there were large dams and significant agricultural water use upstream. It identified that cease-to-flow events are often correlated with dry periods in the climate, with Western NSW cycling between wet and dry periods:

- The 1900s to the 1950s were comparatively dry
- The 1950s to the 1990s were comparatively wet
- Since the millennium drought, Western NSW has been returning to drier conditions.

A chart of the number of cease-to-flow days in the Barwon-Darling (Baaka) system since 1900 is provided in **Figure 3-8** and it clearly shows that cease-to-flow days were much more prevalent in dry periods than wet periods. A chart of cease-to-flow day for this same period at Wilcannia only is provide in **Figure 3-9**.

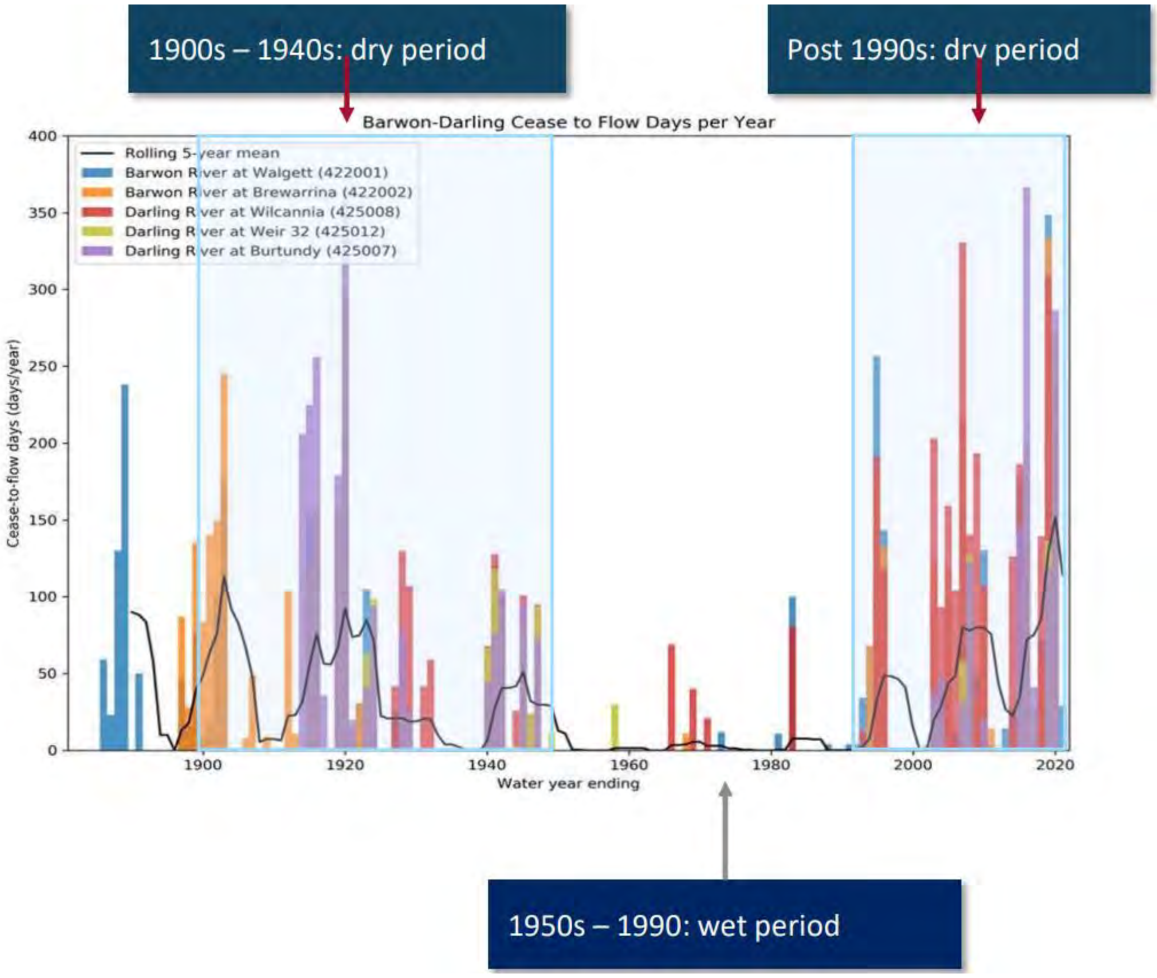


Figure 3-8 Barwon-Darling cease-to-flow days at Walgett, Brewarrina, Wilcannia, Menindee and Burtundy in the historical record

Source: DPIE (2021)

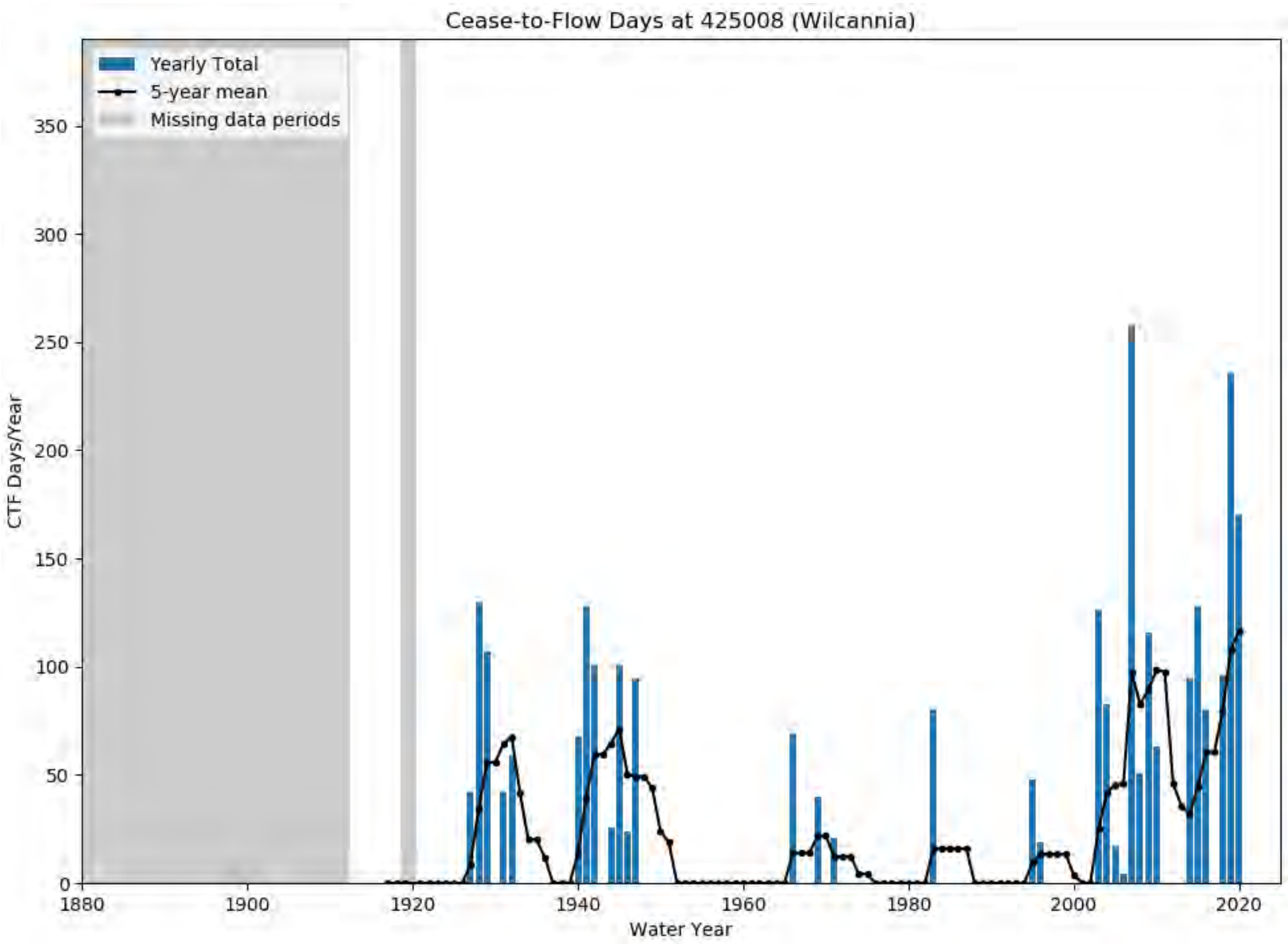


Figure 3-9 Cease-to-flow days at Wilcannia in the historical record

Source: DPE Water (2022)

While low-flow periods are normal in the region, extended periods of low- and no-flow place significant stress on the environment. The frequency of extended low-flow periods has increased over the last 20 to 30 years as indicated in **Figure 3-10**, which shows the duration of resumption of flow events at four gauges in the Barwon– Darling (Baaka) system including the Wilcannia gauge.

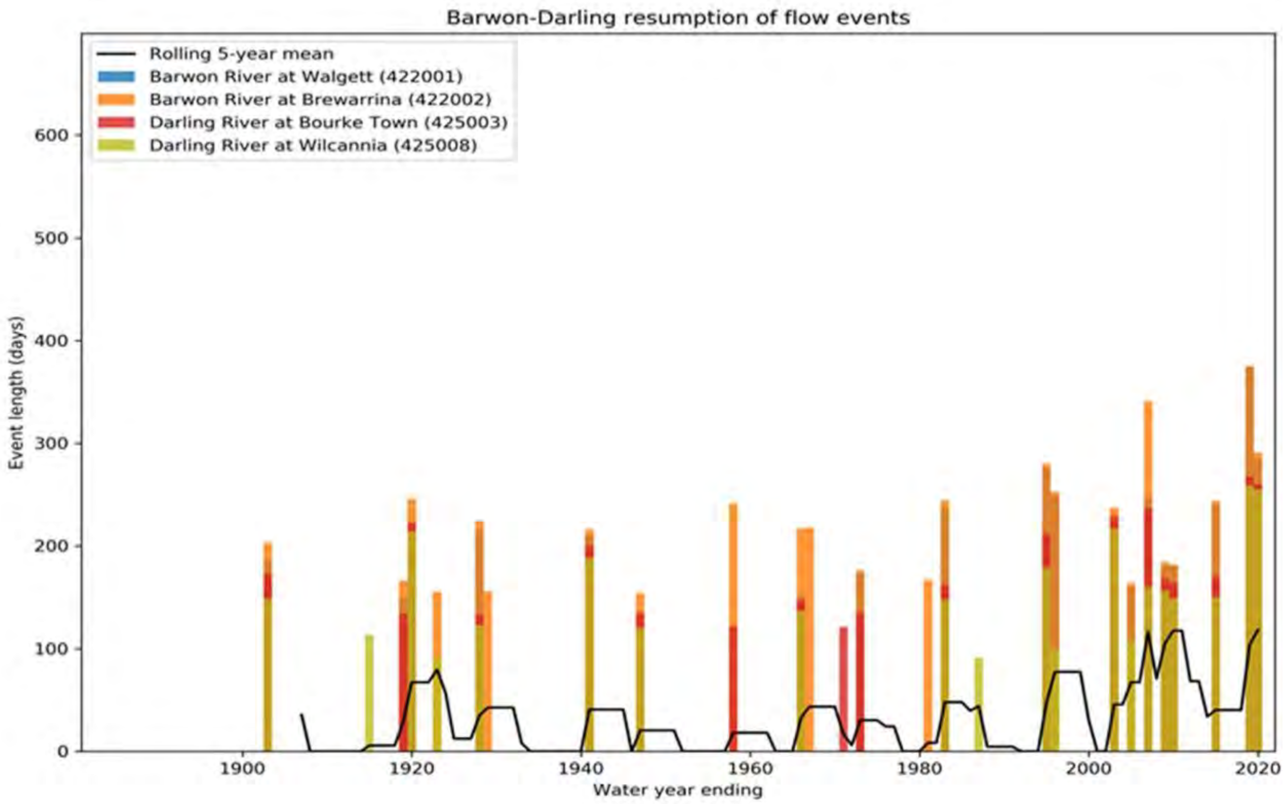


Figure 3-10 Extended low flow events at Walgett, Brewarinna, Bourke and Wilcannia in the historical record

Source: DPIE (2021)

This is consistent with the findings of the MDBA (2018), which analysed historical observed flow data at Wilcannia and identified that dry spells were significantly longer during the millennium drought compared to pre-1945 events (refer to **Figure 3-11**).

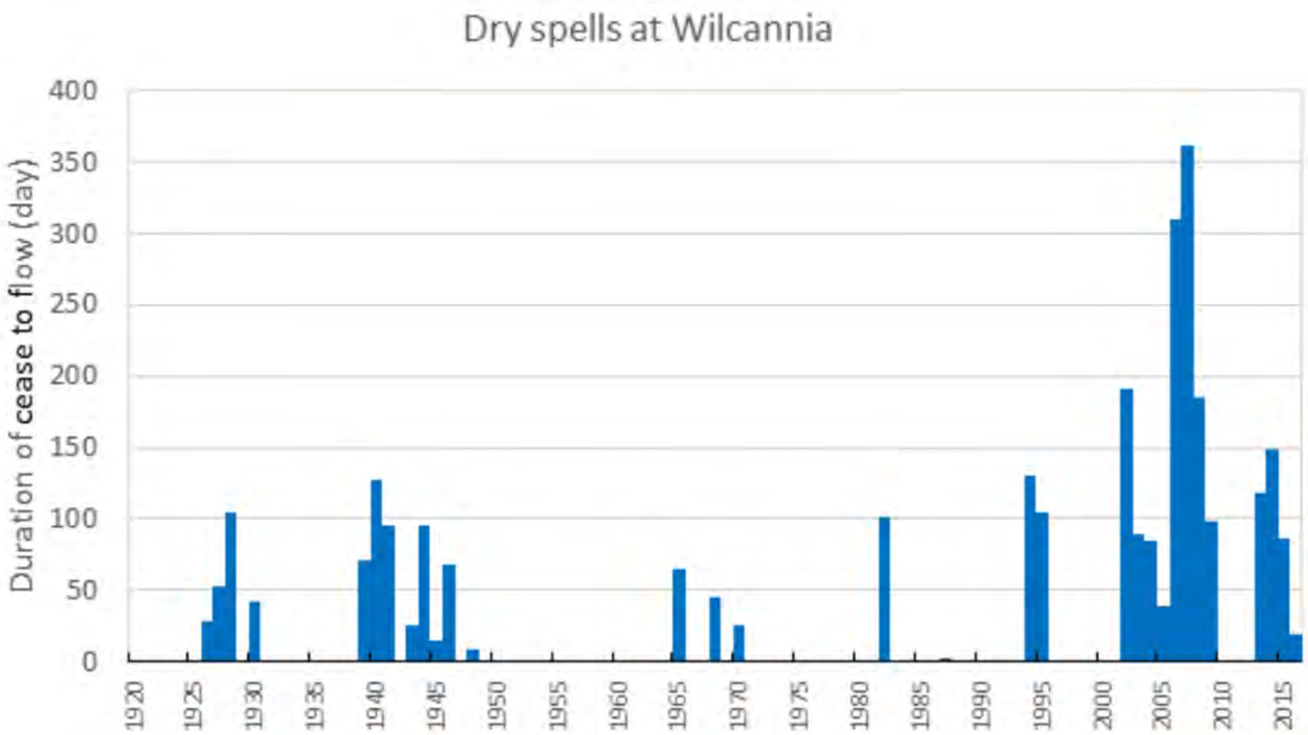


Figure 3-11 Dry spells at Wilcannia (cease-to-flow measured by days of flows less than 10 ML/day))

Source: MDBA (2021)

DPIE (2021) attributes the increasing frequency of cease-to-flow events in the Barwon-Darling (Baaka) system over the last 20 to 30 years to climate change, although it also acknowledges that water management rules and development may also be contributing factors and that it is difficult to be definitive about the role and impacts of climate change.

3.2.3 Geomorphology

The geomorphology of the Darling River (Baaka) at Wilcannia is described in a number of previous publications (Thoms et al. 1996; 2004). Thoms et al. (2004) refer to the reach of the Darling River (Baaka) at Wilcannia as forming part of a larger anabranching zone, the river flowing across a broad low angle fan complex or outwash surface with a series of effluent channels and anabranches, such as Twenty Seven Mile Creek and Talyawalka Creek. The main river channel is characteristic of a 'wash load' system with low bed slopes, high sinuosities, low bank-full stream power and highly cohesive bank materials (Thoms et al. 2004). Cross-sectional geometry does vary along the Darling River (Baaka), however, in general the river channel is 'canal' like in form. In-channel benches are present along this section as well as numerous lateritic outcrops which form large natural pools (Thoms et al. 1996).

A visual survey of selected sites along the Darling River (Baaka) at Wilcannia was carried out at 26 locations from downstream of the new weir to the upstream extent of the extended weir pool when the new weir is in drought security operation mode. Details of the visual survey including photographs are provided in **Appendix E**.

The survey identified signs of bank erosion at all of the sites inspected, as is expected in a meandering channel. Notching/undercutting of banks is more pronounced in the existing weir pool (albeit still relatively minor), compared to the riverbanks upstream and downstream of the weir pool. This is also to be expected in a weir pool with ponding of water against the channel banks. It is not apparent from a review of bathymetric data and site photographs that there is extensive sedimentation within the existing weir pool. Indeed it is noted that the existing weir pool contains a series of pools along its length (refer to **Figure 4-2**). Some sedimentation may occur within these pools, but it is also likely given the fine-grained nature of sediments comprising bed and banks that a large proportion of the sediments are transported as 'wash load' through the extent of the weir pool to the section of river downstream of the existing weir during high flows.

River Styles

The River Styles Framework is a spatial tool used to characterise geomorphology. The framework classifies rivers based on geomorphic qualities that include river type, fragility, sensitivity to disturbance, condition, rarity and recovery potential. River Styles data is available from the NSW River Styles database developed by DPE and Macquarie University. The database includes River Styles data for all third and higher order rivers in NSW.

The River Styles Framework can be used to describe individual rivers, assess their current geomorphic condition and forecast whether a river is degrading or recovering. It also can help in the identification of rare and threatened river forms across NSW.

The characterisation of the Darling River (Baaka) in the NSW River Styles database is based entirely on SPOT5 satellite imagery and does not include field validation. The characterisation of the Darling River (Baaka) at Wilcannia in the NSW River Styles database is summarised in **Table 3-3**. In summary, the Darling River (Baaka) at Wilcannia is characterised as:

- Having a laterally unconfined, continuous channel, meandering fine grained bed
- Being in a laterally unconfined valley setting, with the river channel surrounded by terrace or floodplain

- Having low fragility, which means that it is has little potential to be disturbed or experience change its geomorphic category, although some slight changes in bedform may occur (Outhet et. al., 2004).

Table 3-3 River Styles characterisation of the Darling River (Baaka) at Wilcannia

Attribute	Darling River (Baaka) at Wilcannia
River Style description	Meandering, fine-grained
River Style full name	Laterally unconfined, continuous channel, meandering, fine-grained bed
Confinement level	Laterally unconfined valley setting – continuous
Margin control	Terrace or floodplain
Planform descriptor	Meandering
Floodplain	Planform continuous
Full bed matrix descriptor	Fine-grained
Stream condition	Moderate
Recovery potential	Moderate recovery potential
Fragility	Low
Notes	Primary channel. Majority high sinuosity (i.e. having a high ability to curve and bend) with sections of low sinuosity occurring infrequently. Some lateral confinement / planform control.

Source: NSW River Styles database

An extract from the NSW River Styles database showing the Darling River (Baaka) at Wilcannia is provided in **Figure 3-12**. The figure shows the Darling River (Baaka) is given the 'laterally unconfined valley – continuous channel' River Style.

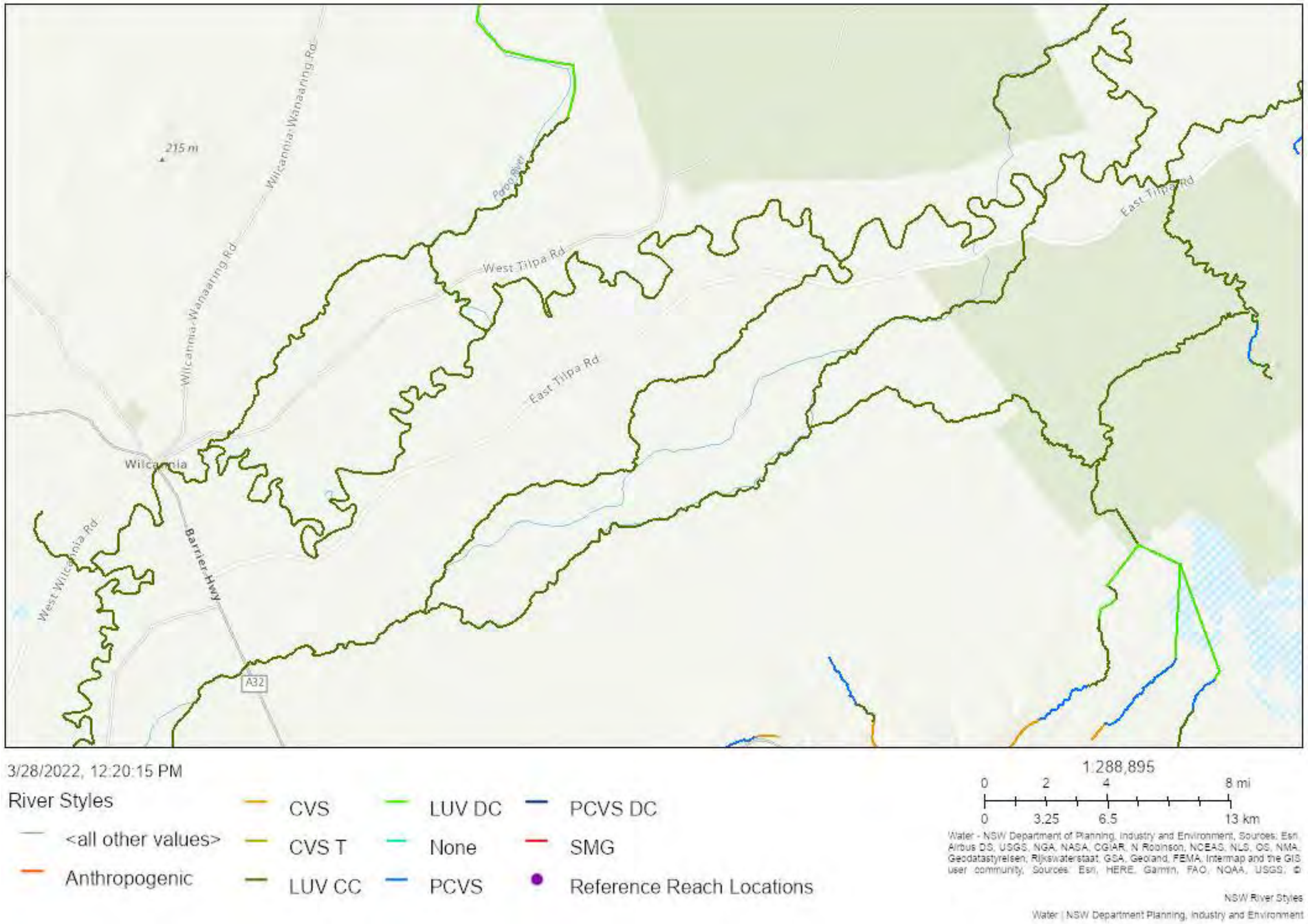


Figure 3-12 Extract from the NSW River Styles database showing the Darling River (Baaka) at Wilcannia

Source: NSW River Styles database

Notes: CVS – Confined valley setting, CVS T – Confined valley setting - terminating, LUV CC – Laterally unconfined valley setting – continuous channel; LV DC - Laterally unconfined valley setting – discontinuous channel; PVCS – Partly confined valley setting; PCVS DC – Partly confined valley setting – discontinuous channel; SMG – Chain of ponds.

3.2.4 Water users

The NSW Water Register maintained by WaterNSW was searched in March 2022 for water access licences in the Tilpa to Wilcannia Management Zone of the Barwon-Darling Unregulated River Source and identified 16 water access licences that are current in the 2021-2022 period, as detailed in **Table 3-4**.

Table 3-4 Water access licences in the Tilpa to Wilcannia Management Zone in the period 2021-2022

Water access licence no.	Category	Tenure type	Share components (units or ML)	Individual daily extraction component (daily flow share)
33608	A Class	Continuing	10.00	0.50
33662	A Class	Continuing	49.00	2.50
33682	A Class	Continuing	49.00	2.50
33705	B Class	Continuing	9.00	0.70
33707	A Class	Continuing	55.00	2.90
33737	A Class	Continuing	49.00	2.50
33738	A Class	Continuing	49.00	2.50
33752	A Class	Continuing	111.00	5.80
33765	A Class	Continuing	49.00	2.50
33766	A Class	Continuing	49.00	2.50
33780	B Class	Continuing	835.00	68.80
33783	A Class	Continuing	51.00	2.70
33802	B Class	Continuing	317.00	26.10
35195	Local water utility	Specific purpose	400.00	N/A
44021	B Class	Continuing	8.00	5.00
44022	B Class	Continuing	350.00	24.50

Source: NSW Water Register

There are two current water access licences in the Wilcannia to Upstream Lake Wetherell Management Zone of the Barwon-Darling Unregulated River Source that are current in the 2021-2022 period, as detailed in **Table 3-5**. One of these water access licences, water access licence number 33804, nominates an expired water supply works and water use approval (number 85CA752979). Also, this water access licence is associated with a property that would adjoin the new town pool i.e. the property includes a section of riverbank that is upstream of the new weir.

The location of the other water access licence in the Wilcannia to Upstream Lake Wetherell Management Zone is located just downstream of the new weir.

Table 3-5 Water access licences in the Wilcannia to Upstream Lake Wetherill Management Zone in the period 2021-2022

Water access licence no.	Category	Tenure type	Share components (units or ML)	Individual daily extraction component (daily flow share)
33643	B Class	Continuing	377.00	31.10
33804	B Class	Continuing	695.00	57.30

Source: NSW Water Register

3.3 Water quality

3.3.1 General

The Barwon-Darling is largely an unprotected catchment. This means that unlike most metropolitan water storages which are surrounded by 'Special Areas' typically containing undisturbed bushland to protect drinking water quality, water entering the Wilcannia weir pool can be subject to several water quality risks.

As noted in **Section 2.3.6**, the *Water Quality Management Plan for the Barwon Darling Watercourse Water Resource Plan* (DPIE, 2019b) identifies relevant surface water quality objectives for the Barwon-Darling watercourse and the water quality targets required to achieve these objectives. The plan uses the NSW water quality index (WaQI) to communicate water quality data in a simple and consistent way. The WaQI is a single score between one and 100 based on water quality data from 2010 to 2015 collected by the NSW State water quality assessment and monitoring program against appropriate water quality targets. Scores are presented in four categories: poor (one to 59), fair (60 to 79), good (80 to 94) and excellent (95 to 100). WaQI scores for the Barwon-Darling water resource plan area are presented in the plan and range from good to poor. The scores decline along the Darling River (Baaka): the WaQI at Mungindi is 90 and it then progressively declines to scores of 33 at Bourke and Louth and decreases further to a score of 26 at Wilcannia.

In general, surface water quality degradation within the Barwon-Darling catchment is the result of a combination of factors including alteration of the river system's natural flow regime, changes to catchment conditions and land-use activities. Surface water quality issues caused by changes to the natural flow regime of the river system are attributable to both high and low flows:

- *High flow* — High flow from rainfall and runoff results in increased sediment loads, which cause higher turbidity levels and higher concentrations of nutrients, pathogens and possibly also pesticides. The Darling River (Baaka) at Wilcannia, generally recorded the highest turbidity, cumulative increase in sediment distance downstream (DPIE, 2019).
- *Low flow* — Low flow occurs not only due to the climatic conditions and low annual rainfall, but also as a 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. This poor quality water can cause downstream impacts when upstream flows recommence and flush standing water downstream.

The *Water Quality Management Plan for the Barwon Darling Watercourse Water Resource Plan* (DPIE 2019b) identifies the likely causes of water quality degradation in the Barwon-Darling catchment and provides commentary on their relevance at key locations along the river system including at Wilcannia. The plan identifies the following as water quality issues for the Darling River (Baaka) at Wilcannia:

- *Salinity* — Land management practices, water flow or water management practices and reduction in stream flow are all causes of elevated salinity levels. The plan notes that at Wilcannia, the landscape is naturally saline. The Darling River (Baaka) at Wilcannia tends to pool and evaporative concentration induces higher salinity in pools. During first flush events the stream salinity increases markedly.

- *Turbidity* — Across the catchment the conversion of land to cropping and irrigation and the degradation of the banks of waterways as a result of grazing practices, feral pigs and stock trampling result in sediment entering waterways. The alluvial soils found on the floodplain have a high clay content which mean sediment is likely to remain suspended in the water column during both high and low flows, causing high levels of turbidity. The invasive noxious fish Carp (*Cyprinus carpio*) is present throughout most of the Barwon-Darling river system and it may exacerbate turbidity by its bioturbation of benthic sedimentation during feeding.
- *Electrical conductivity* — Electrical conductivity is generally lower at Wilcannia Weir than upstream areas of the Darling River (Baaka), however, increased conductivity can occur following first flush events, particularly if there are isolated pools where high levels of evaporation have caused concentration of salt.
- *Nutrients* — The highest concentrations of total nitrogen and total phosphorus in the Darling River (Baaka) are recorded at Wilcannia Weir (DPIE, 2019). Given soils in the area contain low nutrient concentrations, keys sources are likely to be organic matter, animal waste, fertilisers and wastewater and industrial discharge. Concentrations at Wilcannia Weir are higher than upstream areas due to the cumulative impacts of increased nutrients upstream reaching this area.
- *Algal blooms* — Algal blooms are known to occur at times in the Darling River (Baaka), generally occurring when there is little flow, stratification in the water body, sufficient sunlight and nutrient availability.
- *Dissolved oxygen* — Periods of low (and high) dissolved oxygen occur at Wilcannia Weir particularly when flow is low. There are two main causes of oxygen depletion, being: consumption of organic matter by micro-organisms which depletes oxygen faster that it can be replenished; and excessive plant growth due to eutrophication causing both high and low oxygen concentrations outside acceptable ranges. Water with low or zero dissolved oxygen often sits on the bottom of stagnant pools. The flushing of these pools can cause fish kills downstream.
- *pH* — pH concentrations are highest at Wilcannia Weir when compared to upstream in the Darling River (Baaka). High pH is attributed to eutrophic conditions caused by excessive plant growth.

Stormwater management at Wilcannia

Stormwater runoff in Wilcannia township flows to the Darling River (Baaka) by way of four gross pollutant traps located on the right riverbank at Byrnes Street, the Barrier Highway, Cleaton Street and Martin Street. Central Darling Shire Council is responsible for the maintenance of these gross pollutant traps.

Sewage overflow risks at Wilcannia

The existing Wilcannia township sewerage scheme is mostly a pumped common effluent drainage system comprising a septic tank arrangement on each property with a pump and pipework connecting the effluent tank/chamber to the low pressure sewerage reticulation network, which discharges to standard wet well submersible sewage pumping stations. There are several disadvantages associated with this system including the need for residential management of what is essentially an on-site sewage management system with the knowledge and resources to fulfil this task, surcharge of sewage from septic tanks, the cost of effluent pump replacement, and the shallow depth of installation of the low-pressure sewage reticulation network results in frequent damage from heavy vehicles such as garbage trucks.

In contrast to the common effluent drainage system in the township, septic tank infrastructure at the Mallee and Warrali Aboriginal estates was replaced with full gravity sewerage reticulation networks and sewage pumping stations in 2014-15 with funding from the NSW Government's Aboriginal Communities Water and Sewerage Program and the Australian Government's Remote Communities Program. The Mallee Aboriginal Estate comprises 28 residences on a single lot in the north-west of the township, and the Warrali Aboriginal Estate comprises 10 residences east of the Darling River (Baaka).

Central Darling Shire Council propose an upgrade to the Wilcannia township sewerage scheme and the potential cumulative impacts of this upgrade and the proposal are discussed in **Section 8.4.3**.

3.3.2 Existing water quality

This section presents the existing surface water quality of the Darling River (Baaka) within the proposal area based on monitoring undertaken by WaterNSW between June 1981 and November 2020 and from a site visit undertaken on 21 November 2020 (refer to **Section 8.1.2**). Data from the past five years has been used in the assessment to provide sufficient data to establish the range across which water quality is likely to currently vary. WaterNSW monitoring was undertaken at the existing weir (N1042), with the exception of November 2020 when a sample was also collected at the proposed new weir (N1333) (refer to **Table 3-8**).

Existing water quality monitoring

WaterNSW currently operates two water quality monitoring stations in the Darling River (Baaka) in the Wilcannia region:

- Gauging station no. 425008 (Wilcannia Main Channel) — This is WaterNSW's primary water quality monitoring site at Wilcannia. It currently provides continuous measurement of water flows, water levels, electrical conductivity and water temperature. Once the new weir commences operation, this gauging station would be within the new town pool and, therefore, would no longer be used to measure flows. It would continue to measure water level, electrical conductivity and water temperature. Water sampling are collected at the gauging station monthly and analysed at a laboratory for a comprehensive range of parameters including several algal and cyanobacteria parameters, faecal coliforms, alkalinity, conductivity, dissolved oxygen, pH, suspended solids, temperature, total hardness, turbidity, and other analytes. More frequent water sampling occurs on request, typically when there are concerns about algal levels
- Gauging station no. 425058 (Moorabin) — This gauging station was commissioned by WaterNSW in February 2020 to become its new Wilcannia water quality monitoring site once the new weir starts operation. The gauging station is located downstream of the new weir. It is proposed that water quality monitoring at this site will be for the full range of parameters monitored by WaterNSW elsewhere on the Darling River (Baaka), although it is currently only being used to measure logged parameters i.e. continuous measurement of water flow, water level, electrical conductivity, dissolved oxygen and water temperature.

Darling River (Baaka) at Wilcannia Weir

The *Water Quality Management Plan for the Barwon Darling Watercourse Water Resource Plan* (DPIE, 2019b) contains water quality targets for water dependent ecosystems that reflect those contained in the Basin Plan. There are different water quality target values for the various zones of the river system covered by the plan. The relevant target values for the proposal are those for the Darling valley lower and middle zones. Electrical conductivity targets are not identified for each water quality zone. Instead, 'end of valley' targets are used. For the proposal, the relevant electrical conductivity target value is that for the Barwon-Darling valley.

The water quality target values for water dependent ecosystems that are relevant to the proposal are provided in **Table 3-6**. The *Water Quality Management Plan for the Barwon Darling Watercourse Resource Plan* (DPIE, 2019b) specifies that the water quality target values should be applied as follows:

- *Electrical conductivity, total nitrogen, total phosphorus and turbidity* — the annual median should be below the target value
- *Dissolved oxygen and pH* — the annual median should fall within the stated range.

Selected water quality data collected in the Darling River (Baaka) at Wilcannia is provided in **Table 3-6** to indicate performance against the water quality target values for water dependent ecosystems contained in the *Water Quality Management Plan for the Barwon Darling Watercourse Water Resource Plan* (DPIE, 2019b).

Median data from the past five years is presented in the table together with the percentage of the samples taken during this period that comply with the water quality target values. It should be noted that this is a conservative simplification of how the plan measures compliance with the water quality target values, which is based on annual medians as noted above.

The *Water Quality Management Plan for the Barwon Darling Watercourse Water Resource Plan* (DPIE, 2019b) also contains water quality targets for recreational water based on the *Guidelines for Managing Risks in Recreational Water* (National Health and Medical Research Council, 2008). Cyanobacteria and algal targets are contained in the plan and are applicable to all the water quality zones covered by the plan. **Table 3-6** contains median cyanobacteria and algal data collected at Wilcannia over the last five years and shows the percentage of the samples taken during this period that comply with the recreational water target values.

Table 3-6 Existing water quality and compliance with WQO; Darling River (Baaka) at Wilcannia Weir

Indicator	Median (count)	% compliance	WQ target
Water dependent ecosystems			
Electrical conductivity (microSiemens per centimetre)	973 (29)	N/A	389 (median)
Total nitrogen (milligrams per litre)	1.25 (30)	13%	0.5
Total phosphorus (milligrams per litre)	0.1 (29)	17%	0.05
Turbidity (NTU)	39.2 (35)	69%	50
Dissolved oxygen (saturation, %)	94.2% (30)	53%	85-110%
pH	8.59 (35)	20%	6.5-8.0
Recreational water			
Cyanobacterial biovolume (cubic millimetres per litre)	0.4 (59)	80%	<10
Toxic cyanobacterial biovolume (cubic millimetres per litre)	0.035 (59)	76%	<4
Potentially toxic cyanobacteria (cells per millilitre)	402 (49)	78%	<50,000

Source: WaterNSW

The Darling River (Baaka) at Wilcannia Weir generally has poor water quality with respect to the protection of aquatic ecosystems, due to the nominated targets frequently being exceeded. Median conductivity target of 389 microsiemens per centimetre (µS/cm) was not met at the existing weir, with median concentrations over the past five years more than double this. Nutrient concentrations are also elevated at the weir and rarely complied with the target concentrations. Turbidity concentrations and dissolved oxygen saturations met the respective targets for more than 50 per cent of the time over the past five years. Dissolved oxygen non-compliance was a result of both saturations that were too high and too low. The low saturations were generally observed in the warmer months then the water temperature is higher and streamflow is typically lower. High dissolved oxygen saturations were observed both in winter and summer. During cooler weather, the cold water can hold more dissolved oxygen resulting in higher saturations. During warmer weather, the higher saturations are likely the result of photosynthesis from increased algal activity. pH levels were often too high to meet the nominated target upper limit of 8.5 for protection of aquatic ecosystems. The lower limit of 6.5 was always achieved.

The Basin targets for the recreational water quality objective is that potentially toxic cyanobacteria counts and biovolume should be less than 50,000 cells/mL and <4mm^3/L respectively. Additionally, total cyanobacterial biovolume should be less than 10mm^3/L. Despite increasing trends in total nitrogen and total phosphorus, algal data collected in the weir pool over the past five years does not impact on recreational suitability. Whilst there are occasions of high algal numbers, the proportion of toxic cyanobacteria is small and mostly compliant with the *Guidelines for Managing Risks in Recreational Water* (National Health and Medical Research Council, 2008). This indicates that other factors such as flow, turbidity and light are restricting algal growth.

Current monitoring and knowledge of the presence of pathogen issues such as bacteria and microorganisms in the Barwon Darling catchment is limited (DPIE, 2020c). It is expected that with ongoing inputs of human and animal waste and access of stock and animals to rivers and streams that pathogens would be present in waterways. Higher numbers of pathogens would be expected following rainfall and runoff flushing contaminants into the rivers. During dry weather/low flows, high counts may be present in areas of point source pollution (DPIE, 2020c). A single sample was collected at the existing weir site (N1042) and the new weir site (N1333) in November 2020 by WaterNSW and analysed for faecal coliforms. Faecal coliform numbers were higher at the existing weir site (700 cfu/100mL) compared to about two cfu/100mL at the new weir site. At the time of sampling, no rainfall had fallen in the previous seven days.

The quality of raw drinking water should meet the ADWG targets which provide both health and aesthetic guideline limits when treated. Raw water quality data collected by City Water Technology between July 2015 and May 2019 from the current draw off location the on right bank of the river about 80 metres upstream of the existing weir has been compared to the AWDG (2011) to identify if there are any key indicators that could be problematic for treatment of raw water (City Water Technology, 2020). Results are provided in **Table 3-7**.

Median raw drinking water was generally below the ADWG limits with the exception of turbidity, colour and total manganese. High turbidity can be problematic with respect to suitability for drinking water as levels could impact on the efficiency of the disinfection process, particularly with removal of pathogens and can affect the aesthetics of the treated water. Colour, which is generally related to organic content if too high at the point of disinfection can result in higher concentrations of disinfection by-products. Manganese concentrations were below the recommended ADWG Health limit, median concentrations of 0.29 milligrams per litre exceeded the aesthetic guideline limit. Manganese at these concentrations can cause an undesirable taste to water and can stain plumbing fixtures and laundry.

Table 3-7 Summary statistics of surface water quality data (City Water Technology, 2020)

Indicator	Median (count)	ADWG limit	
		Health	Aesthetic
Temperature (°C)	22.4 (44)	-	-
pH	7.6 (51)		6.5-8
Total alkalinity (mg/L)	89 (24)	<200	
Turbidity (NTU)	82.8 (50)	<1	<5
Colour (HU)	101 (17)		<15
Total Iron (mg/L)	0.25 (41)		<0.3
Total manganese (mg/L)	0.29 (26)	<0.5	<0.1
Electrical conductivity (µS/cm)	513 (48)	-	-

Darling River (Baaka) at the new weir site

Water quality at the new weir site from the single sampling event generally met the Basin water quality targets for protection of aquatic ecosystems for nutrients, dissolved oxygen and turbidity. Both pH and electrical conductivity were recorded in concentrations higher than the recommended targets. Recreational water quality targets were met on this sampling event with toxic cyanobacterial biovolume not detected. Data from this single monitoring event is presented in **Table 3-8**.

Table 3-8 Water quality at the new weir site on 10 November 2020

Indicator	Result	WQ target
Water dependent ecosystems		
Electrical conductivity (microSiemens per centimetre)	1073	389 (median)
Total nitrogen (milligrams per litre)	0.5	0.5
Total phosphorus (milligrams per litre)	0.03	0.05
Turbidity (NTU)	24.3	50
Dissolved oxygen (saturation, %)	94.9	85-110%
pH	8.21	6.5-8.0
Recreational water		
Cyanobacterial biovolume (cubic millimetres per litre)	0.026	<10
Toxic cyanobacterial biovolume (cubic millimetres per litre)	0	<4
Potentially toxic cyanobacteria (cells per millilitre)	0	<50,000

Darling River (Baaka) (from the proposed new weir to the proposed weir pool extent)

Water quality results from the sampling event on 21 November 2020 indicates that at the time of sampling, water quality of the Darling River between the new weir site (SW1) and the new weir pool extent (SW4) was variable and many indicators did not meet the nominated targets for protection of aquatic ecosystems as shown in bold text in **Table 3-9**. Electrical conductivity was elevated above the water quality target at all sites, however concentrations were notably lower at the upstream sites (SW7, SW6, SW3 and SW4). The higher conductivity downstream may be attributable to saline groundwater intrusion and the notably lower flow. Nutrients (total nitrogen and total phosphorus) were recorded in high concentrations at different locations throughout the river, with only one site, SW5 had both TN and TP below the nominated WQ targets. Turbidity levels were generally below the limit of 50NTU with the exception of the Darling River between the new and existing weir (SW8) and Darling River upstream (SW7). Both pH and dissolved oxygen exceeded the upper and lower target limit respectively in various parts to the river. Metal concentrations were generally below the limit of detection, however both aluminium and copper were recorded above the ANZG (2018) 95% species protection limit at the upstream sites. There were no detections of organochlorine pesticides, organophosphorus pesticides or phenoxyacetic acid herbicides in the Darling River.

At the time of sampling, potentially toxic cyanobacteria were below 5 cells/100mL and met the water quality target for recreational suitability.

Table 3-9 Existing water quality Darling River (Baaka); from proposed new weir to proposed new weir pool extent

Indicator	**Sites (downstream – upstream)**								**WQ target**
	SW1	**SW8**	**SW2**	**SW5**	**SW7**	**SW6**	**SW3**	**SW4**	
Aquatic ecosystems									
Conductivity (µS/cm)	**1123**	**1155**	**1138**	**1199**	**699**	**643**	**592**	**608**	389
Total nitrogen (mg/L)	**0.6**	0.5	0.4	0.4	**0.6**	0.5	**0.7**	**0.6**	0.5
Total phosphorus (mg/L)	**0.08**	**0.08**	**0.07**	0.03	0.05	**0.07**	**0.08**	0.04	0.05
Turbidity (NTU)	37.5	**69.2**	17.9	22.6	**56.9**	24.1	46.97	26.7	<50
Dissolved oxygen (% saturation)	**79.5**	**81.83**	86.87	**77**	100.53	**74.5**	**53.97**	**45.1**	85-110%
pH	7.69	**8.01**	6.98	**8.17**	7.73	**8.11**	7.69	**8.13**	6.5-8
Aluminium (mg/L)	<0.01	0.01	<0.01	0.02	0.04	**0.1**	**0.08**	**0.09**	0.055
Arsenic (mg/L)	0.001	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.013
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Copper (mg/L)	0.001	0.001	0.001	0.001	**0.002**	**0.002**	**0.002**	**0.002**	0.0014
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0034
Nickel (mg/L)	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.011
Zinc (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008
Iron (mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.05	0.06	0.3
Mercury (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00006
Recreation									
Potentially toxic cyanobacteria (cells/mL)	<5	<5	<5	<5	<5	<5	<5	<5	<50,000

3.4 Geology

The Wilcannia 1:250,00 Geological Sheet (refer to **Figure 3-13**) indicates that the new weir site is within Quaternary alluvial sediments comprising outwash areas, and drainage flats of black and red clayey silt and sand (Frienda et al.,1965). The Darling River channel is incised into the Quaternary Sediments to a depth of 10 to 11 metres below the banks (C.M. Jewell & Associates, 2021).

Underlaying alluvial plains both upstream and downstream of Wilcannia are sequences of interbedded channel and overbank deposits laid down by the meandering Darling River. Underneath the Quaternary sediments are sandstone and quartzites of Devonian- age Mulga Downs Group (C.M. Jewell & Associates, 2021).

Information on the geology and hydrogeology of the site has been developed from a range of published sources but particularly the Groundwater Risk Assessment undertaken by C.M. Jewell & Associates during the Wilcannia Weir upgrade design work (C.M. Jewell & Associates, 2021). The primary evidence as to groundwater occurrence near the new weir site are five deep bores (GW040891, GW040892, GW040893, GW040897, GW804531) associated with the emergency water supply bores for the town. These bores typically intersected a thick clay horizon that extends from between about 20 and 30 metres below ground level to about 45 metres below ground level near the new weir site (refer to **Figure 3-13**). Interbedded sands and clays extend from 45 metres to the borehole terminations at about 67 metres below ground level. The geology logs for these five boreholes are provided in Appendix A of **Appendix D**.

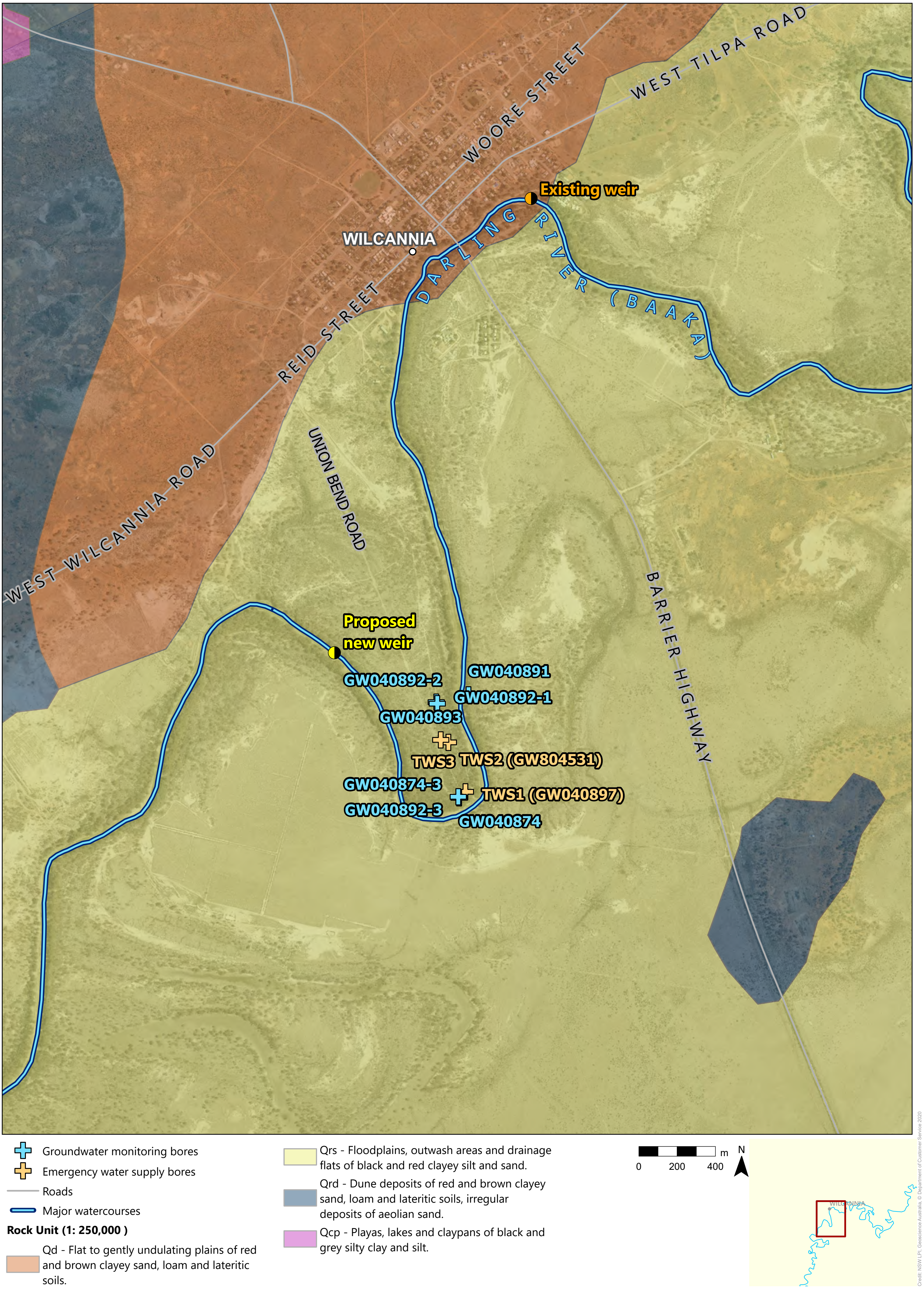


Figure 3-13 Geology of Wilcannia

3.5 Aquifers

The Upper Darling alluvium including the proposal area can be conceptualised as comprising of a shallow and deep aquifer system. The shallow system sediments correspond to the Narrabri formation while the deeper qualifier system corresponds to the Gunnedah and Cubbaroo formations (DPIE, 2019).

The shallow aquifer system occurs to a depth of 25 metres below ground level, the deeper system occurs to depths of 120 metres below ground level, with a pre-Cenozoic paleochannel that runs approximately parallel with the Darling River (Baaka) (DPIE, 2019).

The upper alluvium aquifer is hydraulically connected to the Darling River (Baaka). Subject to topography and geology, the aquifer water levels fluctuate in response to changes in the level of the river. The aquifer system is recharged by the river when there are high river flows and discharges into the river during times of drought. The range of fluctuation decreases with distance from the river and with depth i.e. the fluctuation range is smaller in the deep aquifer. Freshwater sandy lenses and groundwater mounding is evident near the river.

C.M. Jewell & Associates (2021) categorised the top of the Devonian sediments as hydrogeological basement with only the quaternary alluvium of interest to the proposal. Accordingly, the basement sediments have not been considered in this assessment. As described in **Section 3.4**, the quaternary alluvium sediments comprise interbedded clays, silts and sands. The alluvium sands are the target aquifer for extraction bores in the area. Bores GW040891, GW040892, GW040893, GW040897, GW804531 and GW040872 indicate a varied thickness of clay between 30 to 45 metres and have a leaky system behaviour between the upper and lower aquifers. The shallow system is likely to be unconfined to semi-confined depending on the thicknesses and permeability of the overlaying sand and silt aquitard.

In summary:

- There are two aquifers near the river that may be affected by the new weir pool
- The upper aquifer is clearly connected with the river and is likely to respond directly to changes in river level associated with the new weir (this is further described in **Section 7.4.1**)
- The deeper aquifer responds to regional conditions and whilst it has a muted connection to the river may also respond to the weir pool changes.

3.6 Groundwater

3.6.1 Groundwater levels

Groundwater level spot measurements are available for monitoring bores GW040874 and GW040892 located near the town borefield and are provided in **Figure 3-14**. As shown in two bores screened within the shallow alluvium sediments (14 – 17 and 17 – 23 metres below ground level respectively), the water table typically fluctuates between 7 and 10 metres below ground level. This is at a similar level to the Darling River (Baaka) incised riverbed being approximately 10 metres below the typical floodplain surface elevation. However, as indicated in Figure 3-5, the remnant river meanders are at elevations ranging between 65 and 70 metres AHD and below the typical floodplain elevation. The monitoring bores are generally installed in areas of elevated topography including the town’s water supply bores, which are installed at an elevation of 76 metres AHD to allow for flooding. Therefore, in areas of indicated low topography ranging between 65 and 70 metres AHD in the old meander loops near the Darling River (Baaka) (refer to **Figure 3-5**), the groundwater level is likely to be shallower and nearer to two to five metres below ground level instead of seven to 10 metres below ground level.

Regional groundwater levels appear to be similar, based on nearby bore readings, groundwater flow direction is interpreted to be generally north to south, along the river valley.

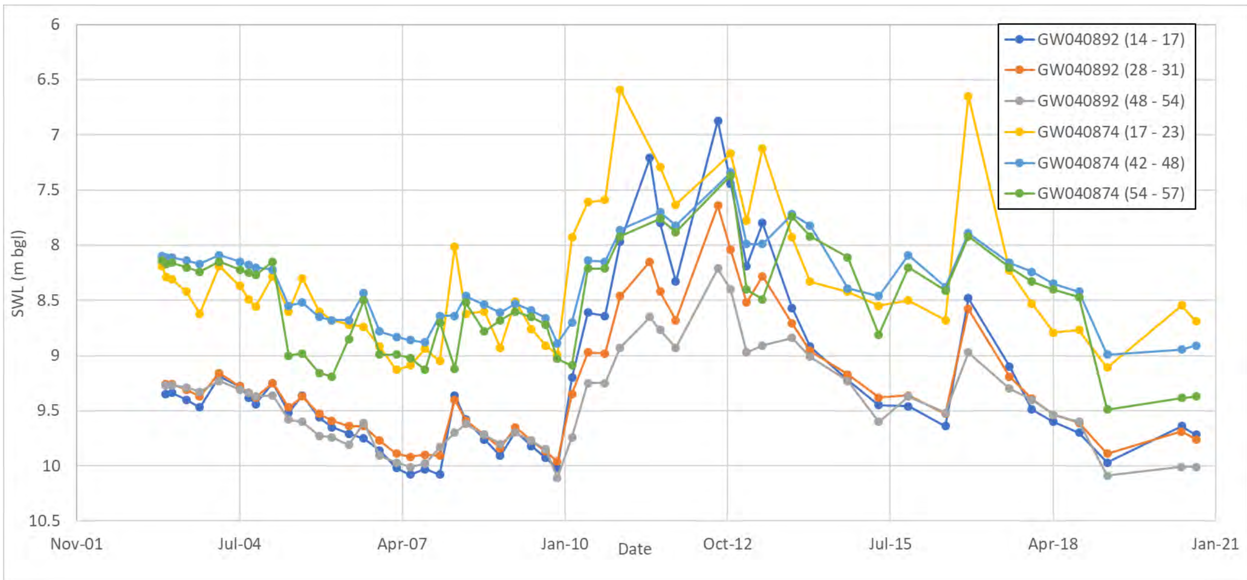


Figure 3-14 Long-term groundwater level data

C.M. Jewell & Associates (2021) undertook a detailed analysis of the groundwater levels in relation to the Darling River (Baaka) stage height. They showed that there was a good correlation between the river stage height and the water table in the upper aquifer. In four flood events between 2004 and 2017, there was an almost instantaneous response to water table rise indicating groundwater recharge to the shallow alluvium aquifer via the Darling River (Baaka). These finding are the same as those documented in the 2019 Darling Alluvium Water Resource Plan hydrogeological model completed by DPIE (2019c).

C.M. Jewell & Associates (2021) classified the proposal specific system as a connected, losing, stream that gains under low-flow conditions (baseflow).

3.6.2 Groundwater quality

Groundwater electrical conductivity in the alluvium aquifers is variable and ranges from fresh values of 300 microsiemens per centimetre to saline values of 52,000 microsiemens per centimetre (DPIE, 2019).

As discussed in **Section 3.5**, fresh groundwater in the upper alluvium is due to rapid recharge mainly via the channel floor and sides of the Darling River (Baaka) during high river flows and the floodplain during flood events. Saline groundwater in the alluvium is due to evapo-concentration of shallow groundwater during long dry periods and sediment mineral weathering (DPIE, 2019).

3.6.3 Groundwater users

Wilcannia has two operational town water supply bores (GW040897 and GW804531) and one new unequipped town bore. The bores are used to augment the town's water supply during periods of drought. The bores are located in the south meander of Wilcannia at Union Bend (refer to **Figure 3-15**), once the new weir is completed, the weir pool would extend past the bores. GW040897 is screened in fine sand from 49 to 55 metres in depth while GW804531 is screened in sand between 48 and 53 metres. As described in **Section 3.5**, a thick clay horizon exists between 20 to 30 metres in depth and extends to 45 metres above where the two town water supply bores are screened.

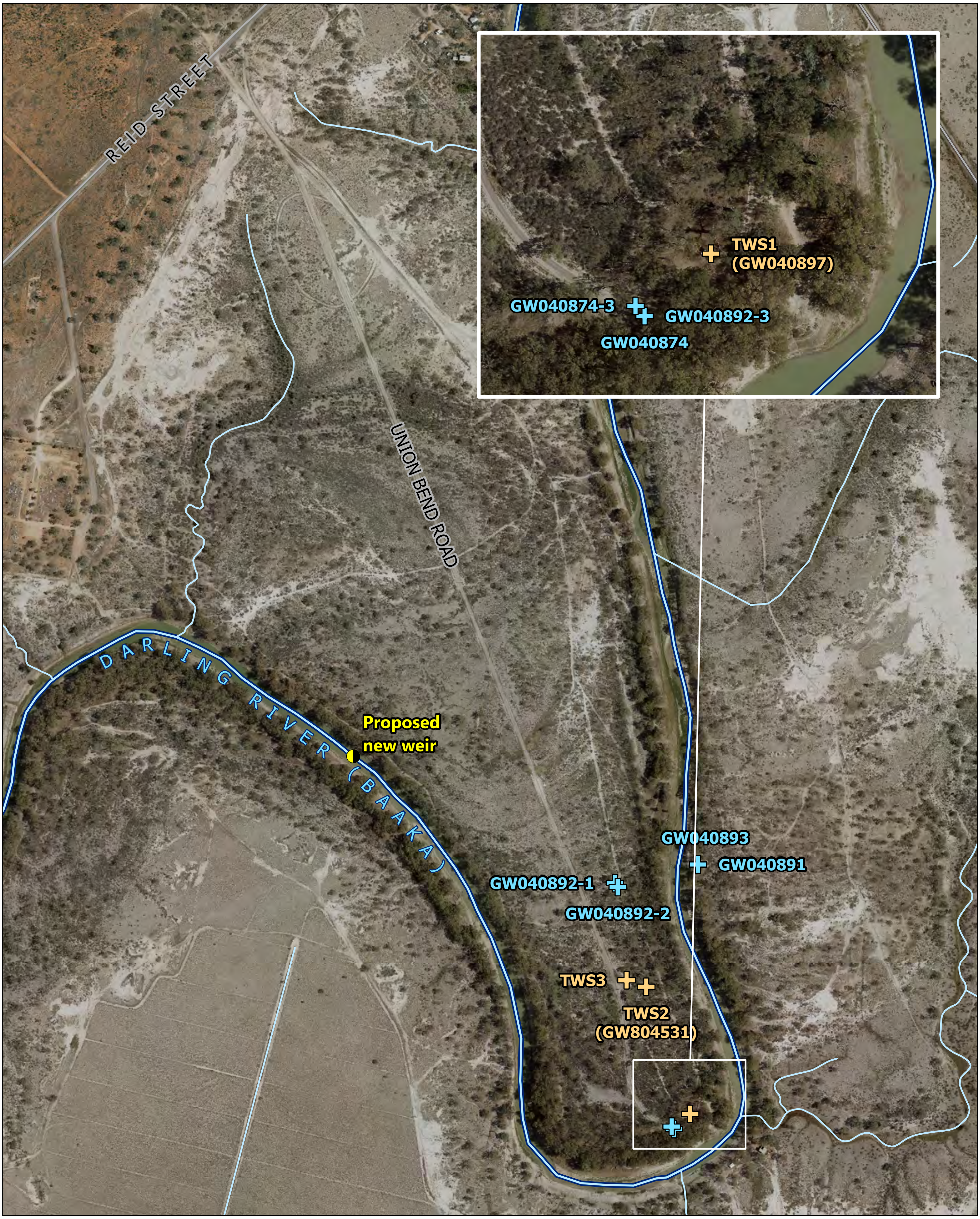
Measured groundwater levels in the town water supply monitoring bores are provided in **Table 3-10**. These measurements were made on 6 February 2020 at the end of a long dry period with low river level and no flow.

Table 3-10 Town borefield standing water levels, 6 February 2020

Bore	**Standing water level** (metres below ground level)	**Surface elevation** (metres AHD)	**Relative water level** (metres AHD)
GW040891	10.21	76.73	66.52
GW040893	10.52	76.92	66.30

Source: CJMA (2020)

A search of the All Groundwater Map on the WaterNSW Water Information Hub on 25 March 2021 identified three groundwater bores in the vicinity of the Darling River (Baaka) at Wilcannia, located within Wilcannia township (GW019002), near Warrawong on the Darling (GW039479), and at a homestead upstream of the confluence of the Darling River (Baaka) and Kallyanka Creek (GWB03951).



Proposed new weir
Groundwater monitoring bores
Emergency water supply bores
Roads
Watercourses
Major watercourses

0 200 400 m

Figure 3-15 Wilcannia emergency water supply bores and monitoring bores

3.6.4 Groundwater dependent ecosystems

Groundwater plays an important role in sustaining aquatic and terrestrial ecosystems including springs, wetlands and rivers. For example, groundwater can contribute to river baseflow during low rainfall periods. Groundwater dependent ecosystems can vary in nature, ranging from partially or infrequently reliant on groundwater to continually and wholly dependent (Bureau of Meteorology, 20220).

There are three types of groundwater dependent ecosystems generally recognised and these are as listed on the Groundwater Dependent Ecosystems Atlas:

- *Aquatic ecosystems* — Aquatic ecosystems are groundwater dependent ecosystems where they rely on the surface discharge of groundwater. They include surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs
- *Terrestrial ecosystems* — Terrestrial ecosystems are groundwater dependent ecosystems if they rely on the subsurface presence of groundwater. They can include forests and riparian vegetation
- *Subterranean ecosystems* — Subterranean ecosystems that are groundwater dependent ecosystems can include caves and aquifer ecosystems.

Potential aquatic and terrestrial groundwater dependent ecosystems have been identified on the Groundwater Dependent Ecosystems Atlas near the proposal:

- Aquatic groundwater dependent ecosystems: The Darling River (Baaka) and the encompassing floodplains have been identified as having a high potential for groundwater dependence (refer to **Figure 3-16**)
- Terrestrial groundwater dependent ecosystems: Floodplain plant community types surrounding the Darling River (Baaka) have been identified as having known and high potential for groundwater dependence based on regional studies, including downstream of the new weir as shown in **Figure 3-17**. The Groundwater Dependent Ecosystems Atlas identifies most of the proposal area and surrounding floodplain as containing moderate to high potential groundwater dependent terrestrial vegetation.

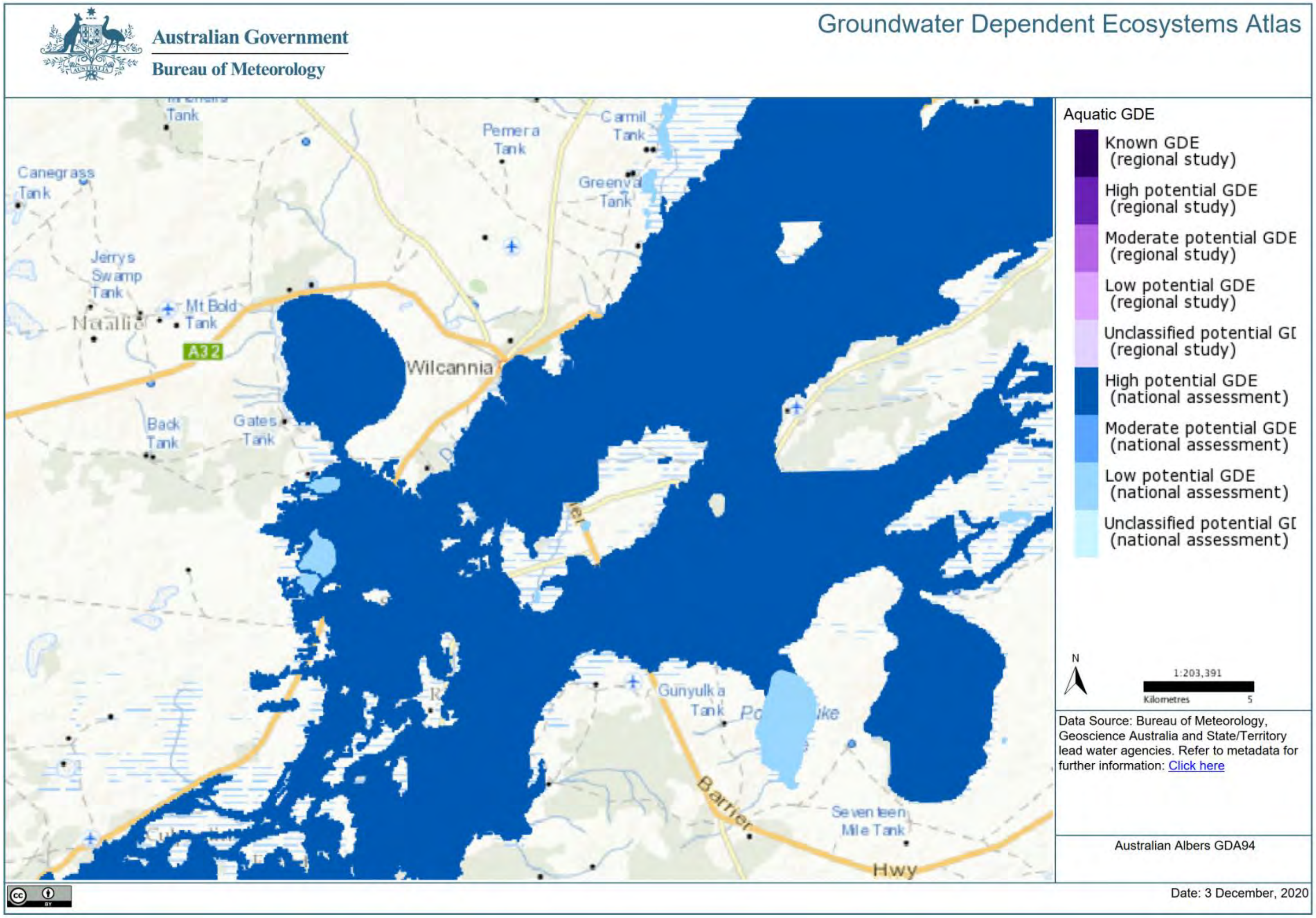


Figure 3-16 Aquatic groundwater dependent ecosystems

Source: Bureau of Meteorology

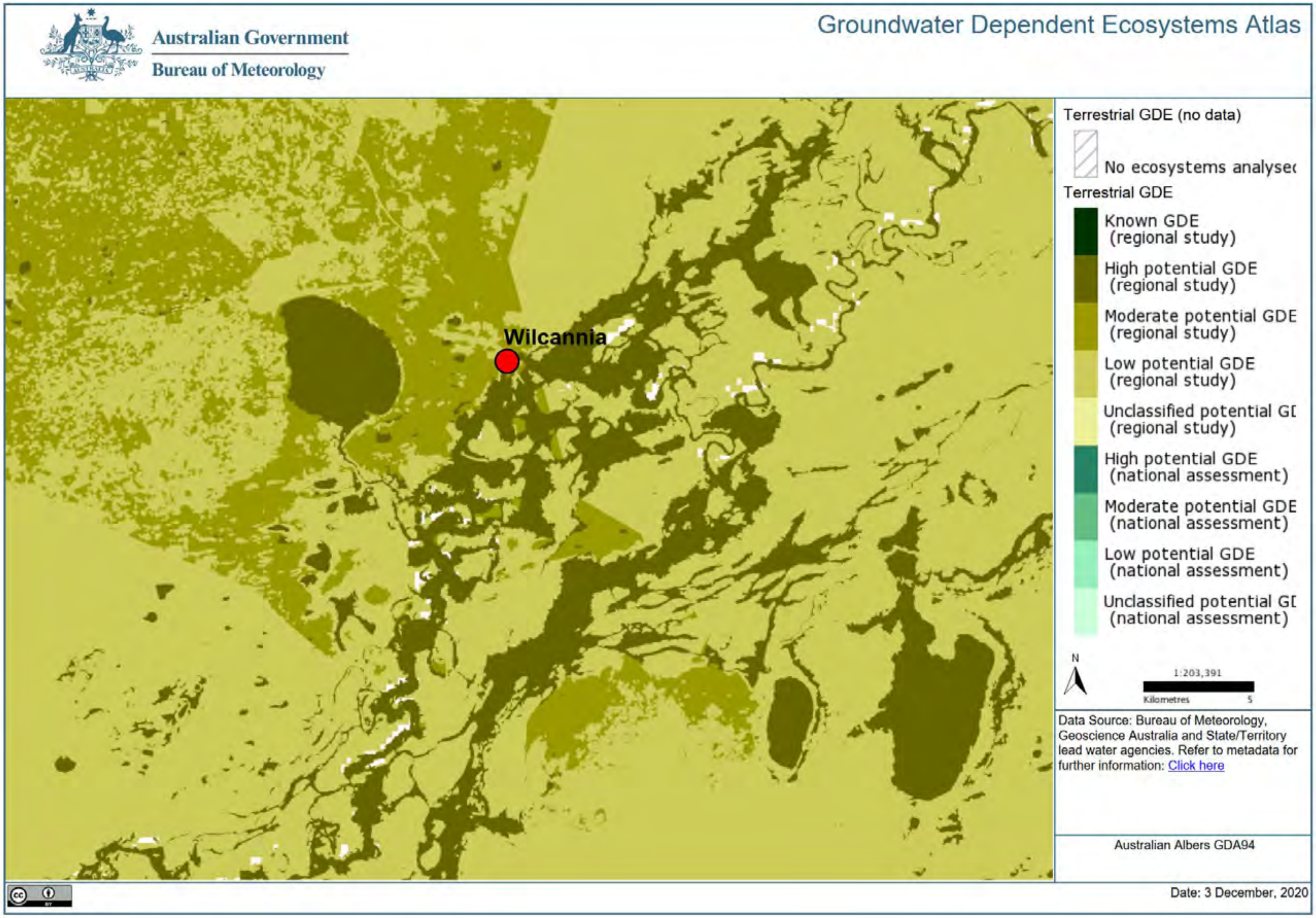


Figure 3-17 Terrestrial groundwater dependent ecosystems

Source: Bureau of Meteorology

4. Proposal description

This section provides a detailed description of the basis for sizing of the new weir and the rules that are proposed to govern the operation of the new weir.

4.1 Sizing of the new weir

4.1.1 Future demand for town water

Annual unrestricted dry year water demand at Wilcannia in 2020 was estimated at 322 megalitres by Public Works Advisory (2021a). This estimate is based on production estimates and data for the period December 2019 to April 2020. The estimate includes 132 megalitres of potable water production at the water treatment plant, losses of about seven megalitres at the water treatment plant, and 183 megalitres of raw water supply.

Public Works Advisory (2021a) has forecast that unrestricted dry year extraction at Wilcannia would increase to 362 megalitres per annum in 2050. The forecast is based on the population of Wilcannia increasing by three percent 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 around 20 per cent.

4.1.2 Secure yield analysis

Water Infrastructure NSW engaged NSW Urban Water Services through Public Works Advisory 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. The secure yield analysis was based on a one-metre raised weir pool, future town water demand (refer to **Section 4.1.1**) and no inflow to the weir pool during the critical drought period. The secure yield analysis is described in detail in **Appendix A** and summarised in the following sections.

Most urban water supply headworks in regional NSW have been sized on a 'security of supply' basis. The NSW security of supply basis was developed to cost-effectively provide sufficient storage capacity to allow water utilities to effectively manage water supplies in future droughts of greater severity than experienced over the past 100 or more years. 'Secure yield' is the water demand that can be expected to be supplied with only moderate restrictions during a significantly more severe drought than has been experienced since about 1895 (from when generally reliable rainfall records are available). The required water restrictions must not be too severe, not too frequent, nor of excessive duration. It has been argued that the definition of secure yield in effect allows meeting demand with moderate restrictions through a severe drought akin to a '1 in 1,000 year' drought (NSW Urban Water Services, 2021)

The NSW security of supply basis was applied to the proposal, which uses a '5/10/10 rule', whereby the new weir is sized so that:

a) Duration of restrictions does not exceed five per cent of the time; and

b) Frequency of restrictions does not exceed 10 per cent of years; and

c) Severity of restrictions does not exceed 10 per cent. Systems must be able to meet 90 per cent of the unrestricted water demand (i.e. 10 per cent average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy a) and b) above (NSW Urban Water Services, 2020).

Imposition of the requirements of the 5/10/10 rule is standard industry practice in NSW. The 5/10/10 rule approximates the severity of a '1 in 1000 year' drought and is necessary to enable a utility to manage its system in a drought more severe than the worst drought in the 120 year historical record (known as the 'critical drought'), with only moderate drought water restrictions. The longest drought on record at Wilcannia is the 'Federation drought', where it was observed that there were zero inflows to the weir for 362 days, from January to December 1902 (NSW Urban Water Services, 2021).

Water supply restrictions

Water restrictions are used by water authorities to limit domestic water demand during dry periods when water supply or storages are low. As noted above, water restrictions need to be considered when calculating the secure yield of the new weir.

The available storage capacity rating for the existing weir was used to determine the corresponding weir pool level at which restrictions are currently implemented. For the purposes of the secure yield analysis, the weir pool levels at which water restrictions would be implemented for the new weir are assumed to be the same as those for the existing weir. This approach is considered to be conservative for the calculation of the secure yield of the new weir because the storage capacity of the new weir at these levels is greater due to the new town pool and this increased storage capacity effectively delays the introduction of water restrictions until later in the drought period.

Targeted percentage demand reductions were determined for each water supply restriction level in consultation with Central Darling Shire Council and is based on the Orana Water Utilities Alliance water restrictions and quantitative guide.

Water restriction levels used in the secure yield analysis and the targeted demand reduction are presented in **Table 4-1** for both the existing and new weirs.

Table 4-1 Water restriction levels and target demand reduction allowances used in the secure yield analysis

Water restriction level	Weir pool level (metres AHD)	Accessible storage capacity (megalitres, %)		Target annual average consumption (litres per person per day)	Target demand reduction (%)
		Existing weir	New weir		
Unrestricted (proposed)	66.71 (drought FSL)	—	5511 (100%)	280 (assumed)	0%
Unrestricted (existing)	>65.71	Flow over weir	—	—	—
1	65.71 (normal FSL)	2030 (100%)	2434 (44%)	260	7%
2	65.43	1523 (75%)	1865 (34%)	240	14%
3	64.96	1015 (50%)	1258 (23%)	220	21%
4	64.63	711 (35%)	888 (16%)	200	29%
5	64.40	508 (25%)	639 (12%)	160	43%
6	63.65 (dead storage)	0	0	120	57%

Source: Public Works Advisory (2021b)

Consideration of climate change

Procedures for considering the effects of climate change in carrying out secure yield analysis are provided in *Assuring Future Urban Water Security, Assessment and Adaptation Guidelines for NSW Local Water Utilities* (draft) (Office of Water, 2013). The guidelines are based on a greenhouse gas emissions scenario that results in a 0.9 degree Celsius (0.9ºC) average temperature increase from 1990 to 2030. The guidelines use 15 global climate models developed by the International Panel on Climate Change that provide daily rainfall and evapotranspiration data suitable for planning purposes. The guidelines call for secure yield analysis to use all 15 global climate models with daily data.

For the proposal, it was not feasible to follow the guidelines to assess the reduction in secure yield for a 1ºC climate warming scenario. Instead, the critical drought of no inflows was initially extended by an additional 15 per cent (55 days) and modelling was undertaken using the historic climate flow series but with the extended critical drought plus considering changes in evaporation and rainfall over the storages' water surface areas for a 1ºC climate warming (NSW Urban Water Services, 2021)

The secure yield for a 1ºC climate warming from extending the critical drought by 55 days of zero flows and allowing for higher evaporation losses was 225 megalitres per annum. This is about 69 per cent less than secure yield of 728 megalitres per annum predicted if climate change is not considered. NSW Urban Water Services considered the size of this reduction to likely be an over-estimation of the impact of climate change based on secure yield studies it has carried out for eight inland systems (i.e. west of the Great Dividing Range) where the reduction varied from about 50 per cent to 20 per cent. Further modelling was carried out to examine the sensitivity to extending the critical drought by 18 days (a five percent extension) and 37 days (10 per cent extension) of zero inflow. The results of this further modelling as well as modelling with no extension of the critical drought with and without changes in evaporation and rainfall over the storage water surface areas are shown in **Table 4-2**.

Table 4-2 Results of consideration of the effects of climate change on the secure yield of the new weir

Inclusion of increased evaporation	Extension of the critical drought (days)	Secure yield (megalitres per annum)	Reduction compared to the historic climate secure yield (%)
No	0	728	Nil
Yes	0	654	-10%
Yes	18 (5%)	561	-23%
Yes	37 (10%)	371	-49%
Yes	55 (15%)	225	-69%

The modelling results were reviewed and the extension of the critical drought by 37 days (10 per cent) was considered to provide the best approximation of the potential effects of climate change. Therefore, the secure yield of the new weir is 371 megalitres per annum. The secure yield of the new weir is greater than the forecast annual unrestricted dry year water demand in 2050 of 362 megalitres per annum (refer to **Section 4.1.1**).

Accessible storage

A longitudinal schematic profile of the new weir pool is provided in **Figure 4-2** and the four pools within the existing weir pool and the accessible storage within each of these pools are described in **Section 3.2.1**.

The new weir would extend the weir pool about 4.92 river kilometres downstream from the existing weir. This new section of the weir pool is known as the 'new town pool'. With the partial removal of the existing weir, Pool 1 and the new town pool would be continuous. Like Pool 1, the new town pool would be accessible down to the maximum operating depth of the intake pump i.e. 63.65 metres AHD.

Table 4-3 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.

The new weir would have an accessible storage volume of about 5,654 megalitres at the drought full supply level compared to about 2,173 megalitres for the existing weir at the normal full supply level. This extra 3,481 megalitres of storage capacity is equal to the volume of water in the upper one metre of the weir pool between the drought full supply level and the normal full supply level plus the volume of the new town pool below the normal full supply level.

The new weir would have an accessible storage volume of about 2,577 megalitres at the normal full supply level compared to about 2,173 megalitres for the existing weir at the normal full supply level. The existing weir capacity at the normal full supply level (65.71 metres AHD) is equal to the storage capacity of the new weir at a level 0.17 metres below the normal full supply level (i.e. 65.54 metres AHD). In other words, the volume of water in the top 17 centimetres of the existing weir pool (i.e. between 65.71 metres AHD and 65.54 metres AHD) is equal to the accessible volume of water in the new town pool below 65.54 metres AHD.

Table 4-3 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	4,207	2,173
New weir pool – normal operation mode	65.71 metres AHD	4,755	2,577
New weir pool – drought security operation mode	66.71 metres AHD	7,832	5,654

The maximum storage volume shown in **Table 4-3** does not reflect the current condition of the existing weir. There is a crest gap on the right abutment where a dilapidated section of timber (plank) sheet piling has resulted in a breach of the weir crest of at least 0.6 metres in height as shown in **Photo 4-1**.

Photo 4-1 Erosion of the river channel and degradation of the right abutment of the existing weir structure

4.1.3 Backwater effect and headwater rating

The new weir would discharge water in a very different way to the existing weir. Being a fixed crest weir with no gates, the existing weir only discharges water when water overtops the weir crest. Once the water level in the existing weir pool is above the full supply level (65.71 metres AHD) all additional inflows to the weir pool pass downstream over the weir crest. In comparison, the new weir comprises a gated fishway, weir gates and a fixed crest portion. The level of all three of these components of the new weir influence the rate at which it can discharge water. Importantly, the about 21-metre long fixed crest portion of the new weir is partly at and partly above the drought full supply level (66.71 metres AHD). When the new weir is in normal operation mode and the water level in the new weir pool is below the drought full supply level, water can only discharge via the fishway and/or weir gates. The combined capacity of the fishway and weir gates is less than the capacity of the existing weir, when the water level is between the normal full supply level (65.71 metres AHD) and at least the drought full supply level (66.71 metres AHD). This means that for the same flow over the new and existing weirs, the upstream water level will be higher for the new weir compared to the existing weir.

A backwater effect occurs when flowing water encounters an obstruction, such as a narrowing of a channel, that limits its forward movement, causing the water level to rise behind the obstruction. The new weir would create a backwater effect compared to existing conditions without a weir. The backwater effect at the new weir would only become negligible at a high flow rate that result in water levels far above the drought full supply level but well below the top of the lowest riverbank (the left riverbank). Due to the greater obstruction represented by the new weir compared to the existing weir, the new weir requires a higher flow before the backwater effect becomes negligible compared to the existing weir.

The backwater effect at a weir can be observed by comparing the weir's headwater rating curve to its tailwater rating curve. A headwater rating curve plots the relationship between the height of water stored behind a weir and the rate at which water discharges from that weir. The tailwater rating curve plots the relationship between the height of water immediately downstream of a weir and the rate at which water discharges from that weir. The tailwater rating curve is generally representative of what the water level would be if the weir were not present and comparison of the headwater rating curve to the tailwater rating curve therefore indicates the backwater effect due to the weir. The obstruction to flows cause by the new weir is greater than of the existing weir and consequently the backwater effect of the new weir would be greater than the backwater effect of the existing weir. The backwater effect diminishes with distance upstream of the weir and eventually become negligible.

4.2 Operating rules

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 weir gates and fishway 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. Water Infrastructure NSW, in consultation with the operating authority, WaterNSW, and other key stakeholders including DPE Water, DPE Environment and Heritage, DPI Fisheries and MDBA would develop operating rules for the new weir prior to its practical completion. The operating rules would be refined during commissioning of the new weir.

Preliminary operating rules for the new weir have been developed as part of the preparation of a preliminary concept design for the proposal. The following sections describe how the new weir would be operated in accordance with the preliminary operating rules.

4.2.1 Modes of operation

The new weir would have dual modes of operation comprising a normal operation mode when it would operate at the existing full supply level (65.71 metres AHD) and a drought security operation mode when it would operate at a new full supply level of 66.71 metres AHD i.e. one meter above the existing full supply level. These full supply levels are referred to from this point on as the normal full supply level and drought full supply level respectively.

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'.

The temporary increase in the full supply level 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 total weir pool length of about 85.52 river kilometres. The extent of the existing and new weir pools is shown in **Figure 4-1**.

A longitudinal schematic profile of the new and existing weir pools is provided in **Figure 4-2**. Due to the large storage capacity of Pool 2 and its proximity to the existing water extraction infrastructure for the town, it is assumed that during a severe drought temporary pumping works would be installed to transfer isolated water in Pool 2 over Bar 1 and into Pool 1, where it would be accessible using the existing extraction infrastructure., although any such extension of the existing water extraction infrastructure does not form part of this proposal. Therefore, Pool 2 may be accessible down to the maximum operating depth of the intake pump i.e. 63.65 metres AHD.

4.2.2 Dynamic storage during normal operation mode

The preliminary operating rules for the new weir were developed with the objective of balancing the need to minimise upstream impacts with the need for efficient rules for operating the weir gates. 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) in response to inflows as follows:

- At low flows the crest of the weir gates would be set at the normal full supply level 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 flow depth of 0.5 metres has been applied for headwater levels up to 67.21 metres AHD (drought full supply level minus 0.5 metres) to control downstream energy dissipation at lower tailwater depths. The minimum fishway flow discharge would be 60 megalitres per day when the crest of the weir gates is at the normal full supply level and no flow is passing over the weir gates.
- 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 continue 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 a nominal minimum flow of about 374 megalitres per day when the headwater level is between 66.21 metres AHD and 66.71 metres AHD, when the gates would be fully raised (closed).
- For headwater levels above 67.21 metres AHD, the weir gates are unable to be raised above the drought full supply level (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 higher tailwater levels and depths.

Discharges via the weir gates and fishway at different headwater levels in accordance with the preliminary operating rules are detailed in **Table 4-4**.

Table 4-4 Headwater rating during normal operation mode

Headwater level (metres AHD)	Weir gates		Fishway discharge (ML/day)	Total discharge (ML/day)
	Crest level	Volume discharging (ML/day)		
65.71 (normal FSL)	65.71	0	60	60
66.21	65.71	374	159	533
66.71 (drought FSL)	66.21	374	420	794
67.21	66.71	374	1488	1862

A headwater rating curve showing the relationship between the total flow volume discharging from the new weir including the fishway and the upstream headwater level during normal operation mode based on the preliminary operating rules is shown in **Figure 4-3**. The figure shows the headwater ratings of the new weir (including the fishway) in black and the existing weir in orange. The preliminary gate operating rules for the new weir are stated within the green boxes. The potential upstream impacts are associated with the difference between the new weir (black) and existing weir (orange) headwater rating curves. For example, at a discharge rate of 800 megalitres per day, the upstream impact is an indicative increase in river level immediately upstream of the existing weir of about 0.67 metres (new weir head of 1.00 metres minus existing weir head of 0.33 metres). The increase in upstream water levels would diminish moving upstream until at a some point the difference would become negligible.

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 with the aim of maintaining a weir pool at the normal full supply level during periods of increasing inflows.

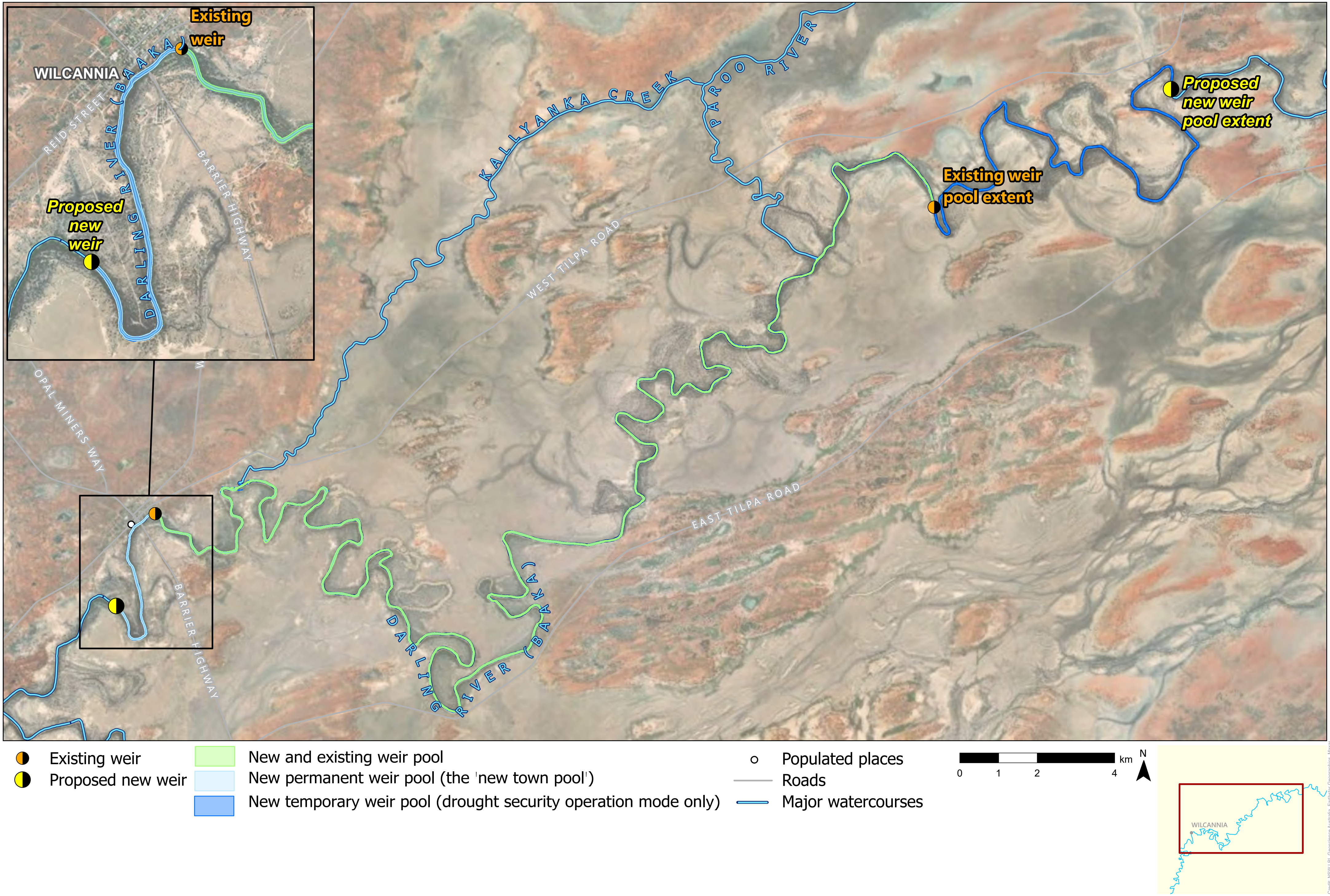


Figure 4-1 Extents of the new and existing weir pools

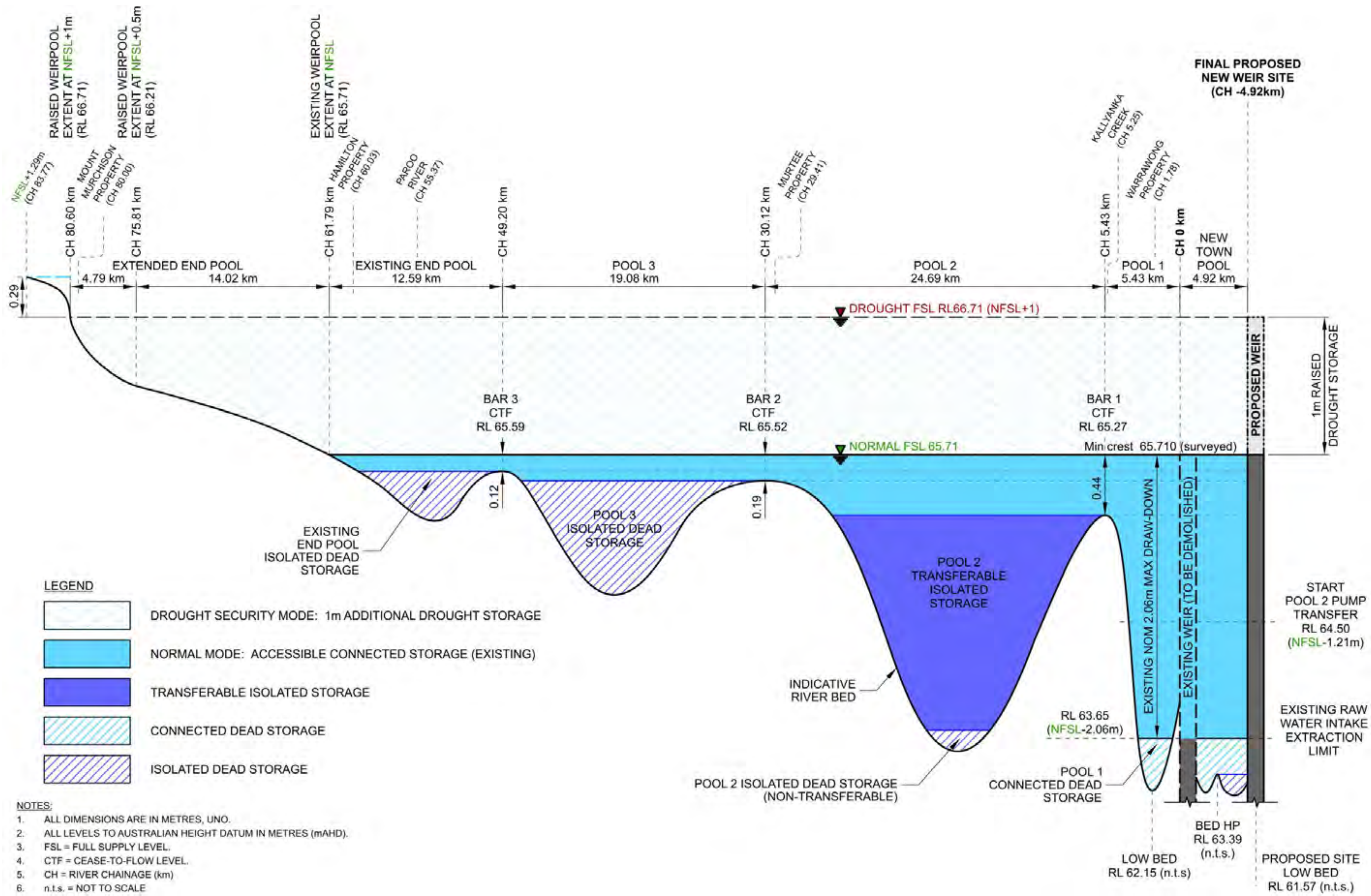


Figure 4-2 Longitudinal schematic profile of the new weir pool

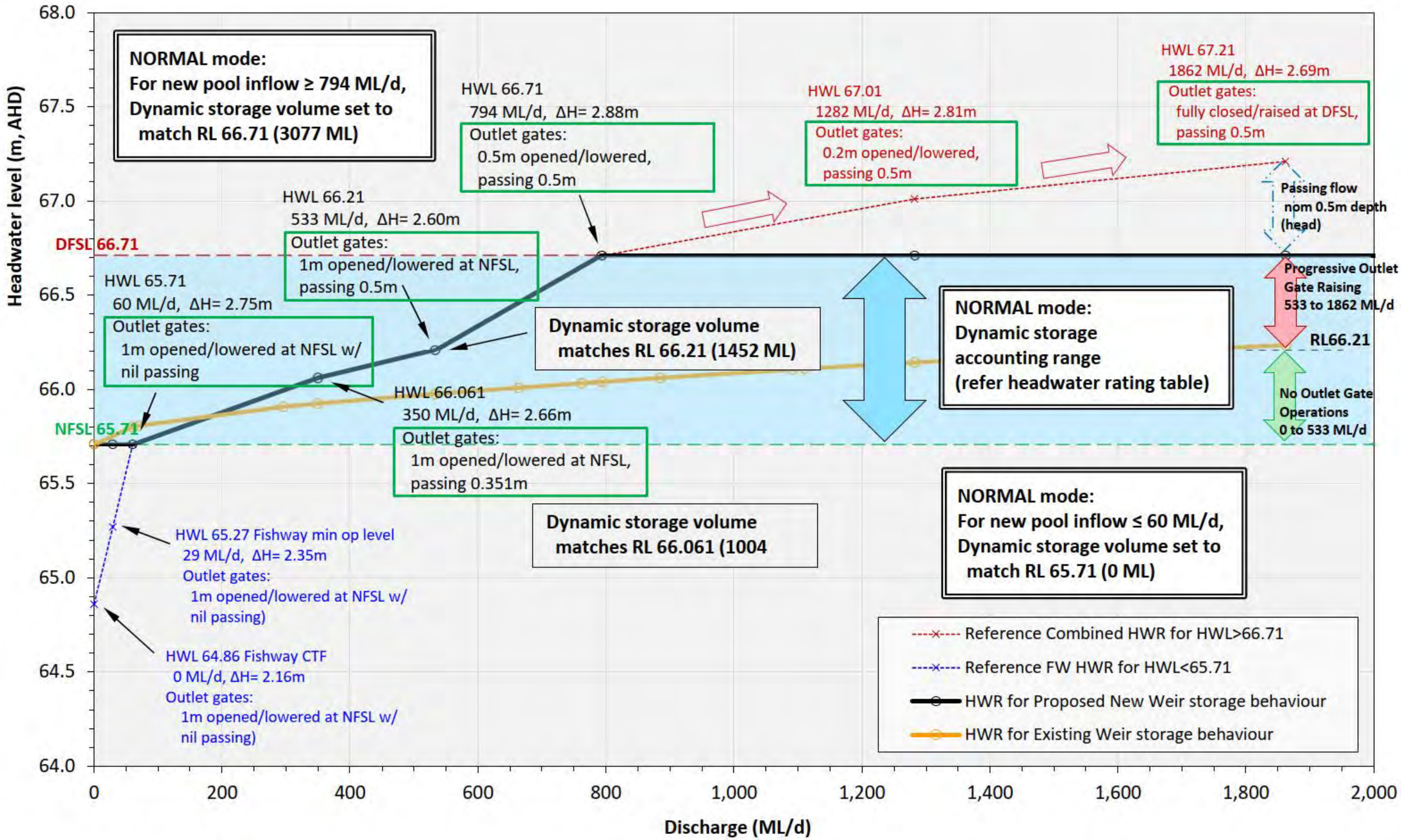


Figure 4-3 Headwater rating curve of the new weir during normal operation mode

4.2.3 Weir operation during high flow events and floods

In accordance with the dynamic storage rules described in **Section 4.2.2**, as flows increase the weir gates would be raised to limit overtopping of the gates to 0.5 metres up until the gate crest is raised to the drought full supply level, at which point increasing river flows would begin to overtop the gate by more than 0.5 metres. As flows continue to increase further it is expected that the weir gates would be progressively lowered until fully opened so that waterway area may be maximised and weir drown-out is able to occur at the lowest possible flow.

4.2.4 Transition phases and trigger levels

The new weir would transition from normal 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 flows were adopted for the purposes of simulating the operation of the proposal using flow time series data derived from the Barwon-Darling Source River System Model for flows past Bourke Town Weir and inflows to Wilcannia Weir:

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

Flows past Bourke Town Weir are represented by the location of the Myandetta gauge (gauging station no. 425038 (Darling River at Myandetta)).

4.2.5 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. The following gate closure logic was included in the modelling:

- The discharge is reduced by 50 per cent of the previous days discharge every day
- The discharge cannot exceed the inflow to the weir pool
- The weir gates would close (and discharges cease) when the discharge reduces to 30 megalitres per day.

4.2.6 Translucency discharges during drought security operation mode

The secure yield of the new weir is based on nil inflows to Wilcannia weir pool during the longest drought on record (refer to **Section 4.1.2**). Because the secure yield assumes nil inflows, any inflows to Pool 1 when the new weir is in drought security operation mode are not needed for town water supply and can be passed downstream without impacting the secure yield. 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 full supply level (66.71 metres AHD) and 65.54 metres AHD (the drought full supply level minus 1.17 metres) (refer to **Section 4.1.2**).

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 and mirror the upstream flow conditions.

The translucency discharges would result in a dynamic storage that would be managed through operation of the fishway gates and weir gates. A nominal minimum translucency flow of 350 megalitres per day would be able to be discharged down to the normal full supply level minus 0.17 metres (i.e. to 65.54 metres AHD).

The implementation of the translucency rule will be detailed in the operations plan for the new weir that will be prepared prior to the start of operation of the new weir in consultation with WaterNSW and other stakeholders. WaterNSW will monitor the effectiveness of the translucency rule during its initial implementation. Based on the findings of this monitoring, WaterNSW may revise the operations plan for the new weir if opportunities are identified to improve the way that 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 revised.

4.2.7 Planned environmental water

The proposed new weir includes weir gates that would enable planned environmental water inflows to the weir pool to be released downstream. This is an improvement compared to the existing weir which has no mechanism for deciding whether inflows to the weir pool should be released downstream. Inflows to the existing weir pool are only passed downstream when the weir pool is at the full supply level.

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.

4.3 Gauging stations

WaterNSW operates water monitoring stations (gauging stations) across NSW to take systematic readings of water levels and flow rates in waterways. There are several gauging stations located within the Darling River (Baaka) basin. Gauging station number 425008 ('Wilcannia Main Channel') measures flows in the main channel of the Darling River (Baaka) at Rock Bar, downstream of the existing weir. It also measures water temperature and electrical conductivity. This gauging station is upstream of the new weir and would be inundated once the new weir commences operation.

In May 2020, a new gauging station was installed about 2.49 kilometres downstream of the proposed new weir site and about 3.18 kilometres upstream of the confluence of Woytchugga Creek and the Darling River (Baaka). This gauging station, number 425058, is known as the Moorabin gauging station and is currently being used to measure water levels, electrical conductivity, water temperature and dissolved oxygen levels. This data is being correlated with historical data from existing gauging stations.

Once the new weir starts operation, the Moorabin gauge would be used to measure flow rates downstream of the new weir pool, thereby serving the same function as the existing gauging station at Rock Bar.

The existing gauging station at Rock Bar would be retained following the commencement of operation of the new weir to monitor water levels in the weir pool. A dissolved oxygen sensor would be fitted to measure dissolved oxygen levels in the weir pool. The gauging station would continue to measure water temperature and electrical conductivity.

5. Hydrology impact assessment

A hydrology impact assessment has been carried out to assess how the proposal would alter flows in the Darling River (Baaka). **Table 1-1** outlines how this assessment addresses the hydrology requirements of SEAR number 2.

5.1 Assessment methodology

5.1.1 Storage behaviour modelling

The operation of the proposal has been simulated by carrying out storage behaviour modelling. Initially, a modified water balance model was used to assess the performance and filling reliability of the weir pool due to the two weir operation modes. The model was further modified to assist with assessment of storage behaviour based on the preliminary operating rules for the new weir. The Barwon-Darling Source River System Model was used to provide input time series data for simulated Wilcannia weir pool inflows and for trigger flows past Bourke Town Weir. Modelling using observed flow data was later carried out.

The Source model is Australia's national hydrology modelling platform and has been developed collaboratively by a partnership of governments, industry and research organisations. Source is used by all Australian government water management agencies and is a nationally consistent platform; with planning, operations and forecasting modes. The Source model integrates water resource assessment and policy and can produce water accounts, determine water allocations and manage rivers according to agreements and rules.

Public Works Advisory oversaw the storage behaviour modelling of the proposal on behalf of Water Infrastructure NSW. A report on the storage behaviour modelling carried out for the proposal is provided in **Appendix B** and summarised in the following sections.

5.1.2 Barwon-Darling Source River System Model

River system modelling is generally applied to river systems where water regulation occurs. It includes representation of how a range of water uses within a system may impact on hydrological regimes, as well as the extent to which hydrological regimes are able to supply the demand for these uses. It can include detailed representation of environmental processes as well as regulatory constraints and requirements. It is typically simulated over a continuous time series of relatively long meteorological data to represent the implications of a range of potential climatic conditions. The simulation time step is often in the range of one day. A river system model may represent:

- The rainfall runoff process
- Dam inflows, outflows and levels
- Consumptive use demand such as based on irrigator planting behaviour
- Transmission losses through the system
- River regulation structures such as weirs including their relevant operational or regulatory rules
- Environmental flows including with relation to environmental water holders.

The 'actual permitted take' scenario has formed a baseline for evaluation of the proposal. In the absence of a Barwon Darling Sustainable Diversion Limit model scenario, this scenario has been assumed to represent the quantum of water that users are legally entitled to access. Consequently, measuring changes relative to this scenario provides an assessment of the allowable impact on flows and diversions.

In this scenario, the most recent set of management rules contained in NSW draft water resource plans and the Queensland resource operations plans are included. Commonwealth water recovery has not occurred in this scenario and these holdings are still used for irrigation with an allocation utilisation similar to other consumptive users. The exclusion of Commonwealth water recovery from the model is important as it results in a conservative prediction of future flows in the Darling River (Baaka). If Commonwealth water recovery was included in the modelling any water recovered upstream of Wilcannia would be reflected in an increase in the predicted inflows to the weir pool and flows downstream of the new weir.

In the Barwon-Darling Source River System Model, all weirs are represented as fixed crested weirs and flow resumption rules are included. Walgett Weir 11A has been modelled to account for the recently completed (2020) one metre weir raising with a design full supply level of RL124.49 metre AHD.

In all but a few instances, simulated model inflows to the Barwon Darling River System Model are taken from the DPE actual permitted take model scenarios. Where these inflows are thought to be inappropriate for use in assessing the proposal, a WaterNSW modelled inflow sequence has been used. A complete list of inflow sequences adopted for the scenario is provided in **Table 5-1**.

Table 5-1 Adopted river system model inflow sequences

Barwon-Darling inflow gauging station	DPE file name	Data used to assess the proposal
416001-Barwon River at Mungindi	416001_APT20	DPE
416037-Boomi River at Boomi Weir offtake	416028_APT20	DPE
416052-Gil Gil Creek at Galloway	Galloway APT_418052	DPE
417001-Moonie River at Gundablouie	Moonie_2020Cap_Gundablouie_417001.res	DPE
418066-Gwydir River at Millewa	Millewa APT_418066	DPE
418058-Mehi River at Bronte	APT_418058	DPE
418070-Moomin Creek at Moomin	APT_418054	DPE
418091-Thalaba Creek at Belarre	Not applicable	WaterNSW
419026-Namoi River at Goangra	GoangraL_APT20	DPE
419049-Pian Creek at Waminda	WamindaL_049APT	DPE
420020-Castlereagh River at Gungalman	Not applicable	WaterNSW
421011-Marthaguy Creek at Carinda	Marthaguy at Carinda Car011-APT20	DPE
421012-Macquarie River at Carinda	Macq at Carinda_421012-w192_car012_20	DPE
421107-Marra Creek at Billybingbone Bridge	Marra 421107_20	DPE

Barwon-Darling inflow gauging station	DPE file name	Data used to assess the proposal
422031-Narran River at Bundah	Narran 009C-395	DPE
422005-Bokhara River at Bokhara	Bokhara 009C-090	DPE
422006-Culgoa River downstream Collerina	Collerina 009C-140	DPE
421023-Bogan River at Gongolon	Bogan 421076_2020	WaterNSW
423001 ad 423002 Warrego River at Fords Bridge and Bywash	Warrego_2020Cap_Fords_Bridge_4230012.res	DPE
424002_Paroo River at Willara Crossing	Not applicable	WaterNSW

The Barwon-Darling Source River System Model was used to provide flow time series data at Bourke and Wilcannia in daily time steps. Two sets of outflows were provided:

- Simulated flows below Bourke Town Weir and into the Wilcannia weir pool
- Low flow adjusted simulated flows, to address the known overprediction of low flows in river system models. WaterNSW undertook flow adjustment on the basis of a comparison of simulated and observed flows at the Tilpa gauge.

Inflows to the Wilcannia weir pool were provided after any extractions and transmission losses along the Bourke to Wilcannia reach but before any weir pool net evaporation, seepage and/or stock and domestic demands had been applied.

The Source model simulates flows in daily time steps. A simulation of the operation of the proposal 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 downstream of the existing Bourke Town Weir as represented by the location of the Myandetta gauge to a point at the upstream extent of the Wilcannia weir pool.

The flow data from the Source model was then used in the storage behaviour water balance model to provide:

- The daily volume of stored water in Wilcannia Weir
- The daily level of the Wilcannia weir pool, for each of pools 1 to 4 (refer to **Figure 4-2**)
- The daily volume of water pumped from Pool 2 to Pool1
- Daily flows downstream of Wilcannia Weir.

Three simulations were undertaken using the Barwon-Darling Source River System Model:

- Simulation 1 (base case): A base case was modelled that simulated the existing Wilcannia Weir with dynamic storage behaviour and existing demand for town water in Wilcannia. The existing weir was modelled with dynamic storage behaviour to allow for the backwater effect. The inclusion of dynamic storage behaviour in the base case was aimed at ensuring a consistent approach with modelling of the new weir (simulations 2 and 3, see below) for the purpose of assessing differences in downstream flow impacts. Not using dynamic storage behaviour for the base case may result in downstream flows occurring slightly earlier and without the inflow attenuation effects of the weir pool storage

- Simulation 2: Proposed new weir with all preliminary operating rules and existing demand for town water in Wilcannia. This scenario can be compared to simulation 1 to assess the impact of the new weir on upstream inundation at Wilcannia and flows downstream of the new weir
- Simulation 3: Proposed new weir with all preliminary operating rules and future demand for town water in Wilcannia. This simulation can be compared to simulation 2 to assess the incremental impact of future demand for water.

A further three simulations were undertaken to test the sensitivity of the above simulations to account for adjusted low flows.

Simulations 2 and 3 included the operating rules detailed in **Section 4.2**.

Flow alterations due to future demand for town water were found to be almost identical to those for existing demand for town water, which is attributed to the small difference between future and existing demand for town water and both future and existing demand for town water being much less than evaporation losses. Comparison of simulation 1 (new weir with future town water demand) to simulation 3 (existing weir with existing town water demand) therefore provides a slightly more conservative assessment of the impacts of the new weir than if it were compared to a base case of the existing weir with future demand.

5.1.3 Downstream low flow-spell analysis

Flow spell analysis is a procedure developed by the UK Institute of Hydrology to analyse the extremes of the hydrograph. 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). A low flow spell analysis of flows downstream of the new weir was undertaken using the outputs of the storage behaviour model simulations. The focus of the analysis was on low spells as the proposal would affect low spells more than high spells.

The analysis of flow alternation 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* (DPIE, 2020b) (refer to **Table 2-1**). The analysis considered changes in the following spell characteristics for key flow categories in Simulations 2 and 3 compared to Simulation 1:

- Total number of spells across the entire 119-year simulation
- Number of years with at least one occurrence of a spell commencing
- Longest spell
- Mean spell duration
- Mean period between spells
- Longest period between high spells.

The results of the downstream low flow spell analysis were very similar for simulations 2 and 3 and therefore only simulations 1 and 3 are considered in the impact assessment.

The results of the modelling are provided in **Section 5.4.3**. The results are only provided for flow rates where the proposal would result in an impact to downstream flows.

5.1.4 Hydrodynamic analysis of the weir pool

A hydrodynamic modelling investigation was also carried out to simulate changes in the velocity of flows through the weir pool as a result of the proposal. The purpose of the investigation was to identify the potential impacts of the proposal on the depth and speed of flowing water within the weir pool. Flow velocity is a key factor that influences native fish spawning and the investigation accordingly considered flow velocities above and below known flow velocity thresholds for fish spawning. The hydrodynamic modelling of the proposal was carried out by Public Works Advisory on behalf of Water Infrastructure NSW and is detailed in a report provided in **Appendix C**.

The hydrodynamic modelling considered flows over an about 105-river-kilometre length of the Darling River (Baaka) between the new weir and a point about 38 river kilometres upstream of the upstream extent of the weir pool when the new weir is in normal operation mode. Hydrodynamic modelling was carried out for both the existing weir and the new weir, enabling the impacts of the new weir on flow velocities to be identified by comparing the two simulations.

The investigation only considered the new weir in normal operation mode. This is because normal operation mode corresponds with periods when the Darling River (Baaka) is flowing at Wilcannia, whereas drought security operation mode generally corresponds with periods when the river has little or no flow at Wilcannia.

Nine flow scenarios were considered:

- 100 megalitres per day
- 200 megalitres per day
- 350 megalitres per day. This is the minimum limiting base flow rate identified in the *Barwon–Darling Long-Term Water Plan Part A* (Department of Planning, Industry and Environment, 2020a)
- 600 megalitres per day
- 800 megalitres per day
- 1400 megalitres per day. This is the minimum limiting small fresh flow rate identified in the *Barwon–Darling Long-Term Water Plan Part A* (Department of Planning, Industry and Environment, 2020a)
- 2,000 megalitres per day
- 3,500 megalitres per day
- 5,000 megalitres per day.

As noted above, flow velocity is a key factor that influences aquatic biodiversity. Additional analysis of the hydrodynamic modelling results and an assessment of the potential biodiversity impact of the predicted changes in water velocity are provided in the aquatic ecology assessment of the proposal in Technical Report 3 and Section 13 of the environmental impact statement.

5.2 Risk

The main hydrological risk associated with the proposal is its potential to impact flows downstream of the new weir such that it causes an increase in the frequency and/or duration of low flow spells and, critically, cease-to-flow events. An increase in low flow spells downstream of Wilcannia would worsen environmental conditions in that reach of the Darling River (Baaka) including importantly the availability of flowing water habitat.

5.3 Avoidance and minimisation of impacts

Impacts to hydrology and particularly flows downstream of the new weir have been avoided and minimised by:

- Dual modes of operation – The dual operation modes of the new weir would minimise the time that it operates at a higher full supply level than the existing weir
- Translucency discharges – The new weir would allow for downstream discharge via the weir gates of any inflows to the new town pool and Pool 1 as detailed in **Section 4.2.6**.

5.4 Assessment of impacts

5.4.1 Construction

The existing weir would continue to operate during construction of the new weir, during which it would remain the primary local influence on hydrology in the Darling River (Baaka) at Wilcannia. Construction of the new weir would require occupation of part of the riverbed at the new weir site. Initially, a work site would be established on the riverbed alongside the right riverbank for construction of the fishway. Works within the river channel would start during a low flow period to minimise the time and effort required to establish a dry work site and reduce the risk of water pollution occurring.

Once the fishway is complete, flow would be directed down the fishway and a work site established on the riverbed alongside the left riverbank for construction of the fixed crest portion of the weir, weir gate bay and associated upstream and downstream embankments. These work sites on the riverbed would be made dry by isolating them from river flows using cofferdams.

Flows in the river would be maintained past the in-stream work site for the new weir during each stage of construction. The width of river channel available to pass flows would be reduced due to the occupation of part of the riverbed by the construction site and cofferdams. During the initial stage of construction when the fishway would be built, the natural level of the riverbed would be maintained alongside the work site, meaning that flows would only be constricted by the narrowing of the river channel and not by any change in level. Therefore, impacts to flows would only occur to the extent that the narrowing of the river channel at the construction site would cause a backwater effect that results in an increased upstream water level, with water temporarily ponding behind the cofferdam before flowing past the construction site.

During the second phase of construction when the fixed crest portion of the weir, weir gate bay and upstream and downstream embankments would be built and flows would be directed into the newly built fishway to pass the work site, the elevation of the upstream end of the bed of the fishway relative to the elevation of the riverbed would result in an increase in upstream water levels before flow would begin to bypass the works via the fishway. The riverbed level at the low point along the axis of the new weir is 61.57 metres AHD and the floor level of the upstream end of the fishway channel would be 64.66 metres AHD assuming no baffles are installed. Hence, water would need to pond to a depth of 3.09 metres before it would spill down the fishway and continue downstream. The time that flows would temporarily not pass downstream would depend on the river flow rate and level at the time of closure of the cofferdam. Extrapolating the proposed storage behaviour modelling, the median time to fill may be less than three days.

Filling of the new town pool would occur following construction of the new weir. The time required for the water level in the new town pool to reach the normal full supply level (65.71 metres AHD) would depend on the amount of water in the existing weir pool and the rate of inflows to the weir pool during the initial filling phase. The storage capacity of the new weir at the normal full supply level is 4,755 megalitres, which is less than the mean daily flow at Wilcannia (refer to **Section 3.1**). As noted in **Section 3.1**, the flow in the Darling River (Baaka) at Wilcannia is very variable, and the median daily flow rate is substantially lower than the mean daily flow rate. Therefore, while it is possible that the new weir pool could fill within a day, it is more likely that it would take a few days to fill.

5.4.2 Partial removal and decommissioning of the existing weir

The existing weir would be partially removed and decommissioned after the new weir is built. The new weir would create the new town pool between the new and existing weirs and this would inundate the existing weir. Subject to suitable flow conditions, the weir gates could be used to manipulate the new town pool level to assist partial removal and decommissioning of the existing weir including to minimise the difference in water levels between the new town pool and existing weir pool when the existing weir is breached.

5.4.3 Operation

The operational impacts of the proposal have been assessed based on the outcomes of the downstream low flow spell analysis and hydrodynamic modelling described in **Sections 5.1.3** and **5.1.4** respectively.

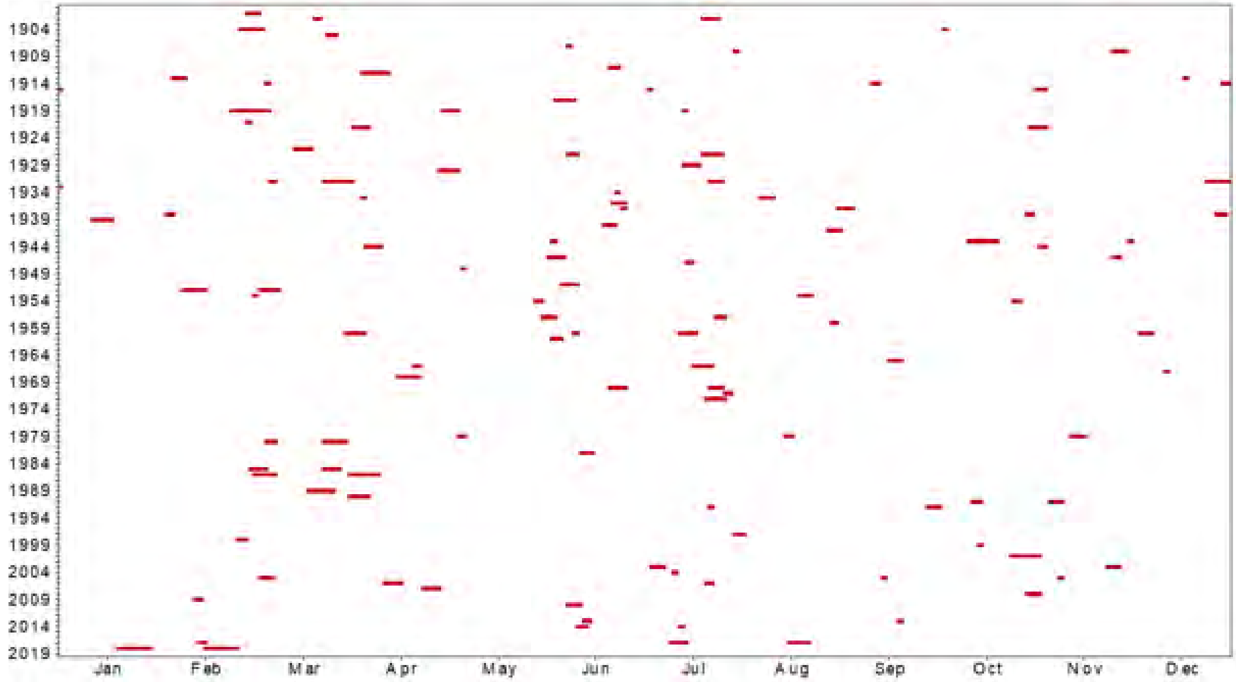
The results of the downstream low flow spell analysis are summarised in the following sections for the relevant key flow categories identified in the *Barwon-Darling Long Term Water Plan Part B* (DPIE, 2020b) for the Wilcannia to Lake Wetherell planning unit (refer to **Table 2-1**).

Cease-to-flow spells

The *Barwon-Darling Long Term Water Plan Part B* (Department of Planning, Industry and Environment, 2020b) defines cease-to-flow conditions in the Wilcannia to Lake Wetherell planning unit as flows of less than one megalitre per day (refer to **Table 2-1**).

The outputs from the storage behaviour water balance model were analysed for cease-to-flow events and it was noted that there were several instances of 'false filling' where the filling phase was triggered but during or shortly after filling the reset phase was triggered. On the basis that future refinement of the trigger for the filling phase should be able to avoid false filling, cease-to-flow spells of 14 days or shorter were removed from the analysis. This change reduced the number of filling phases over the 119-year simulation period from 120 to 86. A plot of cease-to-flow conditions downstream of the new weir due to the filling phase including and excluding cease-to-flow spells of 14-days or shorter for the 119-year simulation period is provided in **Figure 5-1**. The same data is presented in a single plot in **Figure 5-2**.

Cease to flow conditions downstream of the new weir due to the filling phase, 1900 to 2019



Cease to flow conditions downstream of the new weir due to the filling phase excluding cease-to-flow spells of less than 14 days, 1900 to 2019

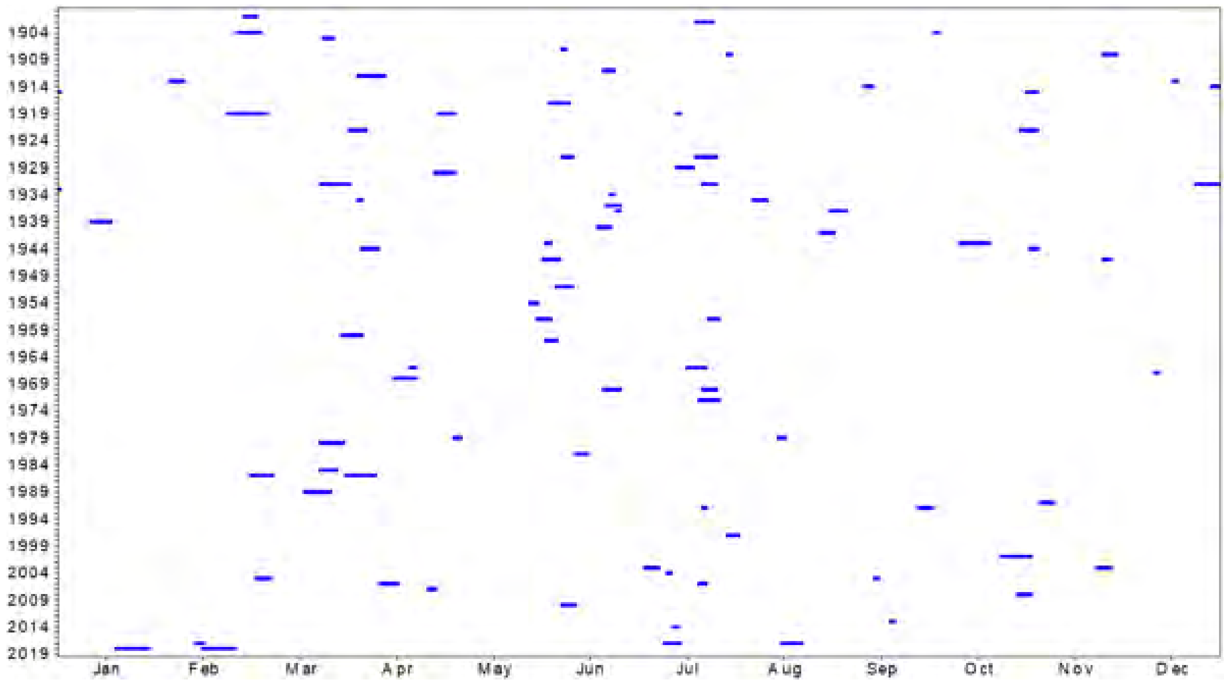


Figure 5-1 Plots of cease-to-flow conditions downstream of the new weir due to the filling phase before (top) and after (bottom) removing cease-to-flow spells of less than 14 days for the 119-year simulation, 1900 to 2019

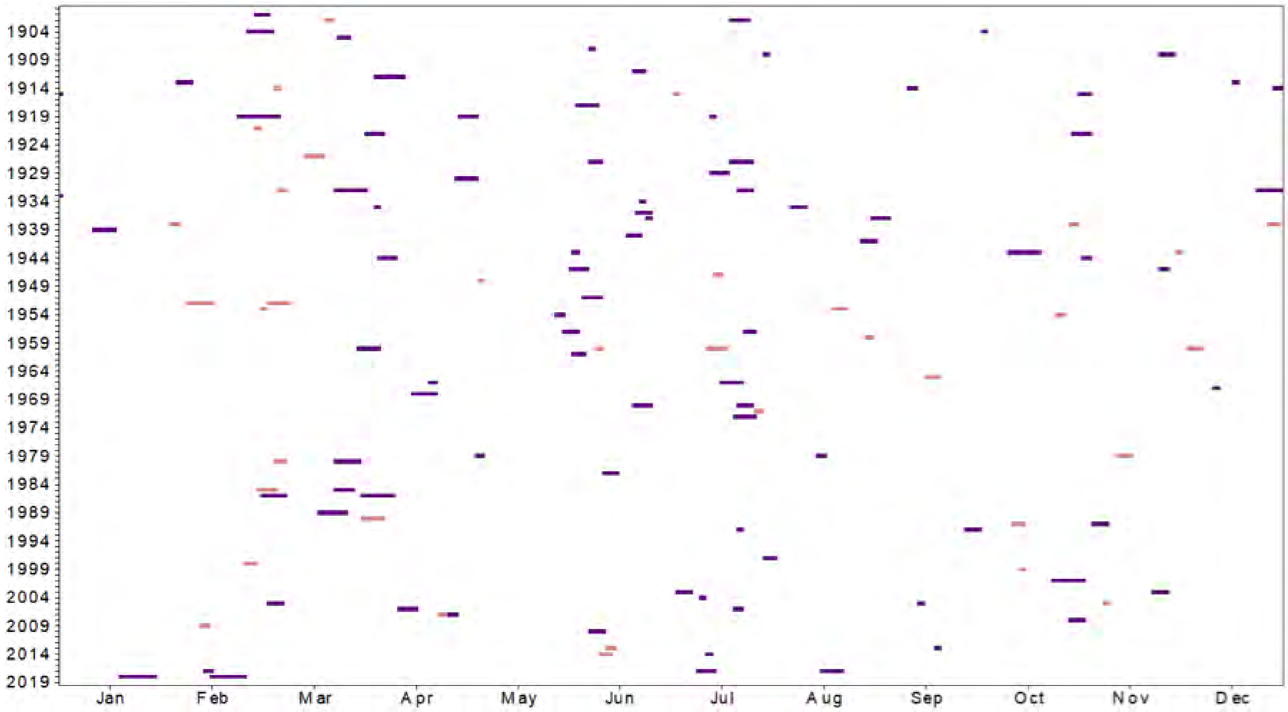


Figure 5-2 Plot of cease-to-flow conditions downstream of the new weir due to the filling phase, with those associated with cease-to-flow spells of less than 14 days shown in red, for the 119-year simulation, 1900 to 2019

A downstream spell analysis of the instances and durations of cease-to-flow spells predicted using the refined storage behaviour water balance model for the existing and new weirs is provided in **Table 5-2**.

Cease-to-flow spell plots for the 119-year simulation period are provided in **Figure 5-3** for the existing and new weirs (simulations 1 and 3 respectively) and a chart comparing the longest cease-to-flow spell each year for each simulation is provided in **Figure 5-5**. Charts comparing the duration of cease-to-flow spells are provided in **Figure 5-6** and **Figure 5-7**. These show that the patterns of cease-to-flow spells are similar for the existing and new weirs. The main differences are:

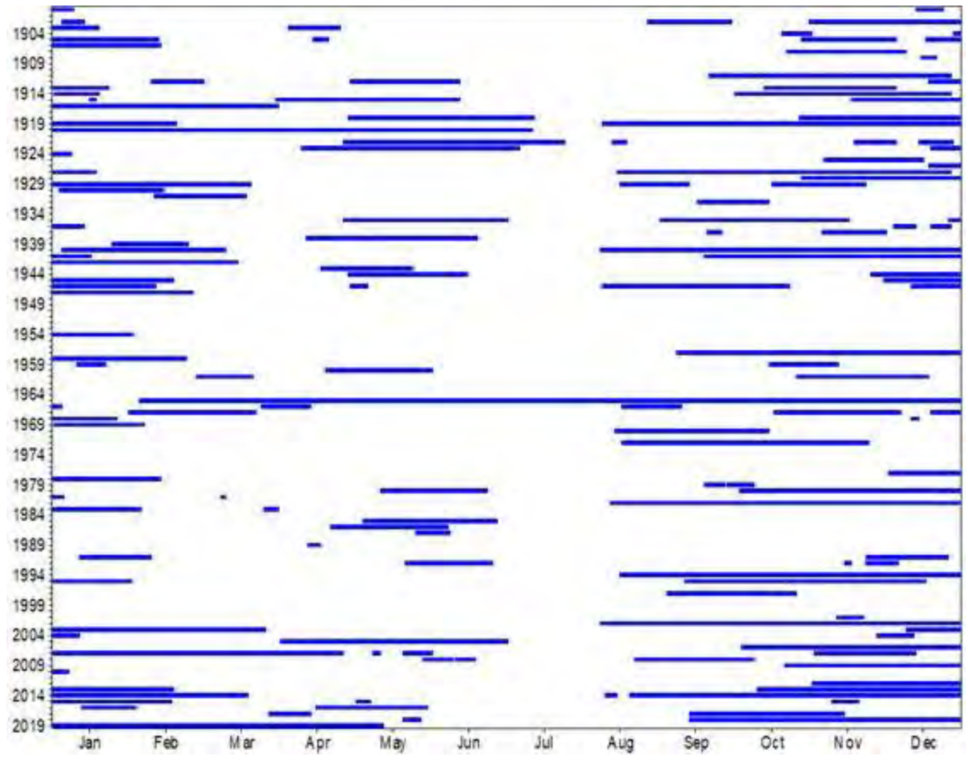
- There is an increase in short duration cease-to-discharge events at the new weir when it is in the filling phase, as shown in **Figure 5-4**. This indicates that despite removing false filling events of 14-days or less there remain many short-duration cease-to-flow spells that could potentially be avoided with refinement of the filling phase trigger
- Some long duration cease-to-flow spells in the existing weir simulation are broken into two shorter duration cease-to-flow spells in the new weir simulation due to the application of the translucency rule when the new weir is in drought security operation mode. This results in a reduction in the mean duration of cease-to-flow spells, from 57 days to 36 days, as indicated in **Table 5-2**. A plot showing when the translucency rule would result in downstream flows that would otherwise not have occurred is provided in **Figure 5-4**. It shows that the translucency rule would mostly result in the early ending of cease-to-flow events but would also on occasion break some long duration cease-to-flow spells e.g. in February 1916, September 1965, January 2014 and April 2016.

Table 5-2 Predicted cease-to-flow spells characteristics downstream of the new and existing weirs over the simulation period, 1900 to 2019

Spell characteristics	**Simulation 1** (Existing weir with dynamic storage behaviour and existing demand for town water)	**Simulation 3** (Proposed new weir with all operating rules and future demand for town water)	Change in spell characteristic
Number of cease-to-flow spells	122	215	+93 (+76%)
Number of years with at least one cease-to-flow spell	87	96	+9 (+10%)
Percentage of years with at least one cease-to-flow spell	73%	81%	+8% (+11%)
Longest cease-to-flow spell (days)	337	342	+5 (+1%)
Mean duration of cease-to-flow spells (days)	57	36	-21 (-37%)
Total duration of cease-to-flow spells over the 119-year simulation period (days)	6,927	7,745	+818 (+12%)

The seasonality of the change in the total number of cease-to-flow spells across the 119-year simulation and median duration of the longest cease-to-flow spell in each year of the simulation is shown in **Figure 5-8** and **Figure 5-9** respectively.

Existing weir



New weir

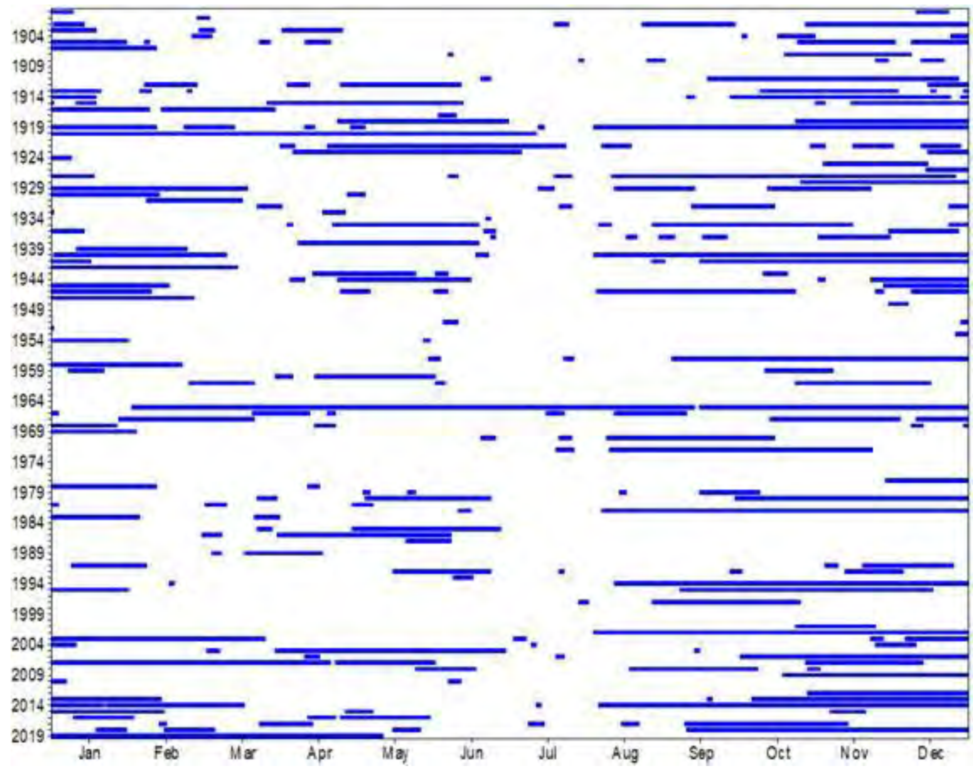


Figure 5-3 Plots of cease-to-flow spells (blue lines) for the existing and new weirs for the 119-year simulation, 1900 to 2019

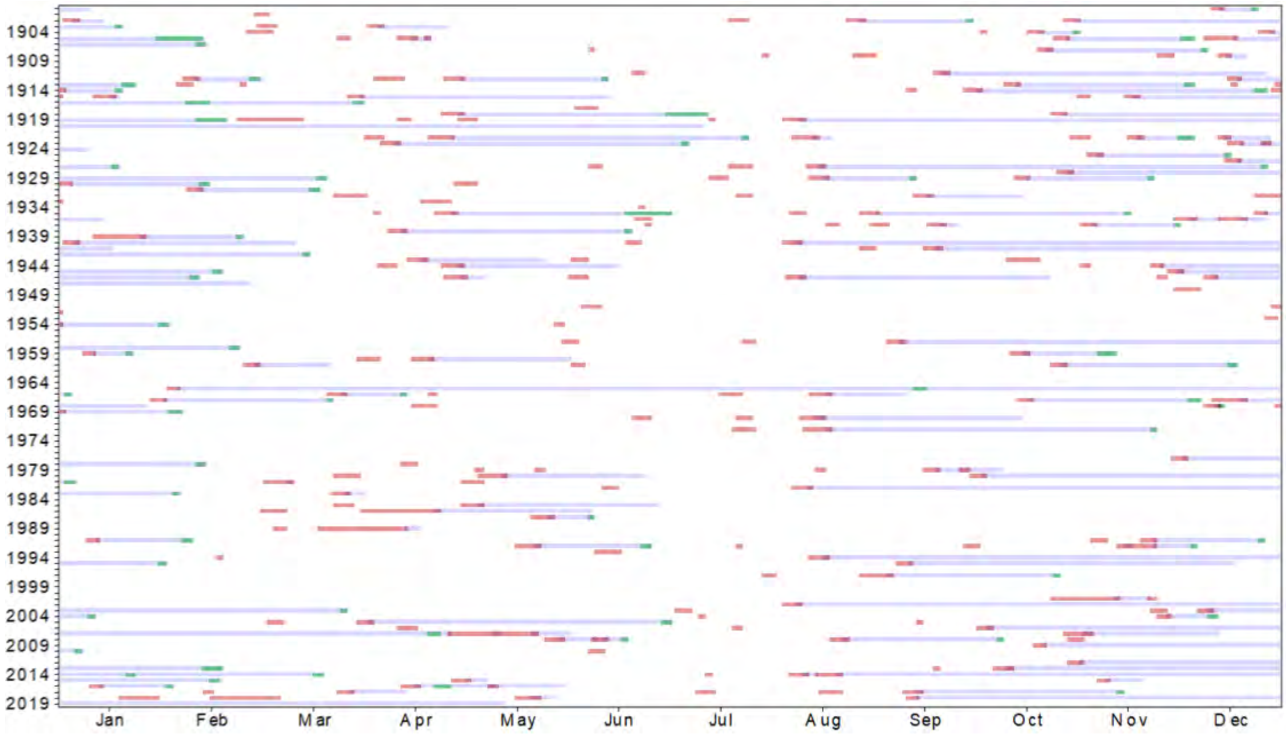


Figure 5-4 Plot of cease-to-flow spells downstream of the new weir for the 119-year simulation, 1900 to 2019, distinguishing between cease-to-flow conditions common with the existing weir (blue lines) and additional cease-to-flow spells or conditions due to the filling phase (purple) or drought security operating mode (red). Translucency flows that result in flows downstream of the new weir when there would otherwise have been cease-to-flow conditions downstream are shown in green

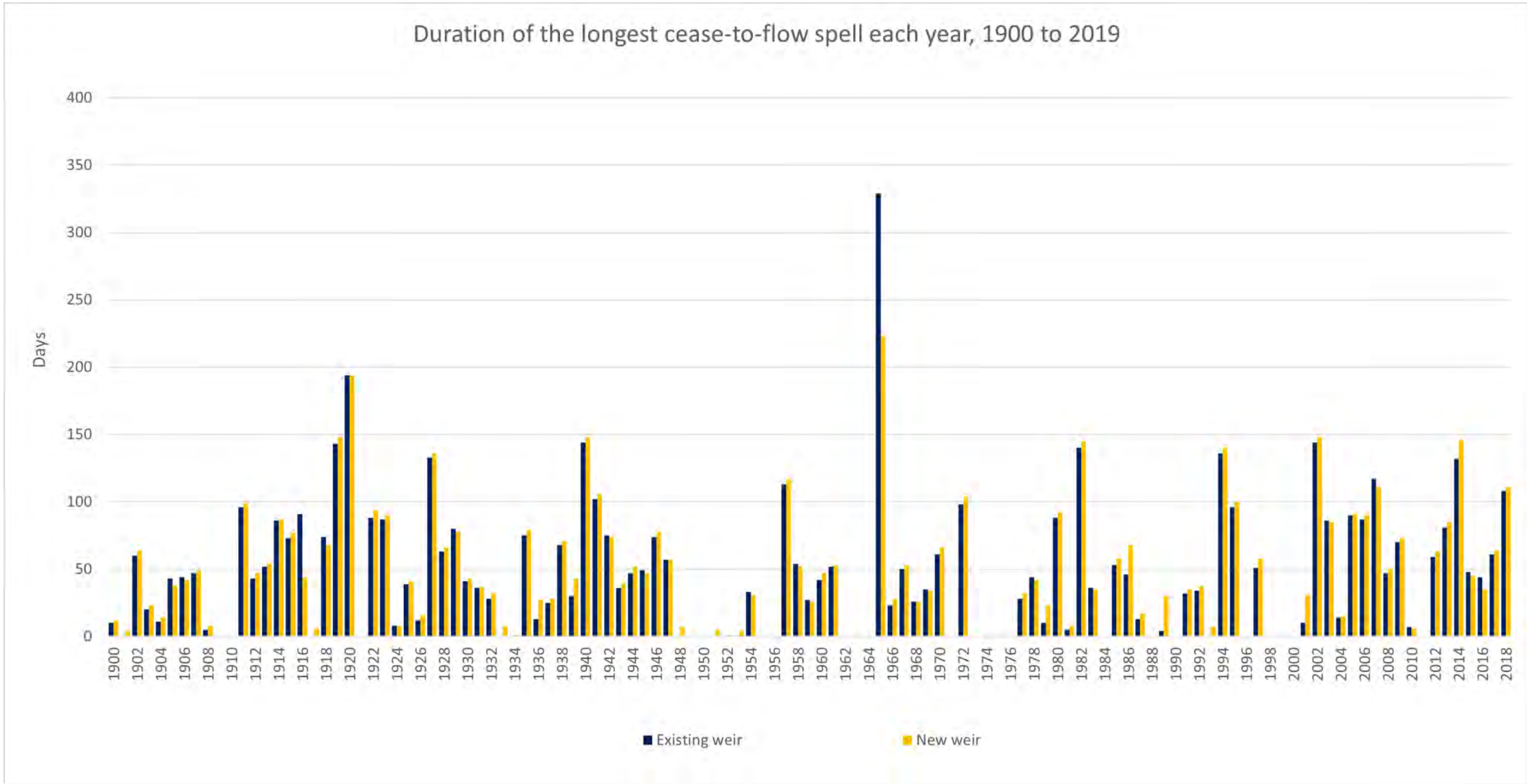


Figure 5-5 Duration of the longest cease-to-flow spells each year for the 119-year simulation

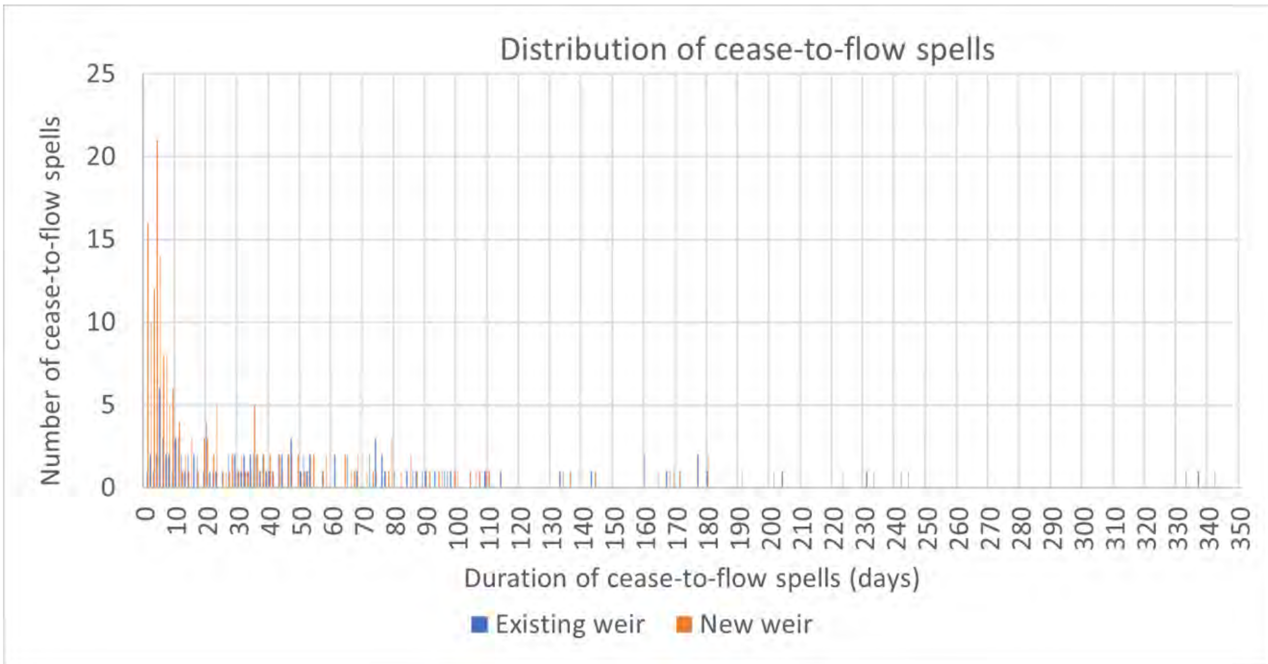


Figure 5-6 Comparison of the duration of cease-to-flow spells for the new and existing weirs for the 119-year simulation

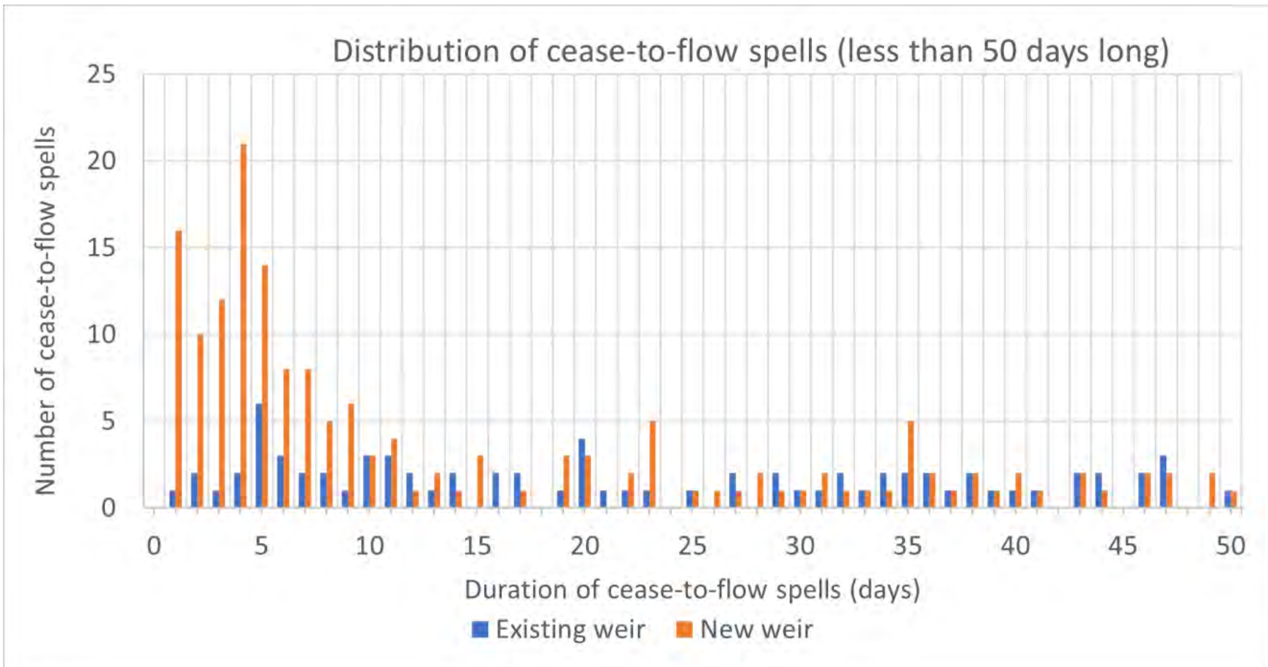


Figure 5-7 Comparison of the duration of cease-to-flow spells of less than 50 days for the new and existing weirs for the 119-year simulation

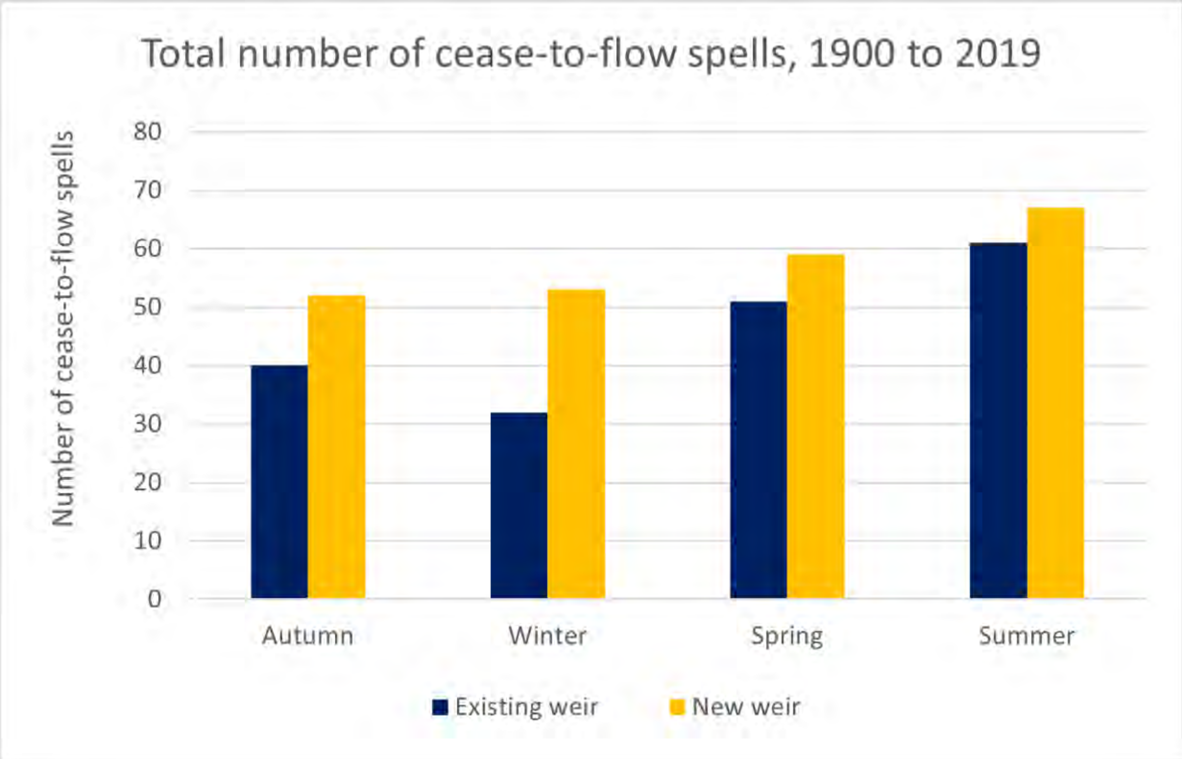


Figure 5-8 Total number of cease-to-flow spells by season for the 119-year simulation

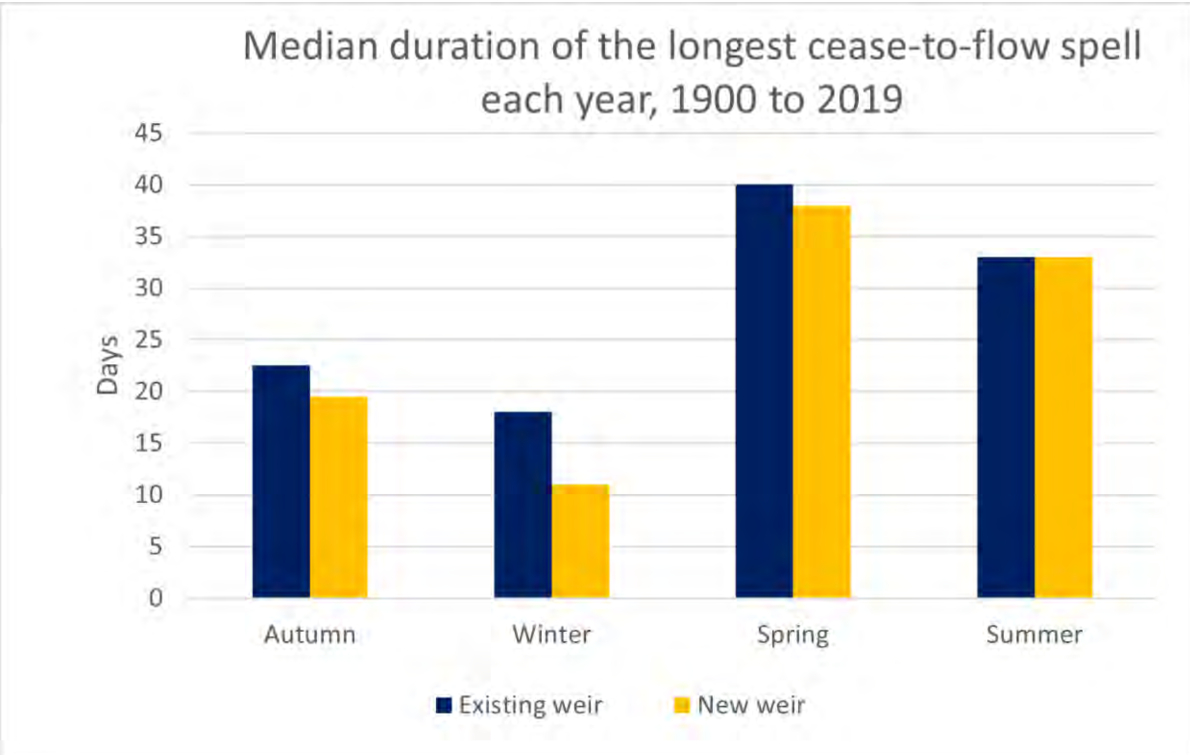


Figure 5-9 Median duration of the longest cease-to-flow spell by season for each year of the 119-year simulation

Very-low-flow spells

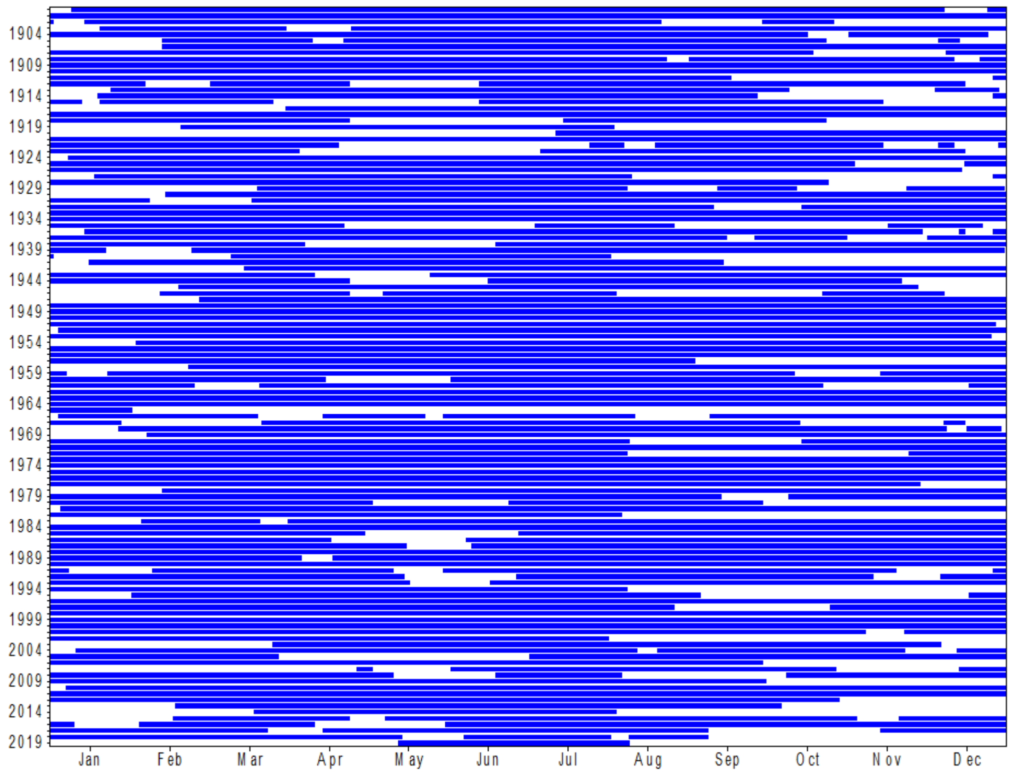
The *Barwon-Darling Long Term Water Plan Part B* (Department of Planning, Industry and Environment, 2020b) defines very-low-flow conditions in the Wilcannia to Lake Wetherell planning unit as flows of more than 30 megalitres per day (refer to **Table 2-1**). A downstream spell analysis of very-low-flows predicted using the storage behaviour water balance model for the existing and new weirs is provided in **Table 5-3**.

Very-low-flow spell plots for the 119-year simulation period are provided in **Figure 5-10** for the existing and new weirs (simulations 1 and 3 respectively). Alteration in very-low-flow spells caused by the new weir is similar to that for cease-to-flow spells, with the number of very-low-flow spells increasing but the mean duration of these spells decreasing. This is attributed to the new weir interrupting some very-low-flow spells due to the filling phase being triggered, with the flow resuming when the weir has filled and the translucency rule is implemented. However, the net result of the predicted increase in the number of very-low-flow spells but decrease in their duration is minor, with the total number of days of very-low-flow spells largely the same across the 119-year simulation period, reducing slightly from 35,915 days to 35,468 days.

Table 5-3 Predicted very-low-flow spell characteristics downstream of the new and existing weirs over the simulation period, 1900 to 2019

Spell characteristics	**Simulation 1** (Existing weir with dynamic storage behaviour and existing demand for town water)	**Simulation 3** (Proposed new weir with all operating rules and future demand for town water)	**Change in spell characteristic**
Number of very-low-flow spells	136	235	+99 (+73%)
Number of years with at least one very-low-flow spell	119	119	No change
Longest very-low-flow spell (days)	1,830	1,830	No change
Mean duration of very-low-flow spells (days)	264	151	-113 (-43%)
Mean period between very-low-flow spells (days)	57	35	-22 (-39%)
Longest period between very-low-flow spells (days)	344	345	+1 (0%)
Total duration of very-low-flow spells over the 119-year simulation period (days)	35,915	35,468	-447 (-1%)

Existing weir



New weir

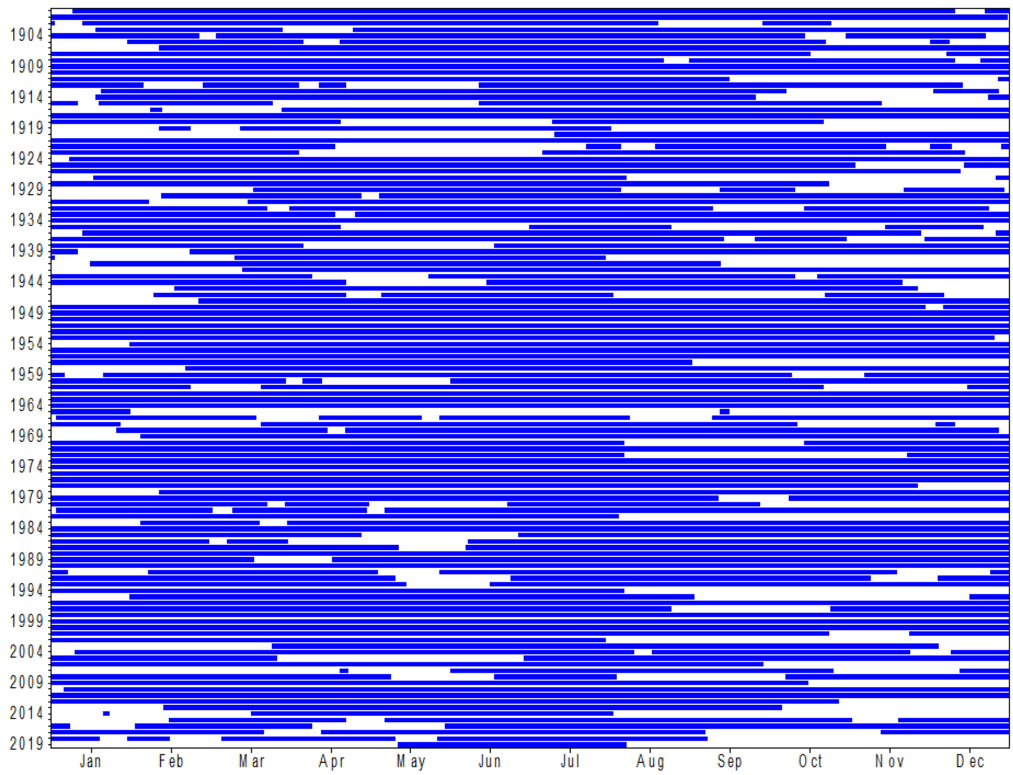


Figure 5-10 Plots of very-low-flow spells (blue lines) for the existing and new weirs for the 119-years simulation, 1900 to 2019

Base flow 1 and base flow 2 spells

The *Barwon-Darling Long Term Water Plan Part B* (Department of Planning, Industry and Environment, 2020b) defines base flow conditions in the Wilcannia to Lake Wetherell planning unit as flows of more than 350 megalitre per day (refer to **Table 2-1**). A distinction is drawn between base flow events that occur between September and March (base flow 2 events) and those that occur at any time throughout the year (base flow 1 events). A downstream spell analysis of base flow 1 and base flow 2 predicted using the storage behaviour water balance model for the existing and new weirs is provided in **Table 5-4** and **Table 5-5** respectively.

Base flow 1 spell plots for the 119-year simulation period are provided in **Figure 5-11** for the existing and new weirs (simulations 1 and 3 respectively). The number of base flow 1 spells would increase by about one-half, but the mean duration of these events would decrease by about 32 per cent, resulting in a small increase in the total duration of base flow 1 spells across the 119-year simulation period, from 28,001 days to 28,854 days.

Base flow 2 spell plots for the 119-year simulation period are provided in **Figure 5-13** for the existing and new weirs (simulations 1 and 3 respectively). The number of base flow 2 events would increase by about one-third, but the mean duration of these events would only decrease by about nine per cent, resulting in an increase in the total duration of base flow 2 spells across the 119-year simulation period, from 21,052 days to 25,598 days.

The predicted changes in base flow behaviour are attributed to the application of the translucency rule during drought security operation mode, which would result in discharges from the new weir when there are inflows to the new town pool and Pool 1, whereas some of these flows would not have passed the existing weir.

Table 5-4 Predicted base flow 1 spell characteristics downstream of the new and existing weirs over the simulation period, 1900 to 2019

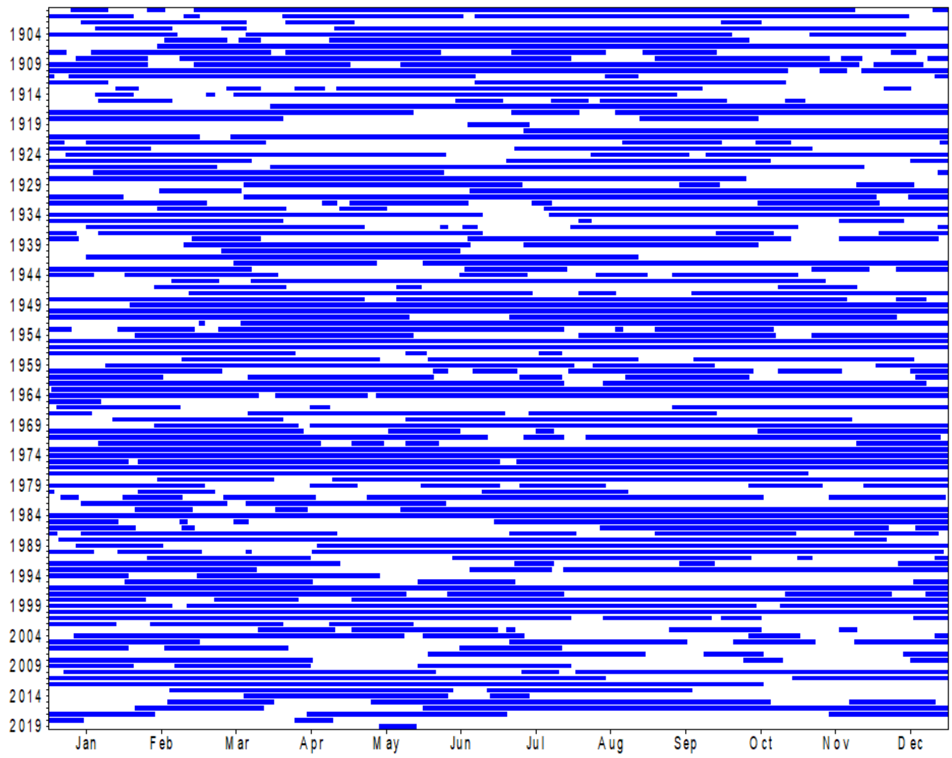
Spell characteristics	**Simulation 1** (Existing weir with dynamic storage behaviour and existing demand for town water)	**Simulation 3** (Proposed new weir with all operating rules and future demand for town water)	**Change in spell characteristic**
Number of base flow 1 spells	283	430	+147 (+52%)
Number of years with at least one base flow 1 spell	119	119	No change
Longest base flow 1 spell (days)	886	954	+68 (+8%)
Mean duration of base flow 1 spells (days)	99	67	-32 (-32%)
Mean period between base flow 1 spells (days)	55	34	-21 (-38%)
Longest period between base flow 1 spells (days)	384	384	No change
Total duration of base flow 1 spells over the	28,001	28,854	+853 (+3%)

Spell characteristics	Simulation 1 (Existing weir with dynamic storage behaviour and existing demand for town water)	Simulation 3 (Proposed new weir with all operating rules and future demand for town water)	Change in spell characteristic
119-year simulation period (days)			

Table 5-5 Predicted base flow 2 spell characteristics downstream of the new and existing weirs over the simulation period, 1900 to 2019

Spell characteristics	Simulation 1 (Existing weir with dynamic storage behaviour and existing demand for town water)	Simulation 3 (Proposed new weir with all operating rules and future demand for town water)	Change in spell characteristic
Number of base flow 2 spells	271	361	+90 (+33%)
Number of years with at least one base flow 2 spell	117	117	No change
Longest base flow 2 spell (days)	214	214	No change
Mean duration of base flow 2 spells (days)	78	71	-7 (-9%)
Mean period between base flow 2 spells (days)	57	42	-15 (-26%)
Longest period between base flow 2 spells (days)	208	208	No change
Total duration of base flow 2 spells over the 119-year simulation period (days)	21,052	25,598	+4,546 (+22%)

Existing weir



New weir

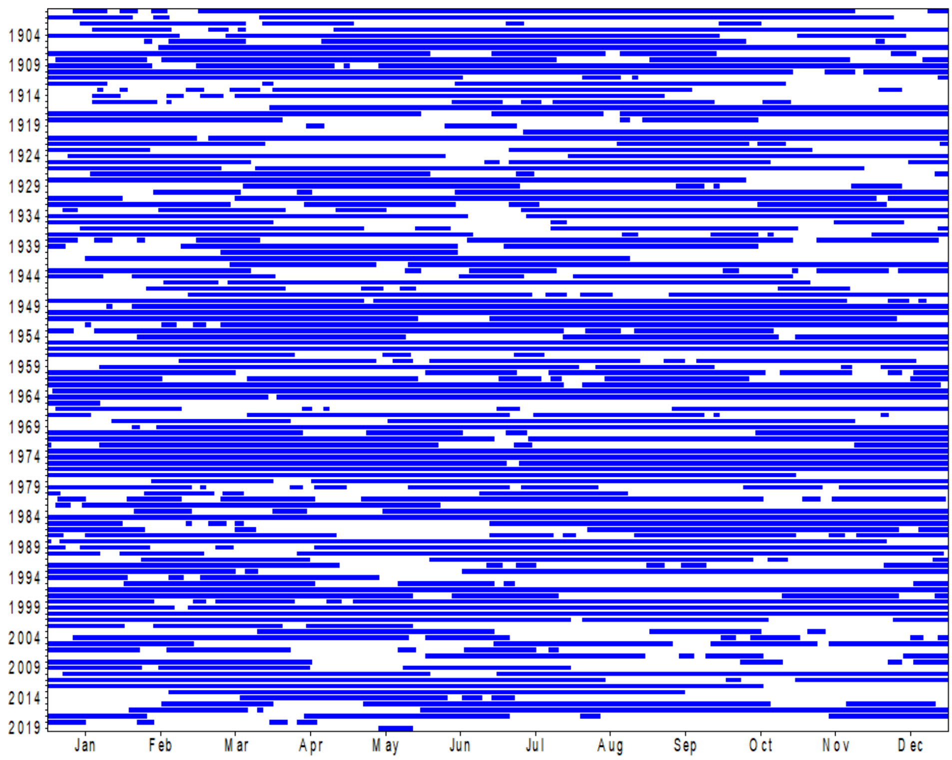
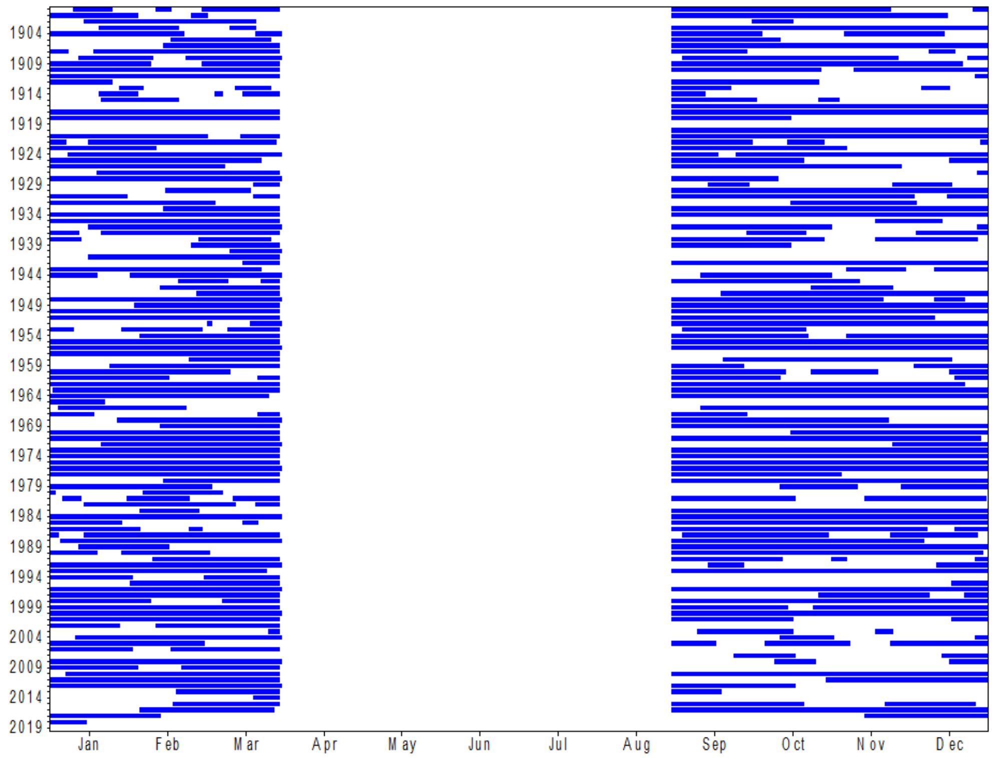


Figure 5-11 Plots of base flow 1 spells (blue lines) for the existing and new weirs for the 119-years simulation, 1900 to 2019

Existing weir



New weir

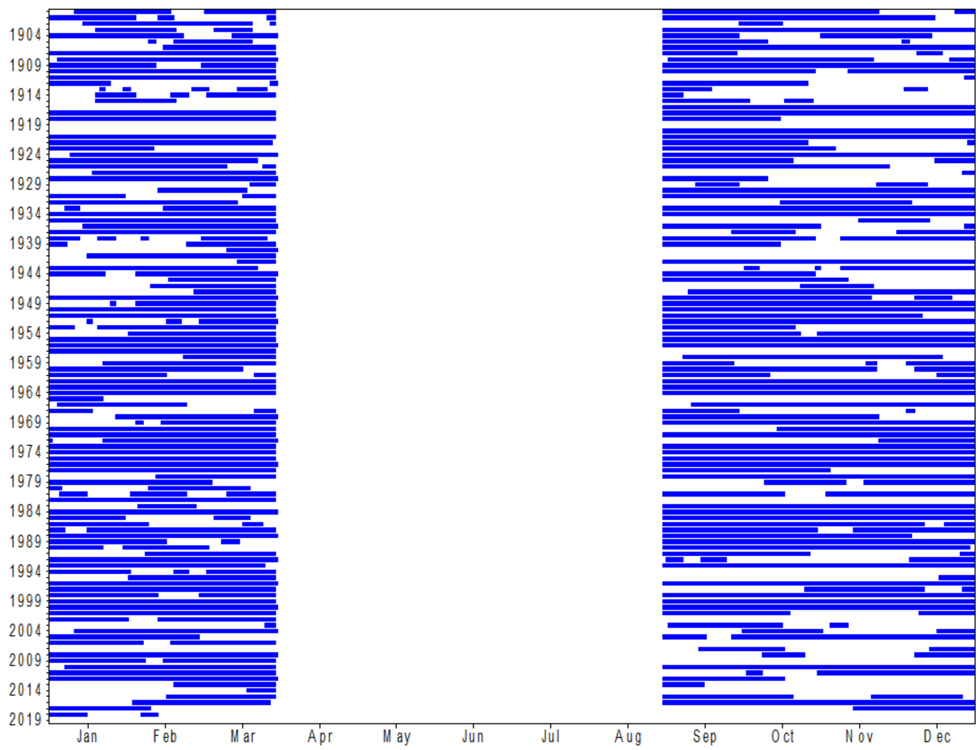


Figure 5-12 Plots of base flow 2 spells (blue lines) for the existing and new weirs for the 119-years simulation, 1900 to 2019

Small fresh 1 and small fresh 2 spells

The *Barwon-Darling Long Term Water Plan Part B* (Department of Planning, Industry and Environment, 2020b) defines small fresh conditions in the Wilcannia to Lake Wetherell planning unit as flows of more than

1400 megalitre per day (refer to **Table 2-1**). A distinction is drawn between small fresh flows that occur anytime but ideally between October and April (small fresh 1 flows) and those that occur in a slightly longer period between September and April (small fresh 2 flows). The ideal timeframe for the small fresh 1 environmental water requirement is shorter than that for small fresh 2 flows and therefore is the more stringent of the two requirements. Downstream spells analyses of small fresh 1 and small fresh 2 flows predicted using the Barwon-Darling River System Model for the existing and new weirs are provided in **Table** 5-6 and **Table 5-7** respectively.

Small fresh 1 and small fresh 2 spell plots for the 119-year simulation period are provided in **Figure 5-13** and Figure 5-14 respectively for the existing and new weirs (simulations 1 and 3 respectively). The proposal would result in very minor changes in small fresh 1 and small fresh 2 spells. This is due to small fresh 1 and small fresh 2 spells by definition involving flows that are likely to result in the new weir operating to optimise downstream flows.

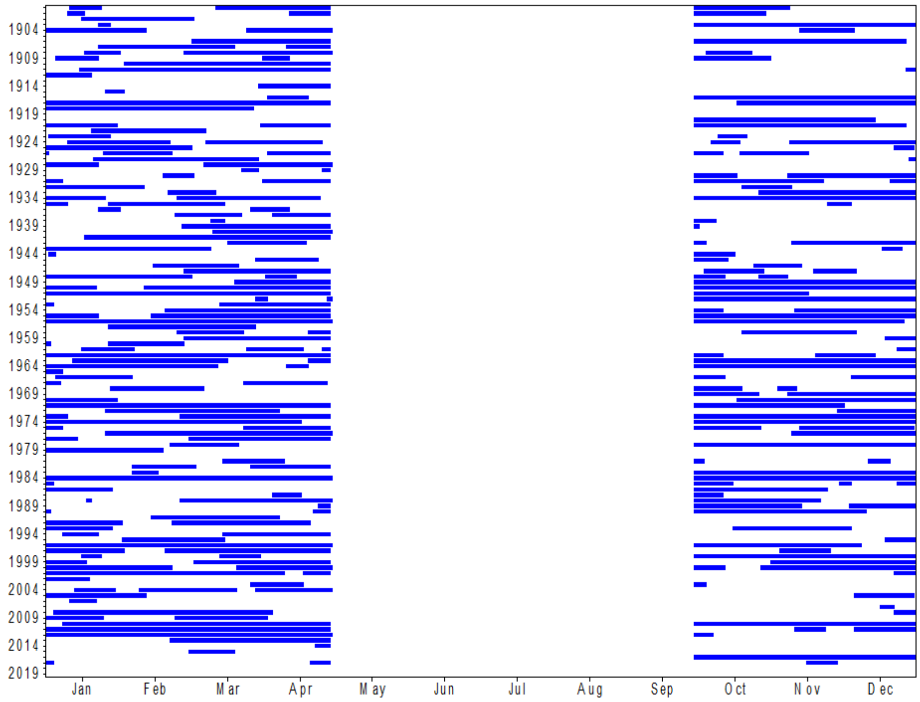
Table 5-6 Predicted small fresh 1 spell characteristics downstream of the new and existing weirs over the simulation period, 1900 to 2019

Spell characteristics	Simulation 1 (Existing weir with dynamic storage behaviour and existing demand for town water)	Simulation 3 (Proposed new weir with all operating rules and future demand for town water)	Change in spell characteristic
Number of small fresh 1 spells	190	192	+2 (+1%)
Number of years with at least one small fresh 1 spell	106	106	No change
Longest small fresh 1 spell (days)	214	214	No change
Mean duration of small fresh 1 spells (days)	59	58	-1 (-2%)
Mean period between small fresh 1 spells (days)	49	50	+1 (+2%)
Longest period between small fresh 1 spells (days)	164	165	+1 (+1%)
Total duration of small fresh 1 spells over the 119-year simulation period (days)	11,203	11,130	-73 (-1%)

Table 5-7 Predicted small fresh 2 spell characteristics downstream of the new and existing weirs over the simulation period, 1900 to 2019

Spell characteristics	**Simulation 1** (Existing weir with dynamic storage behaviour and existing demand for town water)	**Simulation 3** (Proposed new weir with all operating rules and future demand for town water)	**Change in spell characteristic**
Number of small fresh 2 spells	190	189	-1 (-1%)
Number of years with at least one small fresh 2 spell	106	106	No change
Longest small fresh 2 spell (days)	244	244	No change
Mean duration of small fresh 2 spells (days)	68	67	-1 (-1%)
Mean period between small fresh 2 spells (days)	63	62	-1 (-2%)
Longest period between small fresh 2 spells (days)	164	165	+1 (+1%)
Total duration of small fresh 2 spells over the 119-year simulation period (days)	12,835	12,670	-165 (-1%)

Existing weir



New weir

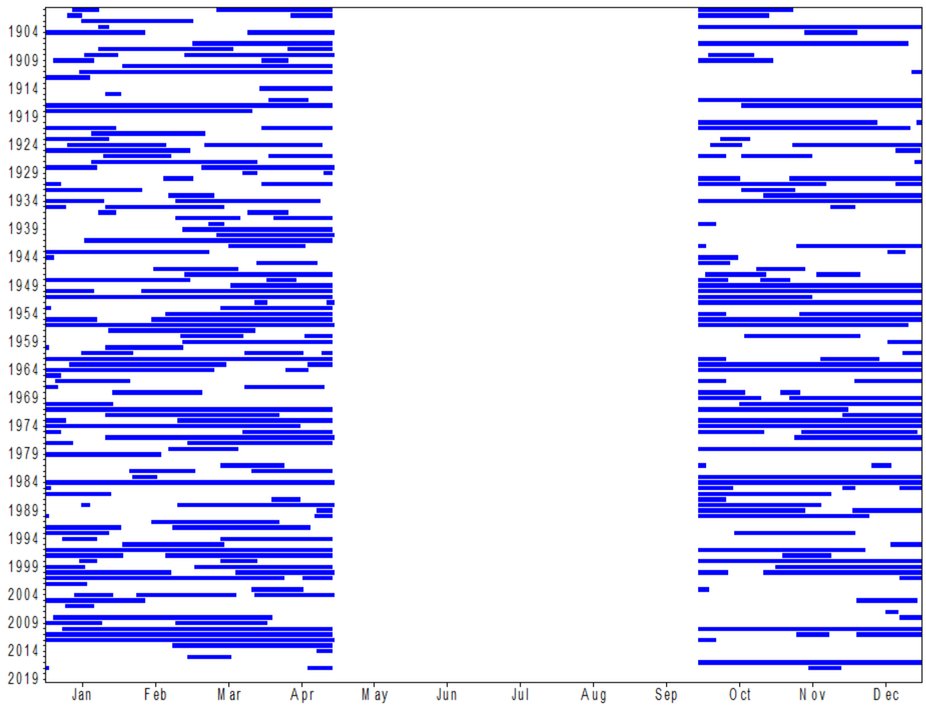


Figure 5-13 Plots of small fresh 1 spells (blue lines) for the existing and new weirs for the 119-years simulation, 1900 to 2019

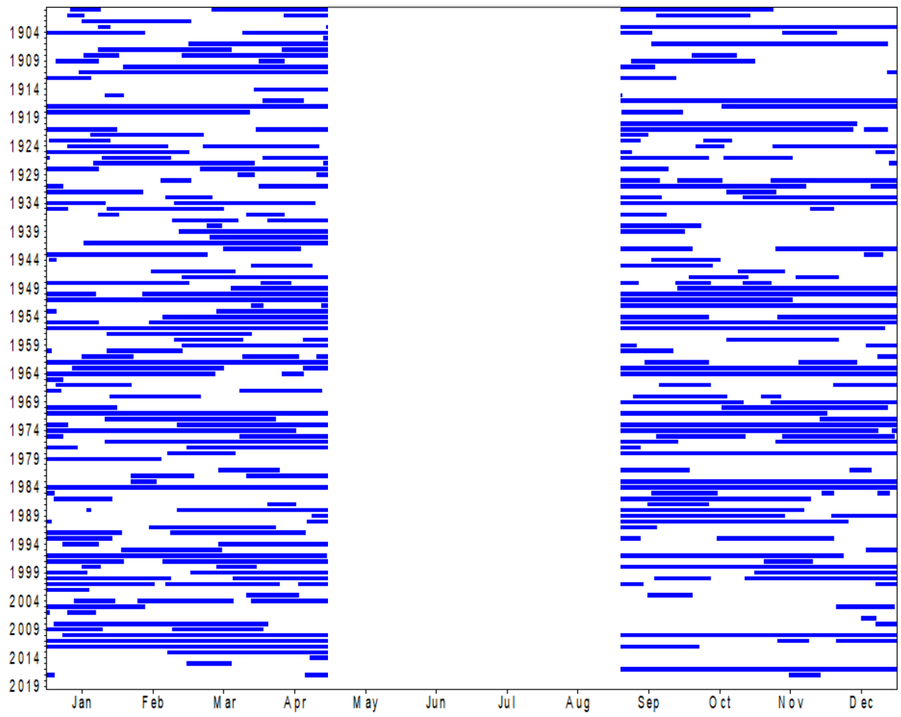
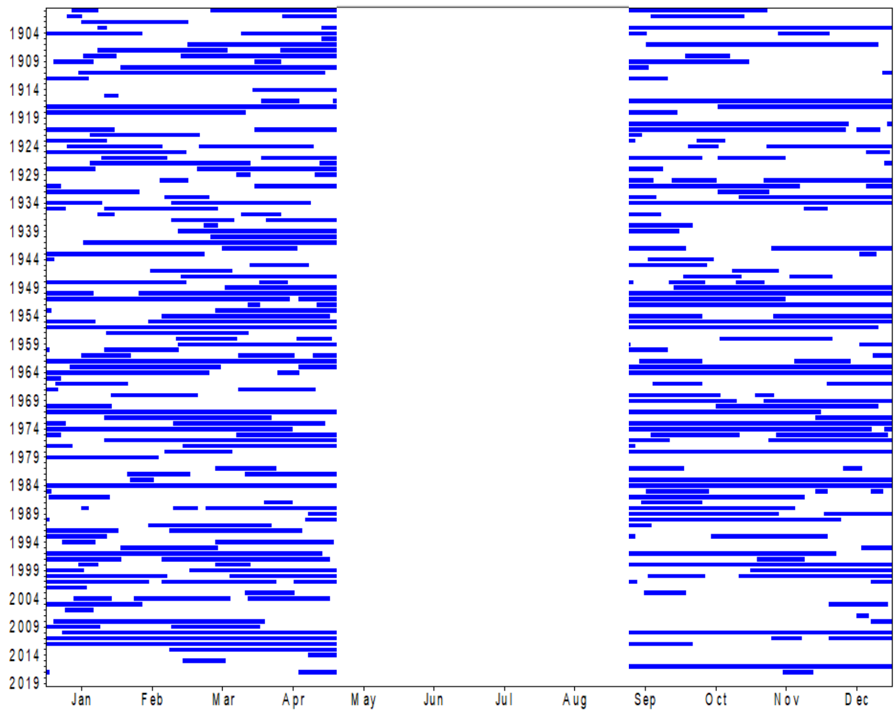
Existing weir	
New weir	

Figure 5-14 Plots of small fresh 2 spells (blue lines) for the existing and new weirs for the 119-years simulation, 1900 to 2019

Annual analysis

The environmental water requirements in the *Barwon-Darling Long Term Water Plan Part B* (Department of Planning, Industry and Environment, 2020b) are expressed in annual terms, whereas the preceding analysis focusses on results across the entire 119-year simulation period. To address this, the results of the simulation are presented in **Figure 5-15** to **Figure 5-19** for each full year of the simulation (1900 to 2018). The inter year results show similar changes in flow spell behaviour to the long-term results presented in the previous sections.

Change in number of spells per year, 1900 to 2018

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Small fresh 2
1900	0	0	1	1	0	0
1901	1	2	1	2	0	0
1902	1	1	2	2	0	0
1903	1	0	1	1	0	0
1904	2	2	1	1	0	0
1905	2	3	3	2	0	0
1906	0	0	0	0	0	0
1907	1	1	0	1	0	0
1908	3	2	0	-1	0	0
1909	0	1	3	1	0	0
1910	0	0	1	0	0	0
1911	1	2	2	1	0	0
1912	1	1	3	3	0	0
1913	4	3	3	3	0	0
1914	2	1	3	1	0	0
1915	2	1	4	2	0	0
1916	1	1	0	0	0	0
1917	1	1	1	0	0	0
1918	0	0	1	0	0	0
1919	4	4	1	0	0	0
1920	0	0	0	0	0	0
1921	0	0	0	0	0	0
1922	2	2	1	2	0	0
1923	0	0	2	1	0	0
1924	0	0	2	0	0	0
1925	0	0	2	2	1	0
1926	0	0	0	0	0	0
1927	2	2	1	0	0	0
1928	0	0	1	1	0	0
1929	1	1	1	2	0	0
1930	1	1	2	0	0	0
1931	0	1	0	1	0	0
1932	3	3	1	1	0	0
1933	2	0	3	0	0	0
1934	1	1	1	0	0	0
1935	2	2	0	0	0	0
1936	0	1	-1	0	0	0
1937	3	2	2	3	0	0
1938	0	0	3	2	0	0
1939	0	0	2	0	0	0

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Small fresh 2
1940	1	1	0	0	0	0
1941	1	1	0	0	0	0
1942	0	0	1	1	0	0
1943	2	3	6	3	0	0
1944	2	2	2	1	0	0
1945	0	0	2	1	0	0
1946	2	2	2	0	0	0
1947	0	0	3	1	0	0
1948	1	1	2	2	0	0
1949	0	0	1	0	0	0
1950	0	0	0	0	0	0
1951	2	1	0	2	0	0
1952	1	0	2	1	0	0
1953	1	-1	3	1	0	0
1954	1	1	1	0	0	0
1955	0	0	0	0	0	0
1956	0	0	0	0	0	0
1957	2	3	2	0	0	0
1958	0	0	3	2	0	0
1959	0	0	1	1	0	0
1960	1	1	2	1	0	0
1961	1	1	2	1	0	0
1962	0	0	-1	-1	0	0
1963	0	0	0	0	0	0
1964	0	0	-1	0	0	0
1965	1	1	0	0	0	0
1966	2	2	2	0	0	0
1967	0	0	2	2	0	0
1968	2	1	1	2	0	0
1969	0	0	0	0	0	0
1970	2	2	2	0	0	0
1971	0	0	0	0	0	0
1972	1	1	4	0	0	0
1973	0	0	-1	0	0	0
1974	0	0	0	-1	0	0
1975	0	0	-1	-1	0	0
1976	0	0	-1	0	0	0
1977	0	0	1	2	0	0
1978	1	1	1	1	0	0
1979	2	3	3	2	0	0

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Small fresh 2
1980	1	1	2	0	0	0
1981	1	1	2	3	0	0
1982	1	1	1	0	0	0
1983	0	0	1	0	0	0
1984	0	0	0	1	0	0
1985	1	1	1	0	0	0
1986	1	2	0	0	0	0
1987	0	0	5	2	0	0
1988	0	0	2	4	0	0
1989	1	1	3	0	0	0
1990	0	0	0	0	0	0
1991	1	1	1	0	0	0
1992	1	2	3	2	0	0
1993	1	-1	0	1	0	0
1994	1	1	1	0	0	0
1995	0	-1	2	0	0	0
1996	0	0	0	0	0	0
1997	1	1	0	1	0	0
1998	0	0	2	0	0	0
1999	0	0	1	1	0	0
2000	0	0	0	0	0	0
2001	0	0	0	0	0	-1
2002	0	0	1	0	0	0
2003	2	2	1	2	0	0
2004	1	1	3	3	0	0
2005	2	3	4	2	0	0
2006	2	2	1	0	0	0
2007	-1	0	2	2	0	0
2008	0	0	2	2	0	0
2009	0	0	1	0	0	0
2010	1	1	-1	0	0	0
2011	0	0	2	1	0	0
2012	0	0	0	0	0	0
2013	1	1	1	0	0	0
2014	1	2	0	0	0	0
2015	0	0	2	3	0	0
2016	1	0	0	0	1	0
2017	3	3	1	1	0	0
2018	2	2	3	0	0	0

0	No change in number of spells compared to the existing weir
1	Increase in number of spells compared to the existing weir
-1	Decrease in number of spells compared to the existing weir

Figure 5-15 Change in number of spells per year compared to the existing weir, 1900 to 2018

Change in mean spell duration, 1900 to 2018 (days)

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1900	1	3	-14	-9	-1
1901	4	-245	-13	-44	-1
1902	-5	-23	-12	-7	0
1903	-4	-1	-24	-29	-1
1904	1	-89	-23	-6	-1
1905	-7	-41	-34	-22	0
1906	-2	2	-1	3	-1
1907	-22	-53	4	-3	-1
1908	0	-47	3	9	0
1909	0	-183	-21	-14	0
1910	0	0	-29	2	0
1911	-45	-68	-16	-4	-1
1912	-3	-25	-44	-13	0
1913	-24	-86	-14	-5	0
1914	-24	-44	-21	-5	0
1915	-13	-21	-10	-6	-1
1916	-50	-135	0	0	0
1917	6	-186	-22	0	-1
1918	-2	-1	-23	0	0
1919	-60	-57	-7	0	0
1920	0	1	0	4	0
1921	0	0	4	4	-1
1922	-6	-14	-2	-11	0
1923	4	-1	-41	-26	-1
1924	0	0	-37	3	1
1925	2	0	-27	-32	-6
1926	4	-2	4	1	0
1927	-35	-55	-23	1	0
1928	3	-1	-144	-10	0
1929	-10	-19	-14	-7	-1
1930	-17	-55	-54	2	0
1931	1	-54	4	-24	-1
1932	-15	-105	-3	-14	0
1933	5	-2	-37	0	-1
1934	1	-183	-55	0	-1
1935	-18	-28	0	1	1
1936	5	-29	15	3	-1
1937	-6	-28	-16	-8	0
1938	3	0	-21	-15	0
1939	13	-5	-50	0	-1

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1940	-31	-27	-1	0	0
1941	-17	-124	-3	1	-1
1942	-1	1	-43	-104	-1
1943	-18	-99	-24	-18	0
1944	-17	-71	-9	-1	-1
1945	1	1	-62	-21	-1
1946	-9	-29	-12	-1	0
1947	0	1	-41	-31	0
1948	7	-187	-42	-20	0
1949	0	0	-165	0	0
1950	0	0	0	0	-1
1951	4	-184	6	-12	-1
1952	1	3	-68	-11	-1
1953	4	61	-14	-8	0
1954	-17	-165	-18	4	-1
1955	0	0	0	0	0
1956	0	0	0	0	-1
1957	-72	-188	-16	1	0
1958	-2	2	-40	-19	1
1959	1	2	-21	-19	0
1960	-16	-56	-4	-5	-1
1961	-10	-25	-10	-24	0
1962	0	0	65	37	0
1963	0	0	-1	4	-2
1964	0	0	63	0	-1
1965	-165	-15	0	1	-1
1966	-3	-27	-21	0	-1
1967	4	-1	-26	-24	-2
1968	-5	-57	-39	-32	-1
1969	-1	3	4	0	-1
1970	-36	-78	-17	1	0
1971	0	0	4	2	-1
1972	-43	-45	-16	1	0
1973	0	0	183	0	-1
1974	0	0	0	109	0
1975	0	0	62	109	0
1976	0	0	185	0	0
1977	4	-2	-157	-29	0
1978	-21	-162	-46	-95	-1
1979	-1	-103	-11	-10	0

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1980	-16	-21	-11	1	0
1981	3	-61	-14	-15	0
1982	-66	-113	-9	0	-1
1983	2	1	-20	0	0
1984	0	0	0	-12	-1
1985	-22	-53	-9	4	-1
1986	-9	-85	4	1	-1
1987	4	-1	-16	-13	0
1988	0	0	-225	-43	-2
1989	13	-66	-85	2	-1
1990	0	0	3	1	-1
1991	-7	-15	-7	1	-1
1992	0	-41	-17	-15	-2
1993	7	56	2	-30	0
1994	-66	-112	-17	0	-1
1995	2	38	-17	0	-1
1996	0	0	0	0	-1
1997	-21	-52	0	-4	-2
1998	0	0	-40	0	-1
1999	0	0	-27	-32	0
2000	0	0	0	0	0
2001	21	-8	6	4	-1
2002	4	-2	-8	0	-1
2003	-24	-173	-3	-10	0
2004	-4	-26	-21	-14	-2
2005	-58	-82	-24	-7	1
2006	-55	-69	-3	0	0
2007	23	-1	-16	-33	-1
2008	4	-2	-18	-7	-1
2009	3	15	-9	0	0
2010	-2	-181	60	0	0
2011	0	0	-72	-24	1
2012	4	-1	0	0	-1
2013	-22	-114	-31	-1	0
2014	-16	-92	2	1	-1
2015	2	0	-32	-24	0
2016	-10	0	0	-3	-44
2017	-19	-49	-13	-27	0
2018	-19	-22	-7	0	0

	One day or less change in mean spell duration compared to the existing weir
5	Increase of more than one day in mean spell duration compared to the existing weir
-5	Decrease of more than one day in mean spell duration compared to the existing weir

Figure 5-16 Change in mean duration of spells per year compared to the existing weir, 1900 to 2018

Change in total spell duration, 1900 to 2018 (days)

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1900	2	5	6	6	-1	1940	11	-7	-1	0	0	1980	18	-10	6	3	0
1901	4	-5	7	-2	-2	1941	8	-6	-3	1	-1	1981	12	-7	10	17	0
1902	15	-8	15	3	0	1942	-1	1	5	-2	-1	1982	9	-6	10	0	-1
1903	7	-3	2	6	-1	1943	17	-15	10	12	0	1983	3	1	6	0	0
1904	15	-10	6	-2	-1	1944	15	-9	9	17	-2	1984	0	0	0	6	-1
1905	5	1	1	-1	0	1945	1	1	6	-2	-2	1985	10	-6	8	7	-1
1906	-2	2	-1	6	-3	1946	17	-8	4	-3	0	1986	29	-25	15	4	-1
1907	3	-2	25	14	-1	1947	0	1	10	6	-1	1987	4	-1	16	11	-1
1908	14	-6	13	6	-1	1948	7	-7	6	0	1	1988	0	0	-1	6	-2
1909	0	-1	17	10	0	1949	0	0	1	0	0	1989	29	-22	9	3	-1
1910	0	0	1	6	0	1950	0	0	0	0	-1	1990	0	0	9	2	-2
1911	6	-7	-1	3	-1	1951	7	-5	12	19	-1	1991	8	-7	13	4	-2
1912	15	-9	10	0	0	1952	1	3	19	16	-1	1992	17	-7	9	6	-2
1913	6	-4	6	2	0	1953	4	4	30	2	0	1993	7	2	5	4	0
1914	6	-3	3	-7	0	1954	0	1	11	8	-2	1994	5	-3	4	0	-1
1915	16	-7	6	-3	-1	1955	0	0	0	0	0	1995	3	0	2	0	-1
1916	-8	6	0	0	0	1956	0	0	0	0	-2	1996	0	0	0	0	-2
1917	6	-6	17	0	-1	1957	11	-10	1	1	0	1997	10	-4	-1	8	-3
1918	-3	-1	3	0	0	1958	-2	2	13	8	1	1998	0	0	12	0	-1
1919	25	-21	11	0	0	1959	1	6	5	8	0	1999	0	0	7	7	0
1920	0	1	0	8	-1	1960	11	-8	36	12	-1	2000	0	0	0	0	-1
1921	0	0	8	7	-2	1961	7	-4	7	1	0	2001	21	-16	23	17	-1
1922	23	-10	14	3	0	1962	0	0	17	8	-1	2002	4	-2	8	0	-1
1923	7	-2	-2	-3	-2	1963	0	0	-1	4	-2	2003	10	-9	7	5	0
1924	0	0	10	6	1	1964	0	0	7	0	-1	2004	1	5	1	5	-2
1925	2	0	3	6	9	1965	0	2	0	1	-1	2005	6	-4	14	18	1
1926	4	-2	8	1	-1	1966	15	-9	8	0	-3	2006	10	-8	8	0	0
1927	11	-11	4	1	0	1967	13	-3	0	0	-2	2007	26	-3	4	3	-1
1928	3	-1	-3	-3	0	1968	10	-6	10	2	-1	2008	12	-7	3	13	-2
1929	10	-7	-7	-6	-1	1969	-1	3	7	0	-2	2009	3	15	14	0	0
1930	8	-6	12	3	0	1970	14	-12	8	1	0	2010	3	-3	15	0	0
1931	1	0	11	15	-2	1971	0	0	11	3	-2	2011	0	0	2	5	1
1932	24	-25	19	7	0	1972	12	-6	23	1	0	2012	4	-1	0	0	-1
1933	9	-4	11	0	-1	1973	0	0	1	0	-1	2013	0	3	6	-2	0
1934	1	-1	4	0	-1	1974	0	0	0	4	0	2014	7	1	5	2	-1
1935	4	-5	-1	4	1	1975	0	0	6	4	-1	2015	5	-1	2	-5	0
1936	16	-8	15	8	-1	1976	0	0	4	0	0	2016	3	-1	0	-3	9
1937	16	-10	11	9	0	1977	4	-2	-4	-3	0	2017	20	-15	7	8	0
1938	3	0	14	14	0	1978	2	-3	9	-3	-1	2018	37	-22	9	0	0
1939	13	-10	12	0	-1	1979	12	-7	10	17	0						

	One day or less change in total duration of spells compared to the existing weir
5	Increase of more than one day in total duration of spells compared to the existing weir
-5	Decrease of more than one day in total duration of spells compared to the existing weir

Figure 5-17 Change in total spell duration per year compared to the existing weir, 1900 to 2018

Change in longest spell duration, 1900 to 2018 (days)

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1900	2	3	-2	0	-1
1901	4	-80	72	-6	-1
1902	4	-32	0	1	0
1903	3	0	0	1	-1
1904	3	-78	-6	5	-1
1905	-5	1	-2	-1	0
1906	-2	2	-1	0	-2
1907	2	-133	6	7	0
1908	3	-25	2	10	0
1909	0	-135	9	1	1
1910	0	0	1	0	0
1911	3	-89	-5	-1	-1
1912	4	-1	-6	-6	0
1913	2	-34	-4	-4	0
1914	1	-16	-6	-4	0
1915	4	-13	-5	-5	-1
1916	-47	2	0	0	0
1917	6	-161	3	0	-1
1918	-6	-4	0	0	0
1919	5	-43	4	0	0
1920	0	1	0	-1	-2
1921	0	0	9	0	-1
1922	6	-19	7	-5	0
1923	3	-1	-3	-1	0
1924	0	0	-7	7	0
1925	2	-1	-7	3	-1
1926	4	-2	6	0	0
1927	3	-63	-4	1	1
1928	3	-1	-5	-5	0
1929	-2	-24	-1	-5	-1
1930	2	-121	6	0	0
1931	1	-22	3	0	-1
1932	4	-155	1	3	1
1933	8	1	0	0	-1
1934	1	-175	-6	0	-1
1935	4	-18	-4	2	1
1936	14	-165	2	9	-1
1937	3	-54	5	3	0
1938	3	1	1	1	0
1939	13	1	-4	0	-1

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1940	4	-47	-1	0	0
1941	4	-18	-3	1	-1
1942	-1	1	6	-5	-1
1943	4	-119	-5	-3	0
1944	5	-19	-4	5	-1
1945	-2	1	-6	-6	-1
1946	4	-16	-3	0	0
1947	0	1	0	-1	0
1948	7	-31	-1	0	2
1949	0	0	-1	0	-1
1950	0	0	0	0	-2
1951	5	-162	8	0	-1
1952	1	3	8	1	-1
1953	4	-2	7	-1	0
1954	-2	-117	-4	7	0
1955	0	0	0	0	-1
1956	0	0	0	0	-1
1957	4	-111	0	1	-2
1958	-2	2	-5	-6	1
1959	-1	0	4	4	0
1960	5	1	13	-1	0
1961	1	-77	-6	2	0
1962	0	0	0	31	0
1963	0	0	-1	4	-2
1964	0	0	40	0	-1
1965	-106	-1	0	1	-1
1966	5	0	0	0	0
1967	3	-1	2	0	-2
1968	0	-87	2	-5	-1
1969	-1	3	62	0	-1
1970	5	-50	-6	1	1
1971	0	0	4	4	-1
1972	6	-19	-1	1	1
1973	0	0	137	0	-1
1974	0	0	0	58	-1
1975	0	0	13	77	0
1976	0	0	19	0	-1
1977	4	-2	-5	-5	0
1978	-2	-64	8	-5	-1
1979	13	-132	-5	2	0

Year	Cease-to-flow	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1980	4	-8	-5	-2	0
1981	3	-57	-6	-1	0
1982	5	-56	5	0	-1
1983	-1	1	7	0	0
1984	0	0	0	2	-1
1985	5	1	2	4	1
1986	22	0	9	4	-1
1987	4	3	-7	-1	1
1988	0	0	-7	-6	-2
1989	26	1	1	3	-1
1990	0	0	6	0	-1
1991	3	-13	1	1	-1
1992	4	-5	0	-2	-2
1993	7	1	41	0	0
1994	4	-51	-2	0	-1
1995	4	1	-5	0	-1
1996	0	0	0	0	0
1997	7	-28	3	0	-1
1998	0	0	-1	1	-1
1999	0	0	-1	-1	-1
2000	0	0	0	0	-1
2001	21	-15	0	1	-1
2002	4	-2	-2	0	-1
2003	-1	-117	6	0	0
2004	1	-32	2	-2	-2
2005	1	-86	-7	4	0
2006	3	-37	17	0	0
2007	-6	-1	1	0	-1
2008	3	-2	-6	3	-1
2009	3	15	6	0	0
2010	-1	-156	31	0	0
2011	0	0	-5	-1	1
2012	4	-1	0	0	-1
2013	4	-13	0	-3	0
2014	14	-21	29	2	-1
2015	-3	-2	-3	-4	0
2016	-9	1	5	-3	-2
2017	3	-60	2	1	0
2018	3	-20	1	0	0

	One day or less change in longest duration spell compared to the existing weir
5	Increase of more than one day in longest duration spell compared to the existing weir
-5	Decrease of more than one day in longest duration spell compared to the existing weir

Figure 5-18 Change in longest spell duration per year compared to the existing weir, 1900 to 2018

Change in longest duration between spells, 1900 to 2018 (days)

Year	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Year	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1	Year	Very-low-flow	Base flow 1	Base flow 2	Small fresh 1
1900	-5	-2	5	1	1940	0	0	0	0	1980	1	-13	-1	0
1901	4	3	0	1	1941	4	0	-1	0	1981	2	-8	-11	1
1902	1	-70	-1	0	1942	0	-6	2	0	1982	4	-9	0	0
1903	2	0	-9	1	1943	1	-32	9	0	1983	0	-5	0	0
1904	0	0	-8	0	1944	1	1	-1	1	1984	0	0	-1	0
1905	-3	25	-54	0	1945	0	-8	-3	1	1985	1	0	18	0
1906	0	0	-7	2	1946	2	2	3	1	1986	17	-30	-2	0
1907	1	0	0	1	1947	0	-8	-9	1	1987	1	0	-10	0
1908	0	3	3	0	1948	7	-3	-9	-1	1988	0	4	-11	0
1909	1	-3	-7	0	1949	0	8	0	0	1989	18	-30	-2	0
1910	0	0	0	0	1950	0	0	0	1	1990	0	-7	-2	1
1911	3	1	1	0	1951	5	-12	-46	0	1991	-1	1	9	1
1912	1	-75	-7	0	1952	0	14	-10	1	1992	1	-3	-3	0
1913	0	2	2	0	1953	-3	-12	-4	0	1993	1	-4	-11	0
1914	-1	1	1	0	1954	2	-3	-8	1	1994	1	-11	0	0
1915	0	-1	6	0	1955	0	0	0	0	1995	2	0	0	0
1916	46	0	0	0	1956	0	0	0	1	1996	0	0	0	1
1917	6	-11	0	0	1957	4	-4	-1	-1	1997	1	1	-1	2
1918	-1	-8	0	0	1958	0	-12	-3	0	1998	0	-12	0	1
1919	14	49	0	0	1959	-5	-14	-14	0	1999	0	-4	-8	0
1920	0	0	-8	1	1960	1	-9	0	0	2000	0	0	0	0
1921	0	-8	-7	1	1961	-1	-2	-2	0	2001	16	-11	-11	0
1922	0	-2	2	0	1962	0	-8	-5	1	2002	0	-7	0	0
1923	1	-2	1	1	1963	0	0	0	0	2003	4	0	13	0
1924	0	-9	-6	0	1964	0	-3	0	0	2004	-4	-5	-10	0
1925	0	-9	-1	1	1965	225	0	0	0	2005	-2	-5	-8	-1
1926	0	-8	-1	0	1966	3	-71	0	0	2006	0	-27	0	0
1927	3	-38	-1	0	1967	-1	2	-54	0	2007	1	0	0	0
1928	0	3	0	0	1968	-1	-10	-10	0	2008	2	-1	-9	1
1929	0	0	3	0	1969	0	2	0	0	2009	0	-6	0	0
1930	-38	-35	-3	0	1970	3	10	-1	1	2010	4	-8	0	0
1931	-1	-3	-8	1	1971	0	-2	-3	1	2011	0	-27	-27	0
1932	1	5	-39	1	1972	0	-40	-1	0	2012	0	0	0	0
1933	3	-9	0	0	1973	0	0	0	0	2013	1	-11	2	0
1934	1	-9	0	0	1974	0	0	0	0	2014	54	-11	-2	0
1935	0	-7	-2	-1	1975	0	-2	0	1	2015	2	-3	-2	0
1936	15	0	0	1	1976	0	0	0	1	2016	1	-1	0	108
1937	-1	-34	-6	0	1977	0	4	-2	0	2017	1	-38	21	0
1938	0	0	-12	0	1978	5	-8	4	0	2018	-4	-39	0	0
1939	10	25	0	0	1979	1	1	0	0					

	One day or less change in longest duration between spells compared to the existing weir
5	Increase of more than one day in longest duration between spells compared to the existing weir
-5	Decrease of more than one day in longest duration between spells compared to the existing weir

Figure 5-19 Change in longest duration between spells per year compared to the existing weir, 1900 to 2018

Flow alteration across the complete flow regime

An analysis of the alteration in the percentage of time a flow is exceeded was conducted to compare flows downstream of the new weir to those downstream of the existing weir for changes unrelated to the environmental water requirements and is presented in **Figure 5-20**. The figure shows that both increases and decreases in the frequency of downstream flows caused by the new weir are small and within two per cent of flows downstream of the existing weir. As indicated in the downstream low flow spell analysis, the changes to flows decrease with increasing flows and become less than half a per cent when flows exceed 1,400 ML/day. There is no change in the frequency of flows between the new and existing weirs for flows above about 2,500 ML/day.

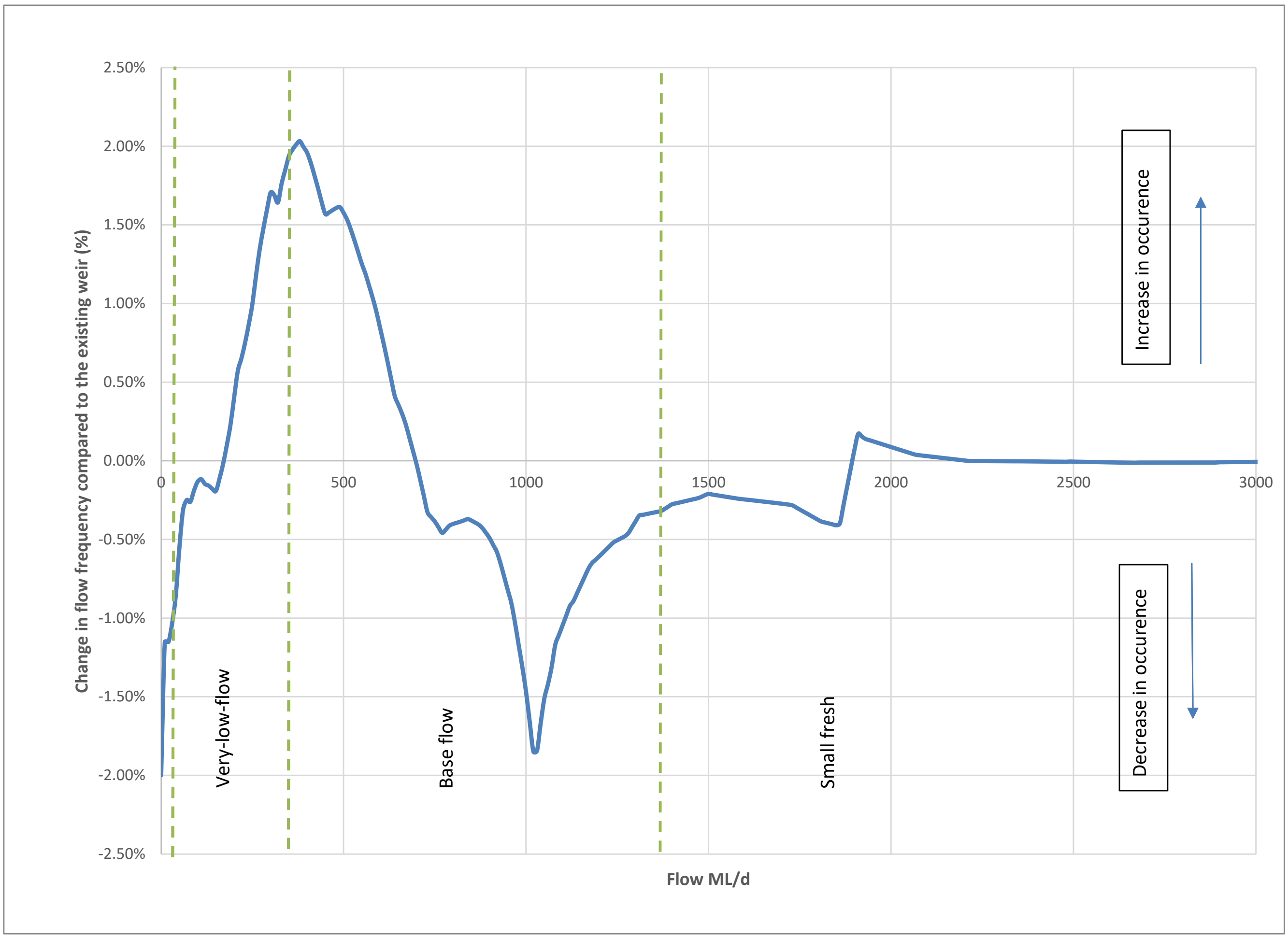


Figure 5-20 Overall flow regime alteration compared to the existing weir, for flows up to 3,000 ML/day

Resumption of flows rule

As discussed in **Section 2.2.3**, the main aim of the resumption of flows rule in the Barwon-Darling WSP is to protect the critical first flows after an extended low-flow or dry period. The rule is triggered when a flow event happens after a continuous period of no or low-flow conditions. It prevents water users from accessing the first flow down the Darling River (Baaka). Normal access conditions apply after the flow has reached a target flow at a specific point in the river. Extraction of water for town water supply is exempt from the resumption of flow rule in accordance with clause 49 of the Barwon-Darling WSP.

The access triggers for the Bourke to Wilcannia section of the river are:

- Access is not allowed for irrigation licenses when flows are less than 200 ML/day for 90 consecutive days at Wilcannia (gauging station no. 425008 (Wilcannia Main Channel) at Rock Bar)
- Access is allowed again for irrigation licenses when flows are greater than 400 ML/day for more than 10 consecutive days at Wilcannia (gauging station no. 425008 (Wilcannia Main Channel) at Rock Bar), or

a cumulative flow past Bourke (gauging station no. 425003 (Darling River at Bourke Town)) (since start of restriction) greater than 30 gigalitres.

The settings of the flow resumption rule triggers mean that there would be times when the new weir would be in the reset phase and filling while irrigation use is restricted. Analysis of the outputs of the storage behaviour water balance model for instances over the 119-year simulation period where the new weir would be in the reset phase and filling when irrigation use is restricted identified nine occasions where this occurred.

Changes in upstream water velocity

Hydrodynamic modelling was carried out by Public Works Advisory, on behalf of Water Infrastructure NSW, for nine flow rates ranging from 100 to 5,000 megalitres per day, when the new weir is in 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.

Longitudinal profiles of the modelled reach of the river upstream of the new weir are provided in **Figure 5-21** to **Figure 5-29** for flow rates between 100 and 5,000 megalitres per day. 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 point 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). The figures show that water velocity is greater and more variable upstream of the existing weir pool (upstream of chainage 61790) 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 as water flows over Bar 3 (chainage 49200), Bar 2 (chainage 30120) and Bar 1 (chainage 5430). Water velocities return to levels similar to those upstream of the existing weir pool when water spills over the existing weir and flows downstream (chainages -5000 to 0). The reduction in water velocities as water flows through the weir pool is more pronounced at low flow rates. As flow rates increase, existing water velocities in the weir pool are only slightly lower than those upstream of the weir pool, particularly at the upstream end of the weir pool.

The longitudinal profiles show that 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. However, elsewhere the impact of the new weir on water velocities would be 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 well less than 0.1 metres per second for all the modelled flow rates except at Bar 1 and Bar 2 when flow starts to exceed 600 megalitres per day. The figures show that the difference in the water velocities between the new and existing weirs is negligible upstream of the existing weir pool (chainage 61790).

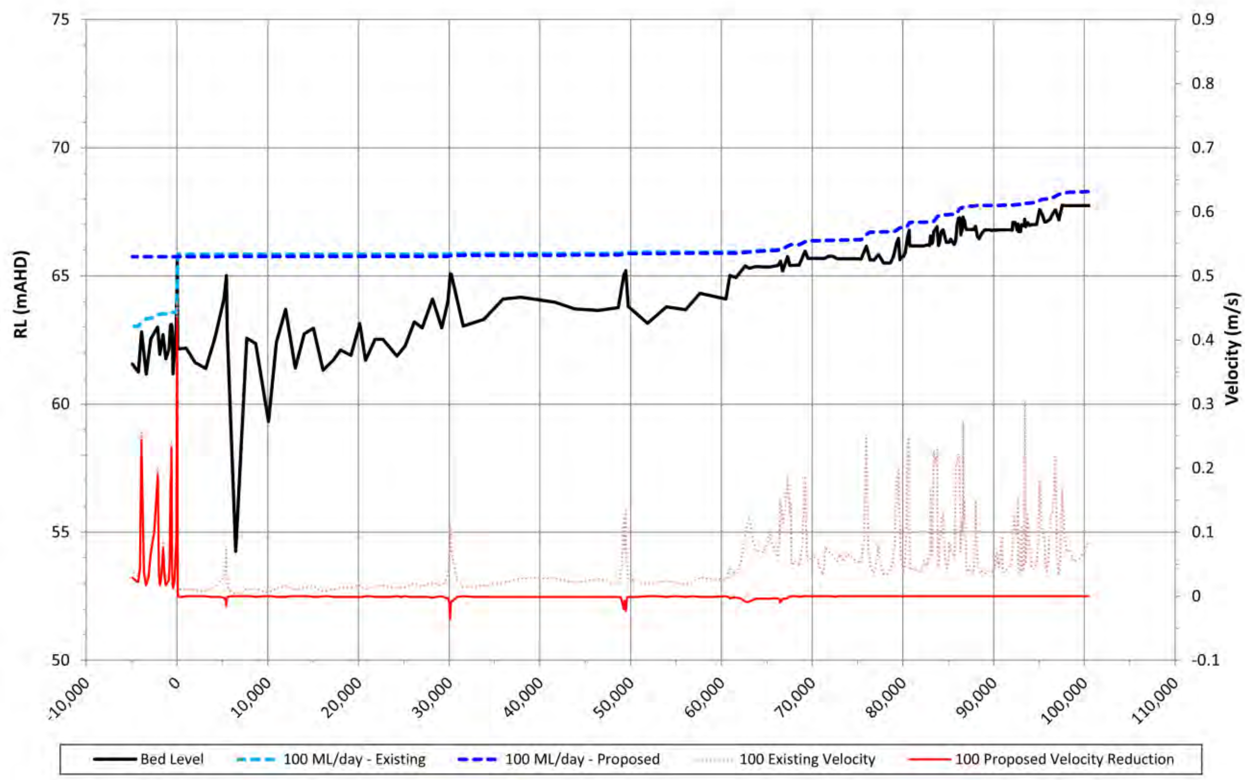


Figure 5-21 Predicted change in water velocity for flows of 100 megalitres per day

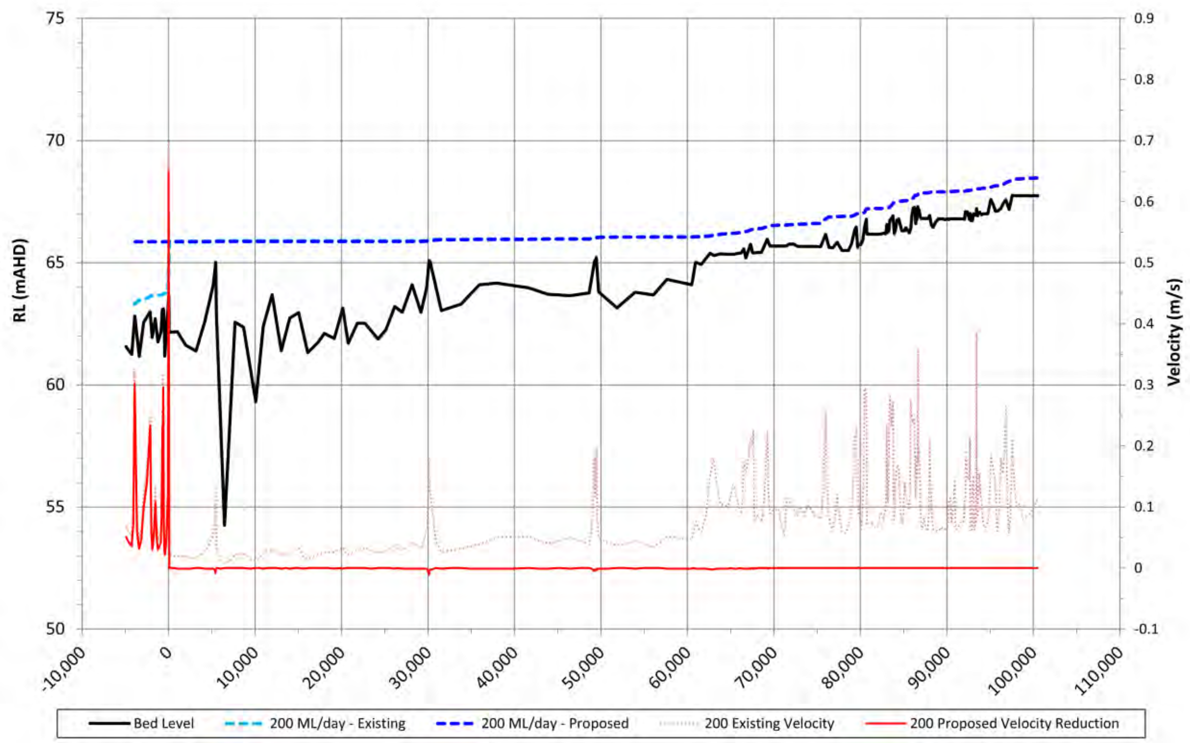


Figure 5-22 Predicted change in water velocity for flows of 200 megalitres per day

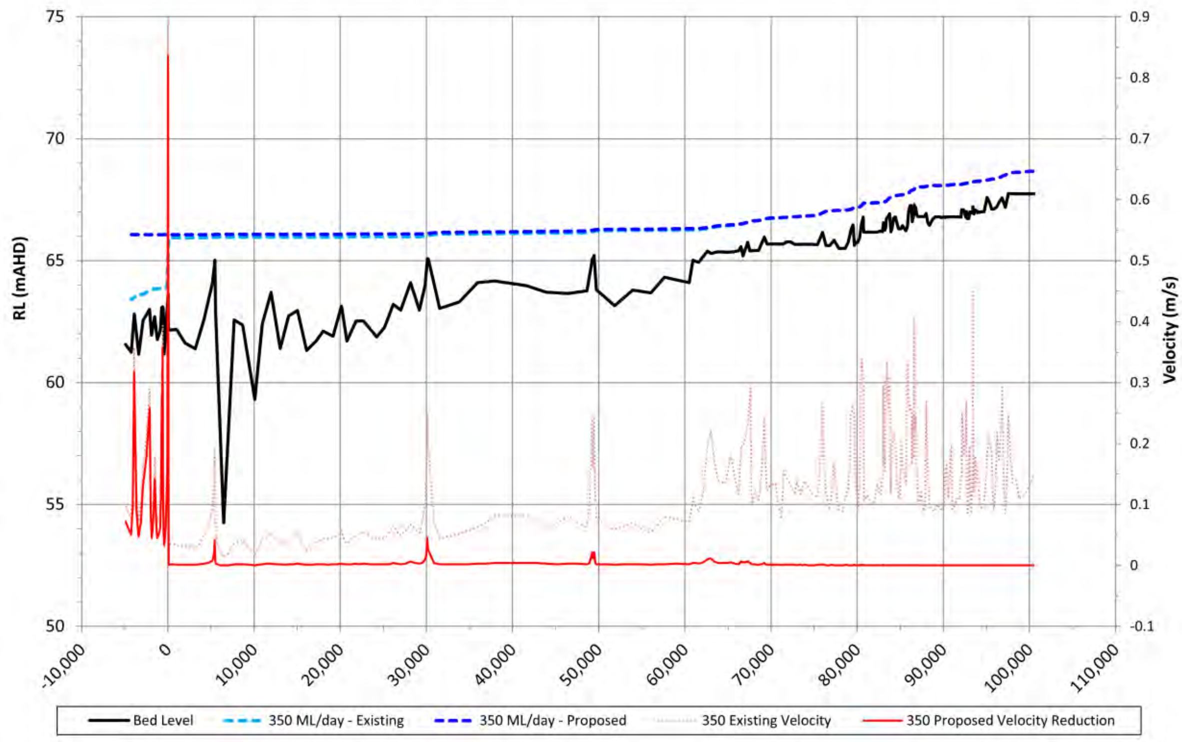


Figure 5-23 Predicted change in water velocity for flows of 350 megalitres per day

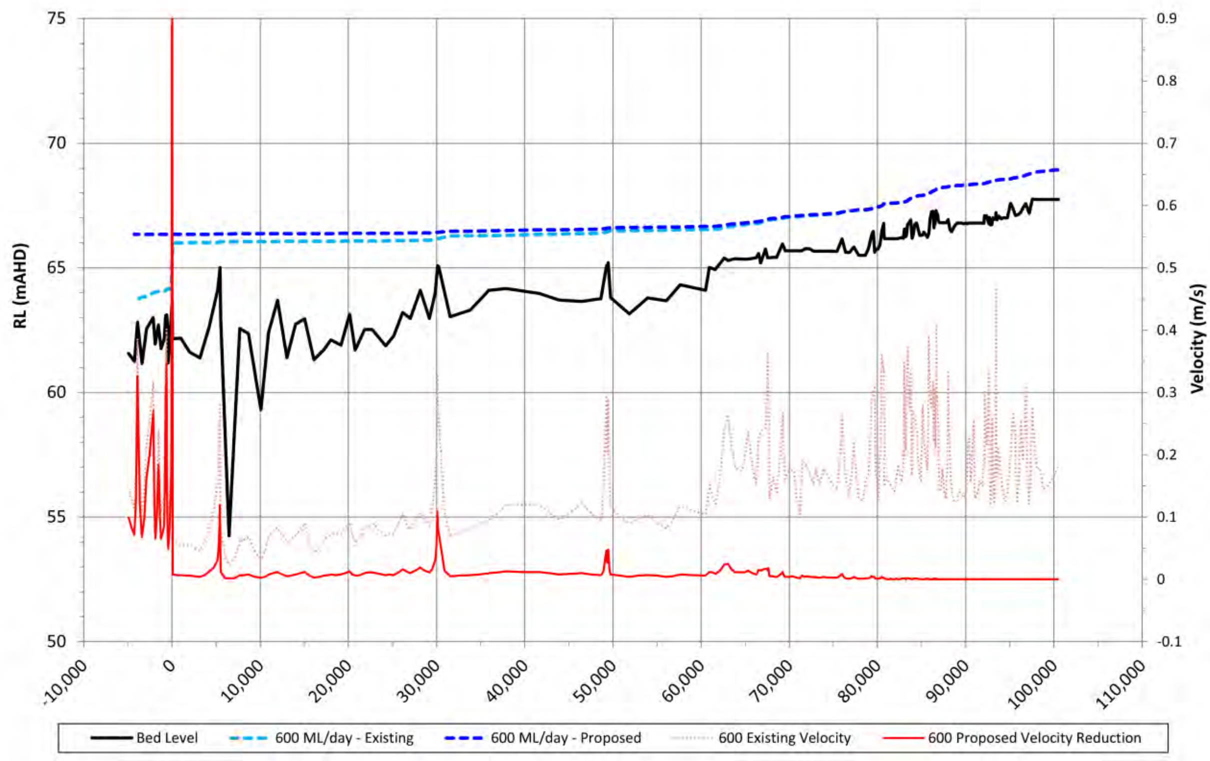


Figure 5-24 Predicted change in water velocity for flows of 600 megalitres per day

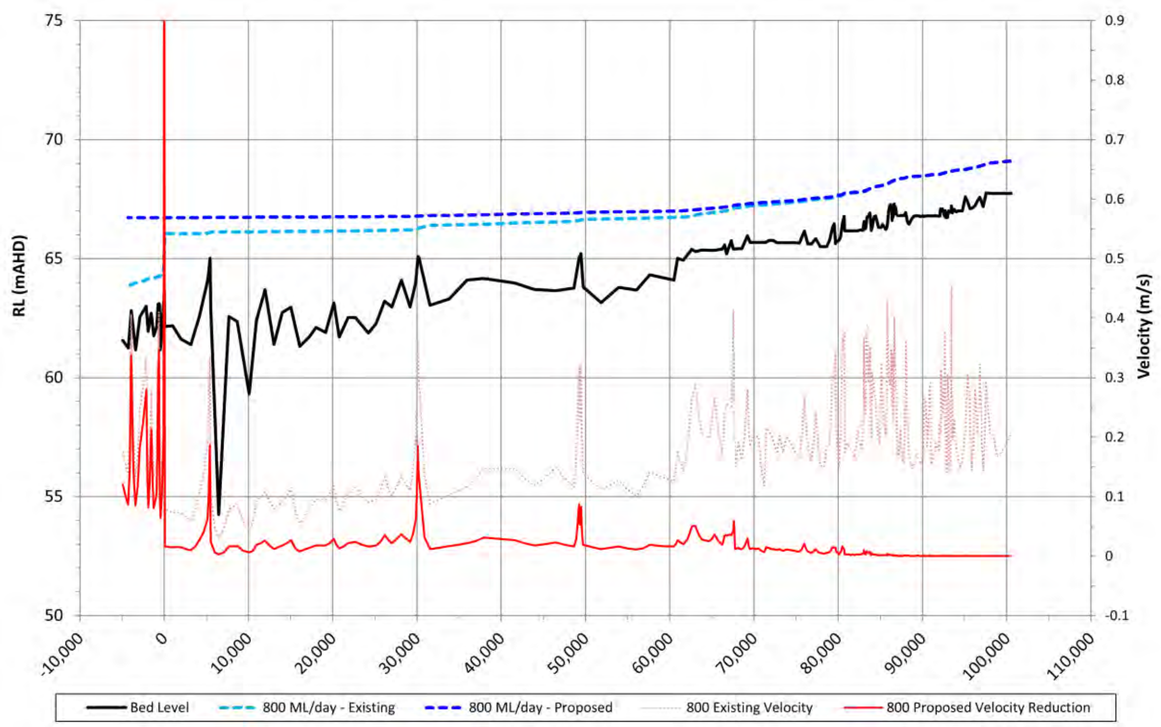


Figure 5-25 Predicted change in water velocity for flows of 800 megalitres per day

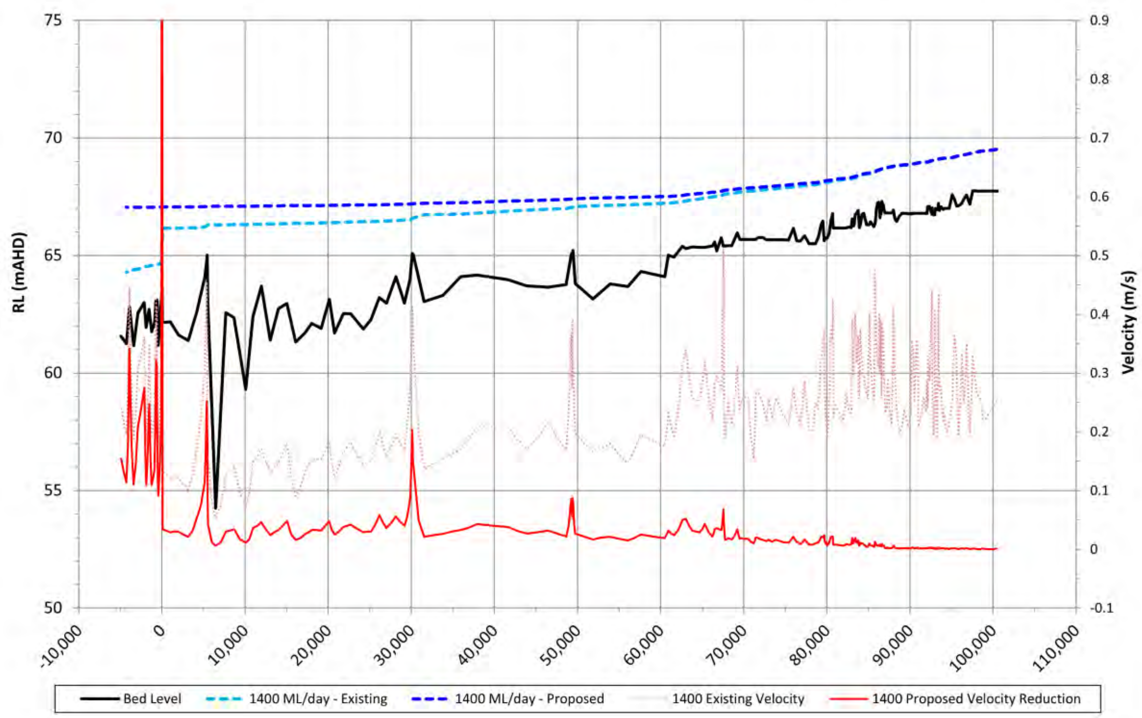


Figure 5-26 Predicted change in water velocity for flows of 1400 megalitres per day

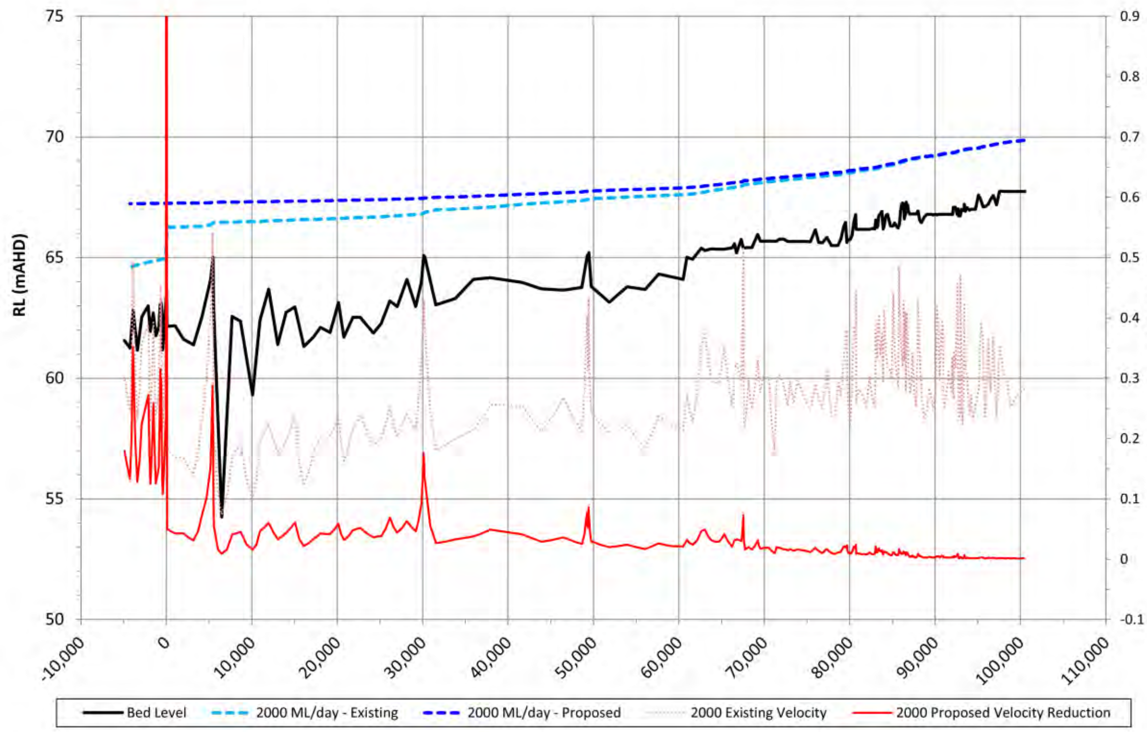


Figure 5-27 Predicted change in water velocity for flows of 2,000 megalitres per day

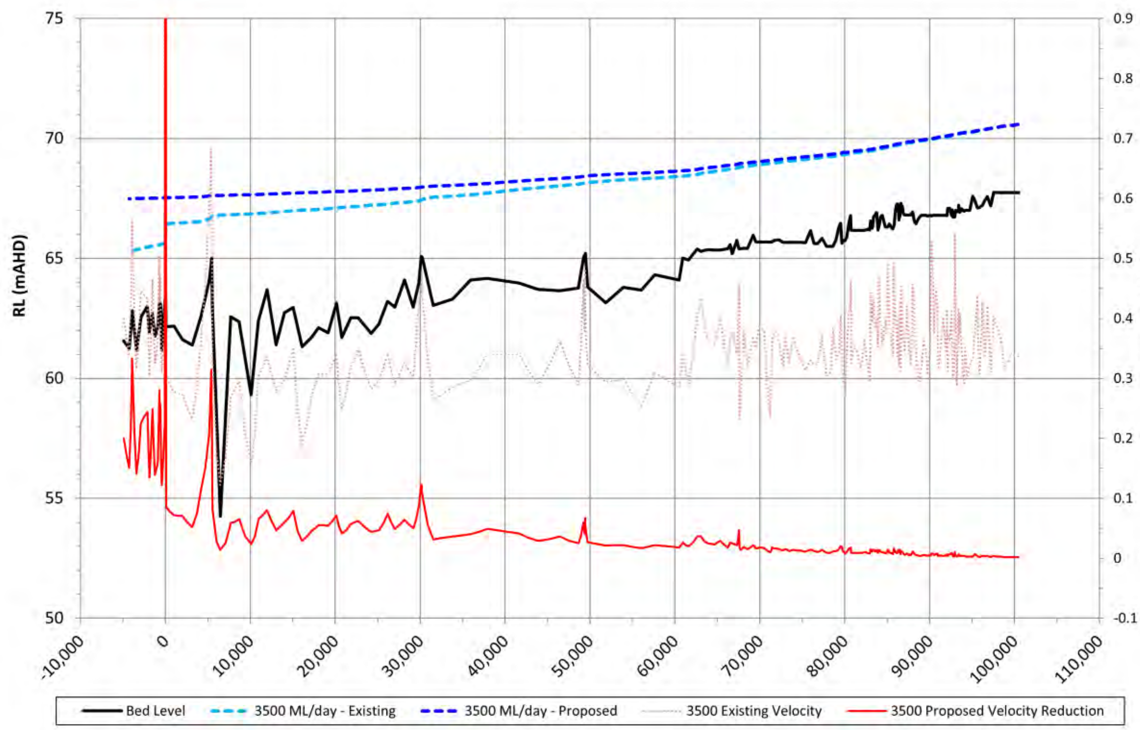


Figure 5-28 Predicted change in water velocity for flows of 3,500 megalitres per day

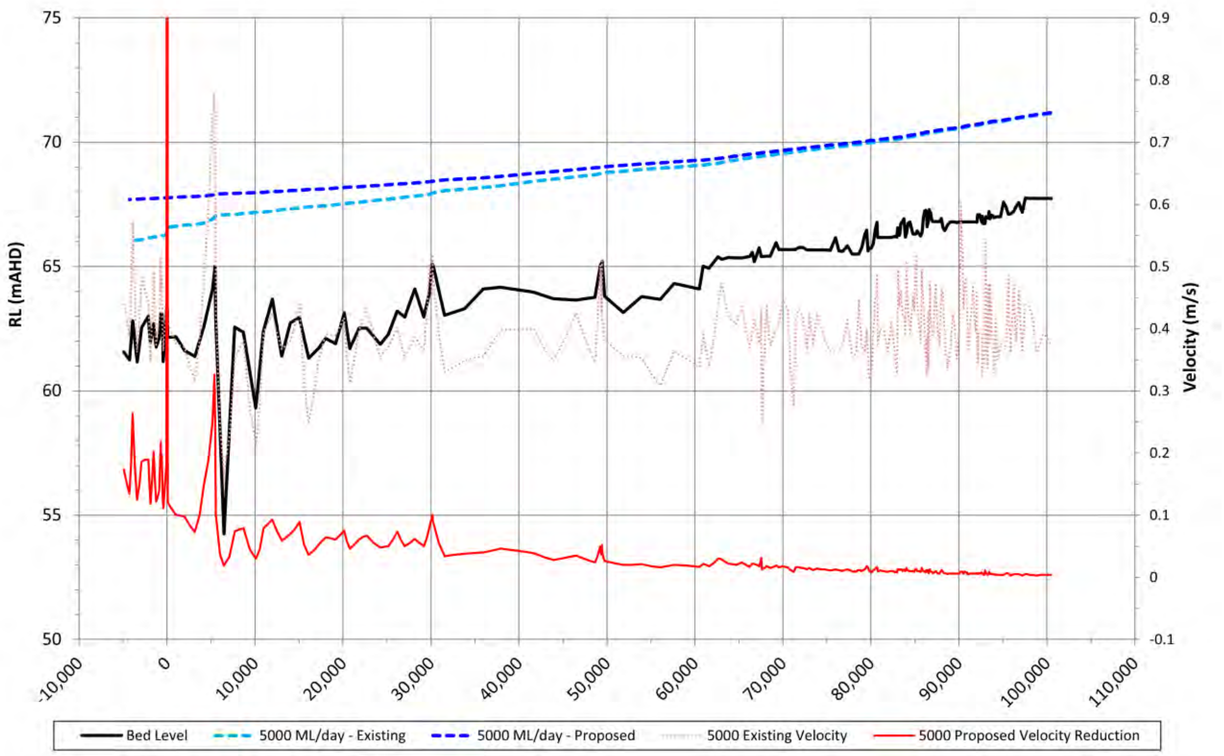


Figure 5-29 Predicted change in water velocity for flows of 5,000 megalitres per day

The predicted reduction in water velocities upstream of the new weir are 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. This is seen in **Figure 5-30** and **Figure 5-31**, which show the water level in the weir pool upstream of the existing and new weirs respectively at different flow rates. As shown in these figures, the backwater effect increases as the flow rate increases, with the greatest increase in the water level of the weir pool occurring nearest to the weir.

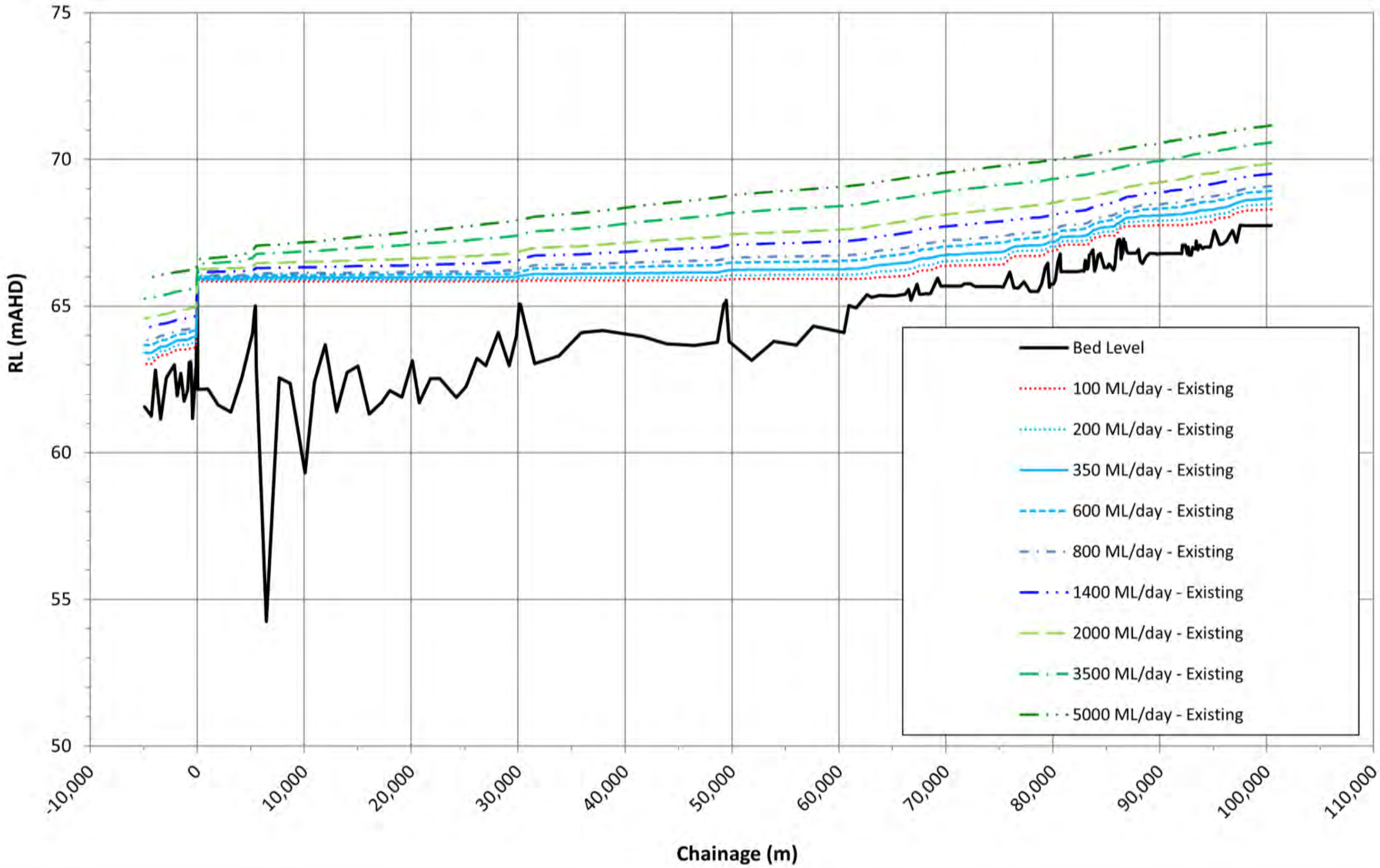


Figure 5-30 Existing water level in the Darling River (Baaka) at different flow rates, from the new weir site to 100-river-kilometres upstream of the existing weir

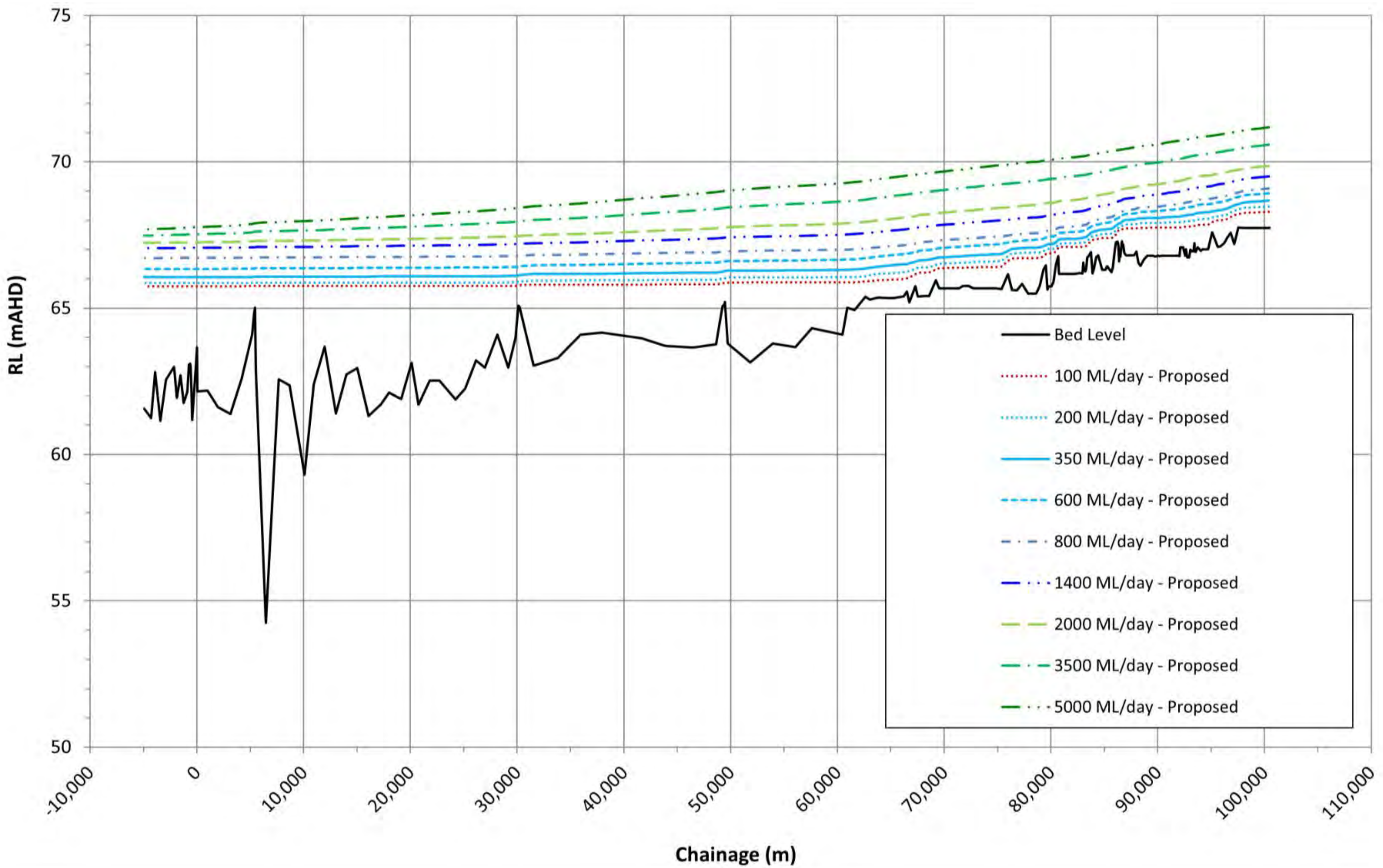


Figure 5-31 Water level in the Darling River (Baaka) at different flow rates when the new weir is in normal operation mode, from the new weir site to 100-river-kilometres upstream of the existing weir

5.4.4 Impacts to water users

The proposal would not impact water users in the Tilpa to Wilcannia Management Zone of the Barwon-Darling Unregulated Water Source because it would not change the volume of water flowing in this reach of the river.

As mentioned in **Section 3.2.4**, there is only one water access licence associated with a current water supply works and water use approval in the Wilcannia to Upstream Lake Wetherell Management Zone of the Barwon-Darling Unregulated Water Source. This water user would potentially be impacted by the changes to flows downstream of the new weir described in **Section 5.4.3**.

5.4.5 Cumulative impacts

There are no developments proposed within the extent of the weir pool behind the new weir when it is drought security operation mode (i.e. along the about 85.52 kilometres of river channel upstream of the new weir) or in the reach of the Darling River (Baaka) downstream of Wilcannia to Menindee that would result in cumulative hydrology impacts.

5.5 Management and mitigation measures

There is potential to minimise hydrology impacts during construction through considered staging, timing and design of the work. Environmental management measure HY01 will be implemented to pursue this outcome as detailed in **Table 5-8**.

The operational hydrology impacts of the proposal are directly linked to the design of the new weir and the rules that would govern its operation. These elements of the proposal have been developed to minimise hydrology impacts while providing water security for Wilcannia. The new weir would have no re-regulation function or capacity, which means that there are limited opportunities for the new weir to improve hydrology outcomes while still maintaining water security. However, the preliminary operating rules that have formed the basis for the assessment of the proposal's impacts in this environmental impact statement are considered to be robust and the hydrology impacts are worst-case impacts. There may be opportunities to refine the operating rules in consultation with WaterNSW and other relevant stakeholders . For example, the trigger for the filling phase to start could be refined to reduce the instances of 'false starts' where flows at Bourke rise above the trigger for the reset phase shortly after the filling phase has been triggered. Environmental management measure HY02 is proposed specifically to address the opportunity to refine the filling phase trigger, as detailed in **Table 5-8**.

Water Infrastructure NSW will consult with relevant NSW and Commonwealth government agencies regarding the integration of the operating rules for the new weir into government policy.

Table 5-8 Proposed management and mitigation measures

Impact	Reference	Environmental management measure	Timing
HY01	Obstruction of flows during construction	Plan and design the construction work to minimise hydrology impacts including: ▪ Schedule work that requires occupation of part of the riverbed to occur during periods of low flow ▪ Maximise the waterway area of the river channel available to allow for flows to be diverted pass instream construction sites.	▪ Pre-construction ▪ Construction
HY02	Triggers for the filling phase	In consultation with WaterNSW, investigate opportunities to refine the triggers for the filling phase with the aim of	▪ Pre-operation ▪ Operation

Impact	Reference	Environmental management measure	Timing
		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 ▪ Anticipated flows from upstream of Bourke Town Weir ▪ Climatic conditions and prevailing weather.	
HY03	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 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.	▪ Operation

6. Geomorphology impact assessment

The development of a new weir, partial removal and decommissioning of the existing weir and introduction of operating rules for the new weir that would result in different weir pool filling and discharge patterns have the potential to impact the processes that can lead to changes in the form of the river channel. A geomorphology impact assessment has been carried out to assess the potential for the proposal to affect geomorphological processes in the Darling River (Baaka). The assessment addresses the geomorphology requirements of SEAR number 2. **Table 1-1** outlines how this assessment addresses the requirements of SEAR number 2.

6.1 Assessment methodology

The methodology for the geomorphology impact assessment included:

- Undertaking a desktop review of previous geomorphology studies of the Darling River (Baaka) upstream and downstream of Wilcannia (refer to **Section 3.2.3**)
- Reviewing River Styles mapping of the Darling River (Baaka) upstream and downstream of Wilcannia (refer to **Section 3.2.3**)
- Considering the geomorphology risks associated with the proposed location of the new weir
- Assessing the effects of partially removing the existing weir on geomorphology
- Assessing the potential impacts of the preliminary operating rules for the new weir on geomorphology.

6.2 Risk

Weirs can impact channel geomorphology by trapping sediments from upstream and storing them in the weir pool. Without a supply of sediment to replenish areas that have been eroded downstream by increased flow velocities and turbulence below the structure (otherwise known as clearwater erosion), the natural sediment balance is disrupted. Additionally, the manipulation of flows and the associated increased flow velocities immediately below a weir can result in the alteration of natural stream morphology by increasing erosion rates, which can result in the deepening and widening of rivers (Department of Primary Industries, 2006).

The sedimentation that occurs within weir pools further affects organisms within the stream by filling in fish habitat holes, smothering benthic organisms, and in some cases affecting fish respiration. The reduction in stream depth allows a greater surface area of the waterway to be subjected to sunlight penetration and evaporation, increasing water temperature particularly during the summer months. The trapped sediment may also contain pollutants and nutrients that may contribute to a reduction in water quality. Turbid conditions resulting from sediments in the weir pool or increased erosion downstream can decrease light penetration into the water column and limit photosynthesis, thereby reducing the overall productivity of the system (Department of Primary Industries, 2006).

6.3 Avoidance and minimisation of impacts

The Department of Primary Industries encourages the removal of redundant structures from waterways, with weir removal providing the greatest benefit to the health of the waterway by enabling unrestricted fish passage and reinstatement of natural sediment fluxes within a system (Department of Primary Industries, 2006). The proposal includes removal of the central section of the existing Wilcannia Weir, which would lessen the obstruction created by this structure to sediment fluxes.

The new weir would have dual modes of operation as detailed in **Section 4.2.1** and this would result in the about 18.81 river kilometres of additional weir pool at the upstream end of the existing weir pool being temporary inundated when the new weir is in drought security operation mode. This section of the river would alternate between flowing water, still-water and, at times, sections of dry riverbed, which would reduce the impact of the new weir on natural sediment fluxes in this reach.

6.4 Assessment of impacts

6.4.1 Construction

The construction of the new weir would require the right riverbank alongside the fishway and the left riverbank next to the weir crest to be excavated to construct the new infrastructure. This would create the potential for riverbank erosion and a loss of bank stability. The impacted sections of riverbank would adjoin the dry work sites created on the riverbed for the construction of the fishway and weir crest as shown in **Figure 1-2** and so would not be subject to erosion by flowing water except in the event of a sufficiently large flood that overtops the cofferdams.

The riverbanks at the new weir site would be reformed and trimmed as part of the construction works so as to tie-in with the undisturbed riverbanks upstream and downstream. Riverbank slopes and erosion protection would be aimed at reducing the risk of bank erosion occurring after completion of construction.

6.4.2 Operation

The operation of the new weir would result in an extension of the existing weir pool both upstream and downstream and these new sections of weir pool are expected to be subject to the same geomorphological impacts as are observed at the existing weir pool. Undercutting/notching of the riverbanks is expected to occur in the new town pool and within the about 18.81 river kilometres of temporary new weir pool upstream of the existing weir pool due to ponding of water against the riverbanks. Similar to the existing weir, this impact is expected to be relatively minor. As mentioned above in **Section 6.3**, the temporary nature of the inundation upstream of the existing weir pool is expected to result in a lesser impact than currently occurs at the upstream extent of the existing weir.

It is likely that sedimentation would occur in the about 18.81 river kilometre section of additional weir pool at the upstream end of the existing weir pool when it is inundated. It is also expected that these sediments may be remobilised and transported further downstream into the existing weir pool. As a large proportion of the sediment is fine grained and forms 'wash load' it is expected that mobilised sediment may still be transferred beyond the extent of the new weir, particularly during larger flood events. This would reduce the potential for sediment starvation downstream of the new weir.

Based on the response of the riverbanks in the existing weir pool to the about 80-years of operation of the existing weir, fluctuations in the level of stored water in the weir pool associated with the operation of the new weir are not expected to impact the stability of the riverbanks. Fluctuations in the level of stored water in the weir pool are not expected to induce changes in pore water pressures that would weaken bank materials and promote bank failure.

Changes to flows downstream of the new weir are expected to have minimal impact on the geomorphology of the river downstream of the weir.

6.4.3 Cumulative impacts

There are no developments proposed within the reach of the Darling River (Baaka) at Wilcannia that would result in cumulative geomorphology impacts.

6.5 Management and mitigation measures

Mitigation and management measures for geomorphology impacts are provided in **Table 6-1.**

Table 6-1 Mitigation and management measures for geomorphological impacts

Ref	Impacts	Management and mitigation impacts	Timing
GE1	Riverbank stability	The riverbanks at the new weir site will be reformed and trimmed so as to tie-in as seamlessly as possible with the riverbanks upstream and downstream. Riverbank slopes and erosion protection will aim to reduce the risk of riverbank erosion occurring after completion of construction.	Construction
GE2	Riverbank stability	During the reset phase, lowering of the weir level will be limited to a maximum of 0.2 metres per day to reduce the potential for riverbank erosion within the weir pool.	Operation

7. Groundwater impact assessment

A hydrogeological assessment of the proposal has been carried out to identify potential impacts and risks to groundwater associated with the construction and operation of the proposed new weir. The assessment addresses the groundwater requirements of SEAR number 2. **Table 1-1** outlines how this assessment addresses the requirements of SEAR number 2. The assessment has been informed by the Groundwater Risk Assessment undertaken by C.M. Jewell & Associates (2021), which is provided in **Appendix D**.

7.1 Assessment methodology

A desktop assessment of the potential hydrogeological impacts of the proposal has been carried out. The methodology for assessing the potential hydrogeological impacts of the proposal included:

- Collating and reviewing existing hydrogeological documentation and information in the study area
- Determining the possible impacts of construction and operation of the proposal on the region's groundwater sources and adjacent water users (specifically the emergency town water supply bores)
- Identifying possible impact to groundwater dependent ecosystems from the proposal (positive or negative)
- Identifying any potential salinisation impacts of the proposal to the groundwater system.

7.2 Risk

The key risk to groundwater due to the proposal is the potential for salinisation where there is new or increased inundation of the river channel. Water stored in the weir pool has the potential for increased salinity during periods of low or no flow and this can affect the local groundwater resource where there is interaction between the river (weir pool) and groundwater system.

7.3 Avoidance and minimisation of impacts

Potential impacts to groundwater have been minimised by designing the new weir to have dual modes of operation so that an increase in the full supply level (and as a consequence a deeper and extended weir pool) would be temporary. Storage behaviour modelling of the operation of the new weir (refer to **Section 5.1.2**) showed that it would be in drought security operation mode for about 30 per cent of the time over the 119-year simulation period. This minimises the potential for groundwater impacts along the about 18.81 river kilometres of extended weir pool upstream of the existing weir pool when the new weir is in drought security operation mode.

7.4 Assessment of impacts

7.4.1 Impacts to groundwater levels

The water table at Union Bend near the existing emergency town water supply bores has fluctuated between seven and 10 metres below ground level in the last 17 years (about 61 to 66 metres AHD, refer to **Figure 3-14**). This has resulted in the Darling River (Baaka) being either a gaining or loosing system depending on low or high flow conditions respectively. The shallow groundwater levels are the result of high river flow that contributes to rapid groundwater recharge.

During operation of the proposal, the long-term local groundwater level increase near the new town pool would be similar to the normal full supply level in the weir pool of 65.71 metres AHD and the groundwater level near Pool 1 upstream of the existing weir.

The two groundwater monitoring bores at Union Bend screened in the shallow alluvium aquifer GW040874 and GW040892 are at elevations of 70.93 and 75.32 metres AHD respectively. Groundwater levels at these bores were 9.6 and 10.35 metres below ground level respectively in February 2020. After the new weir starts operating, the groundwater level at Union Bend near the groundwater monitoring bores would rise as the nearby reach of the Darling River (Baaka) changes from a naturally flowing river to a weir pool. When the new weir is in normal operation mode, the groundwater level at GW040874 and GW040892 may reach 5.22 metres and 9.61 metres below ground level respectively, as indicated in **Table 7-1**.

Table 7-1 Current and likely future groundwater level at Union Bend

Monitoring bores		Standing water levels			
Impact	**Elevation** (metres AHD)	**Current water levels** (metres AHD)	**New town pool during normal operation mode** (metres AHD)	**Current water levels** (metres below ground level)	**New town pool during normal operation mode** (metres below ground level)
GW040874	70.93	61.33	65.71	9.60	5.22
GW040892	75.32	64.97	65.71	10.35	9.61

Groundwater elevation upstream of the existing weir is not expected to change measurably because the full supply level of the new weir during normal operation mode would be the same as the full supply level of the existing weir. Groundwater elevation along the about 18.81 river kilometres of temporary weir pool upstream of the existing weir pool is also not expected to change measurably because inundation of this reach of the river would only occur during the about 30 per cent of the time when the new weir is in drought security operation mode, the depth of inundation would be between zero (at the upstream extent of the extended weir pool) and one metre (at the upstream extent of the existing weir pool) and it would start to be drawn down as soon as the rate of inflows to the weir pool is less than the rate of extraction plus evaporation losses.

7.4.2 Salinisation

C.M. Jewell & Associates (2021) noted that a water quality risk assessment had been carried out in 2012 to assess hazards relating to the construction of the new weir noting that there was an existing risk of high salinity water in the weir pool due to drought and prolonged periods of no or low flow of the Darling River.

Shallow groundwater (less than three metres below ground level) has the potential to become saline through evapo-concentration over time. Groundwater mounding in the about 4.92-river kilometre new town pool between the new and existing weirs is likely to occur up to 100 metres away from the banks of this section of the Darling River (Baaka). Long-term groundwater salinisation in low-lying areas next to the new town pool would be similar to that which has already occurred upstream of the existing weir in low-lying areas.

7.4.3 Impacts to the emergency town water supply bores

The new town pool is expected to contribute to aquifer recharge of the shallow alluvium aquifer; however, it is unlikely to contribute to the deeper alluvium aquifer due to the 20-metre-thick clay aquitard. The emergency town water supply bores screen the deep alluvium, although the overlaying clay aquitard is likely to leak, it will limit the direct connection to the Darling River (Baaka). Currently the salinity of groundwater pumped from the town water supply boreholes, while acceptable, is higher than that of good quality river water. Any increased salinisation in the upper aquifer is unlikely to impact the deeper aquifer quality.

As the emergency town water supply bores are not directly connected to the Darling River (Baaka), the risk to the town water supply bores from the construction of the weir is considered low. Further, the water security that the proposal would provide to Wilcannia would end the town’s reliance on the emergency town water supply bores during periods of severe drought.

The proposal would have minimal impacts on groundwater upstream of the existing weir in the vicinity of the weir pool and therefore is not expected to impact the three groundwater bores identified in **Section 3.6.3** (bores (GW019002, GW039479 and GWB03951).

7.4.4 Impacts to groundwater dependent ecosystems

As identified in **Section 3.6.4**, the Darling River (Baaka) and its floodplains have a high potential for groundwater dependent ecosystems. The Darling River (Baaka) receives baseflow during times of drought and contributes to groundwater recharge during high flows. Low to high potential terrestrial GDEs have been identified based on regional studies along the riverbanks and throughout the floodplains.

Groundwater dependent ecosystems located near the Darling River (Baaka) between the new and existing weirs would currently experience fluctuating groundwater levels as the river rises and falls, as described in **Section 3.6.1**. As a result of operation of the proposal, equilibrium groundwater levels near the new town pool are expected to rise to within five metres of the ground surface and this would be supportive of groundwater dependent ecosystems in these areas. An exception is low-lying areas near the new town pool that are less than three metres below ground level which would experience salinisation similar to that which is already occurring upstream of the existing weir, as discussed in **Section 7.4.2**. Any salinisation impact to groundwater dependent ecosystems in low-lying areas near the new town pool would be similar to that which is already occurring upstream of the existing weir.

7.4.5 Construction impacts

Construction of the proposal would present a minor risk to groundwater due to the potential for spills or leaks onto the ground to drawn down into groundwater causing localised contamination of the groundwater resource.

7.4.6 Cumulative impacts

There are no developments proposed in the vicinity of the new town pool or in the about 18.81-river kilometre reach of the river upstream of the existing weir pool that would be subject to temporary inundation when the new weir is in drought security operation mode that have the potential to cause cumulative impacts to local groundwater.

7.5 Management and mitigation measures

Management and mitigation measures for groundwater impacts are provided in **Table 7-2**.

Table 7-2 Mitigation and management measures for groundwater impacts

Ref	Impacts	Management and mitigation impacts	Timing
GW1	Contamination of groundwater during construction	Emergency spill measures will be developed to avoid and manage accidental spillages of fuels, chemicals and fluids to minimise human health impacts and contamination of groundwater.	▪ Construction
GW2	Increase in the water table near the new town pool	Groundwater level data from monitoring bores GW040874 and GW040892 will be analysed 12 months and five years following the start of operation of the new weir and compared to data collected prior to the start of construction to verify whether the groundwater level increases are in line with predictions. If the monitoring finds that groundwater levels are higher than predicted further investigations will be	▪ Operation

Ref	Impacts	Management and mitigation impacts	Timing
		carried out to understand the causes of this change and the need for any additional measures. To assist in monitoring impacts to groundwater: ▪ A combined real-time water level and electrical conductivity logger will be installed in monitoring bore GW040892 ▪ The existing real-time water level logger in monitoring bore GW040874 will be upgrades to also measure conductivity ▪ Records will be maintained of pumping times and rates from all of the emergency town water supply bores.	

8. Surface water quality impact assessment

A surface water quality assessment of the proposal has been carried out to identify potential impacts and risks to surface water associated with the construction and operation of the proposed new weir. The assessment addresses the surface water quality requirements of SEAR number 2. **Table 1-1** outlines how this assessment addresses the requirements of SEAR number 2.

8.1 Assessment methodology

The methodology for the assessment of surface water quality included:

- Undertaking a desktop review and analysis to understand the existing environment and identify the potential surface water quality risks of the proposal
- Site visits and water quality monitoring to support and enhance the findings of the desktop analysis and refine the understanding of potential surface water quality risks
- Classifying sensitive receiving environments and identifying environmental values relevant to the proposal
- Assessing the potential construction and operational impacts relating to water quality
- A qualitative assessment of potential cumulative water quality impacts by identifying major projects with a construction program that is likely to overlap with construction of the proposal and/or is within the same water catchment
- Identifying appropriate measures to mitigate and manage the potential impacts to surface water quality resulting from construction and operation of the proposal.

A study area for this surface water quality assessment was defined to include the area either directly or indirectly affected by the proposal. The study area includes the construction footprint, the extent of the new weir pool and an about 50-metre reach of the river immediately downstream of the new weir where discharging water has the potential to cause scouring and increased erosion.

8.1.1 Site classification

Sensitive receiving environments

Sensitive receiving environments are environments that have a high conservation or community value or support ecosystems/human uses of water that are particularly sensitive to pollution or degradation of water quality. The Darling River within the study area has been identified as a sensitive receiving environment (Type 1 – Highly Sensitive Key Fish Habitat) because the waterway is known to support threatened species listed under the EPBC Act and FM Act.

Water quality objectives

Water quality objectives for the Barwon-Darling have been nominated in the Basin Plan and contribute towards maintaining appropriate water quality, including salinity, for environmental social, cultural and economic activity. The Barwon-Darling Watercourse Water Resource Plan (DPIE, 2019a) together with the ANZG (2018) provide the targets for assessment of existing water quality. The objectives and indicators are provided in **Table 8-1**.

Table 8-1 Water quality objectives for the Darling River (Baaka), associated indicators and nominated water quality targets

Water quality objectives	Water quality targets
Maintain water quality to protect First Nations people's water dependent values and uses	Currently no specific guidelines
Maintain water quality to protect and restore water dependent ecosystems	Turbidity - 50NTU Total phosphorus - 0.05mg/L Total nitrogen - 0.5mg/L Dissolved oxygen - 85-110% pH - 6.5-8.0 Temperature – between the 20th and 80th percentile of natural monthly water temperature Toxicants - protection of 95% of species (ANZG, 2018) Electrical conductivity^ - median 380µS/cm; 80%ile 453µS/cm
Maintain the quality of raw surface water for treatment for human consumption	As per the ADWG
Maintain the quality of surface water for irrigation use	The target applies to sites where water is extracted by an irrigation infrastructure operation for the purpose of irrigation, such as NSW Irrigation Corporation, Private Irrigation Districts and Private Water Trusts. NSW DPIE (2019) states there are no irrigation infrastructure operators that deliver services in the Barwon-Darling water resource plan area.
Maintain the quality of surface water for recreational use	As per Chapter 6 of the *Guidelines for Managing Risks in Recreational Water* (National Health and Medical Research Council, 2008), fresh recreational waterbodies should not contain: ▪ ≥ 10 µg/L total microcystins; or ≥ 50,000 cells/mL toxic Microcystis aeruginosa; or biovolume equivalent of ≥ 4 mm^3 /L for the combined total of all cyanobacteria where a known toxin producer is dominant in the total biovolume; or ▪ ≥ 10 mm^3 /L for total biovolume of all cyanobacterial material where known toxins are not present; or ▪ Cyanobacterial scums consistently present. As per Chapter 5 of the *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008) in the absence of microbial assessment categories for freshwater, those derived for coastal waters should be applied. The microbial values below are expressed in terms of 95th percentile of numbers of intestinal enterococci per 100mL and the level of risk based on exposure.

<table>
<tr><th>Water quality objectives</th><th>Water quality targets</th></tr>
<tr><td></td><td>
<table>
<tr><th>Category</th><th>95^{th} percentile enterococci/100ml</th><th>Notes</th></tr>
<tr><td>A</td><td><40</td><td>Gastrointestinal illness risk < 1%
Acute febrile respiratory illness risk <0.3%
This value is below the 'no observed-adverse-effect level'. The upper 95^{th} percentile value of 40/100 mL relates to an average probability of less than one case of gastroenteritis in every 100 exposures.</td></tr>
<tr><td>B</td><td>41-200</td><td>Gastrointestinal illness risk 1-5%
Acute febrile respiratory illness risk 0.3%-1.9%
The 200/100 mL value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a 'no observable-adverse-effect level' or 'lowest observed-adverse-effect level' for gastro-intestinal illness and acute febrile respiratory illness.</td></tr>
<tr><td>C</td><td>201-500</td><td>Gastrointestinal illness risk 5-10%
Acute febrile respiratory illness risk 1.9%-3.9%
This represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data are available.</td></tr>
<tr><td>D</td><td>>501</td><td>Gastrointestinal illness risk >10%
Acute febrile respiratory illness risk >3.9%
Above this level there may be a significant risk of high levels of illness transmission.</td></tr>
</table>
</td></tr>
<tr><td>Maintain the value of a water quality characteristic if it's at a level that is better than the target value</td><td>As noted in Section 2.3.2, the water quality targets relevant to the proposal are set out in the Murray-Darling Basin Plan, the Murray-Darling Basin Agreement and the ANZG (2000) Water Quality Guidelines.</td></tr>
</table>

^ end of valley salinity targets as described in Schedule B, Appendix 1 of the Commonwealth *Water Act 2007* and are listed in the Barwon-Darling Watercourse Water Resource Plan (DPIE, 2019a)

8.1.2 Field data collection and monitoring

A site visit was carried out on 21 November 2020 to sample the water quality of the Darling River (Baaka) and to visually assess the conditions of the watercourse. Eight sampling sites were selected based on key features of the proposal, and tributary inflows. Sampling locations are listed in **Table 8-2** and shown in **Figure 8-1.**

Table 8-2 Spot water quality sampling sites on the Darling River (Baaka)

Sampling site no.	Sampling site description
SW1	Darling River (Baaka) at the new weir site

Sampling site no.	Sampling site description
SW2	Darling River (Baaka) at the existing weir
SW3	Darling River (Baaka) at existing weir pool extent
SW4	Darling River (Baaka) at proposed new weir pool extent
SW5	Darling River (Baaka) upstream of Kallyanka Creek confluence
SW6	Darling River (Baaka) downstream of Paroo River inflow
SW7	Darling River (Baaka)
SW8	Darling River (Baaka) between existing weir and new weir

Water quality was measured in-situ and via the collection of grab samples. In-situ water quality parameters, temperature, conductivity, salinity, pH and dissolved oxygen, were measured using a calibrated YSI Pro Plus multi-parameter water quality meter. Turbidity was measured using a Hach turbidimeter.

Measurements were generally collected between 15 and 30 centimetres below the surface of the river depending on the depth of water. Sampling depth was recorded in the field. For each parameter measured in-situ, three replicate measurements were recorded about 10 metres apart from the access point to the site. Each parameter was then reported as the average (arithmetic mean) of the three measurements.

Grab samples were also collected at each site and sent to the laboratory for analysis. The analytical suite for laboratory analysis included:

- Total suspended solids
- Dissolved major cations
- Dissolved organic carbon
- Dissolved metals (aluminium, arsenic, cadmium, chromium, copper, lead, nickel, zinc, iron and mercury)
- Nutrients (oxidised nitrogen, total nitrogen, total phosphorus and filterable reactive phosphorus)
- Organochlorine pesticides
- Organophosphorus pesticides
- Phenoxyacetic acid herbicides
- Chlorophyll-*a*
- Blue green algae (including species, total and toxic).

Monitoring quality assurance and quality control (QA/QC) comprised of calibration of field equipment prior to sampling, duplicate sample collection and laboratory QA/QC at the National Association of Testing Authorities accredited laboratory where samples were submitted for analysis. Holding times were met for all analytes.

Figure 8-1 Spot water quality sampling sites

Figure 8-1 Spot water quality sampling sites

Figure 8-1 Spot water quality sampling sites

8.2 Risk

The proposal presents a risk to surface water quality because it would involve construction work within the Darling River (Baaka). Cofferdams would be used to create dry work sites for the construction of the fishway and later for construction of the weir embankment and crest. In the first phase of construction, a cofferdam would isolate about half the width of the river to enable construction of the fishway, with river flows past the work site in the other half of the river. Once the fishway is complete, the second phase of construction would use cofferdams to create a dry work site for construction of the weir embankment and crest, with river flows directed down the fishway.

Establishing and maintaining these dry work sites within the river would require dewatering of any seepage that enters the work area. This water would need to be appropriately managed to prevent sediment-laden water entering the river.

Other risks to surface water quality during construction of the new weir would include sediment-laden run-off entering the river from the construction compounds, stockpile areas and laydown areas on either side of the river, accidental leaks or spills of hydrocarbons that flow into the river.

The partial removal and decommissioning of the existing weir also presents a risk to surface water quality because it too would involve construction work within the Darling River (Baaka). The operation of an excavator and trucks within the riverbed would disturb sediment that could affect water colour and cause an increase in turbidity and suspended solids.

Risks to surface water quality during the operation of the proposal include mobilisation of sediment due to erosion of reformed, stabilised and revegetated riverbanks at the new and existing weir sites, and scouring of the riverbed downstream of the new weir site. Additionally, locating the weir further downstream introduces additional sources of faecal and other pollution such as stormwater from the Wilcannia township and sewer overflows including during storm events.

Similar to the existing weir, under certain climatic and hydrological conditions there would be a risk to the quality of water stored upstream of the new weir due to thermal stratification, variable dissolved oxygen, increased nutrients and sediment and algal blooms.

8.3 Avoidance and minimisation of impacts

Protecting surface water quality is a key consideration in the design of the proposal. Construction at the new weir site would be staged and restricted to about half the width of the river at any one time so as to enables flows past the instream construction site. Water quality protection ponds would be used to treat water extracted from within the cofferdams.

At the existing weir site, demolition work would be timed to occur during a period of low flow in the river and silt curtains would be used upstream and downstream of the work site to minimise sediment plumes travelling beyond the work area.

To minimise scouring during operation of the proposal, the design of the new weir includes rockfill on the downstream embankment.

To minimise the risk of sewer overflows entering the weir pool due to power or mechanical failures, Water Infrastructure NSW proposes to install two emergency sewerage storage tanks at both pumping stations (PS1 and PS2). This would provide additional storage capacity so that untreated wastewater is not discharged into the new weir pool. These works do not form part of the proposal.

8.4 Assessment of impacts

8.4.1 Construction

Construction of the proposal presents a risk to degradation of downstream surface water quality if management measures are not implemented, monitored and maintained throughout the construction phase. The main construction activities (and sub-activities) with the potential to cause surface water quality impacts includes but is not limited to:

- **Access tracks –** upgrade of the existing tracks and provision of new access tracks. It involves movement and use of vehicles across exposed earth, excavation, vegetation clearing and mulching and transport of materials to and from site.
- **Compounds –** construction compounds and lay down areas would be established on both sides of the river. Potential activities occurring at compounds include movement and use of vehicles, stockpiling, vegetation clearing and mulching, concrete batching plants, establishment of water quality controls such as water quality ponds.
- **Weir construction –** involving instream works, including building temporary cofferdams, piling, grouting, cutting and later reinstating the riverbanks, concreting as well as vegetation clearing in streambed and banks.
- **Testing and commissioning of the new weir –** following construction of the new weir, there would be a commissioning phase during which there would be testing of the performance of the weir gates, fishway gates, and the systems for remotely controlling the operation of the weir.
- **Decommissioning of the existing weir –** partial demolition of the existing weir would occur once the new weir is operational. It would be undertaken during low flow and involve establishment of an access road, temporary construction compound, installation of water quality controls such as silt curtains, excavation and stockpiling.
- **Site restoration –** rehabilitation and landscaping of disturbed areas (including construction compounds and access tracks including southern access to the riverbed) to similar to pre-construction conditions where required. Rehabilitation of the riverbank at the existing weir site would include reshaping and stabilisation of the riverbank so that it is commensurate with upstream and downstream reaches.

Potential impacts to water quality associated with the construction activities of the abovementioned proposal elements are discussed below. The Darling River (Baaka) is the only waterway at risk.

Erosion and sedimentation

There is a risk of erosion and sedimentation from various activities associated with construction including: establishment of access tracks and movement of heavy vehicles across exposed earth; stockpiling; vegetation clearing, excavation, dewatering, instream works such as streambed levelling and piling and landscaping/site restoration. Prior to any activity that could potentially result in erosion and sedimentation, appropriate erosion and sediment controls will be implemented to ensure minimal entrainment of sediment or pollutants into the Darling River (Baaka).

Erosion and sedimentation can result in increased turbidity and poor water clarity, impacting on visual amenity and potentially lead to smothering of benthic organisms and reduced visibility for fish. Sediments may contain high concentrations of nutrients which can lead to increased risk of algal blooms and subsequently result in reduced light penetration therefore limiting growth of aquatic vegetation. Algal blooms may also result in a reduction of dissolved oxygen in the waterway, which may impact certain aquatic organisms. In addition to nutrients, mobilised sediments maybe contain elevated concentration of metals and other contaminants which can negatively impact on aquatic life.

While the water quality of the Darling River (Baaka) has the potential to be temporarily reduced as a result of sediment-laden runoff and pollutants from erosion and sedimentation, it is unlikely to cause major or long term impacts to the overall condition of the river as erosion and sedimentation will be managed with implementation of silt curtains and water management ponds. Furthermore, additional environmental management measures outlined in **Section 8.5** will be implemented to avoid and/or manage erosion and sedimentation impacts from construction activities.

Release of tannin leachate

While vegetation removal has been minimised where possible by using existing tracks and avoiding trees and other substantial groupings of vegetation, removal of some vegetation would be required during site preparation at the new weir. Cleared vegetation would be mulched and could result in the release of tannin leachate which can cause dark coloured water to be discharged into downstream waterways altering the instream pH and reducing visibility and light penetration. Tannins can also increase the biochemical oxygen demand (BOD) in the waterway which can decrease instream dissolved oxygen concentrations which can impact on aquatic ecosystems.

Procedures would be established for the disposal, stockpiling and reuse of cleared vegetation to ensure that this occurs away from areas where runoff could cause tannin leachate into receiving waterways, as outlined in the environmental management and mitigation measures in **Section 8.5**. Therefore, the risk of release of tannin leachate to the Darling River is very low and unlikely to result in a significant impact to surface water quality.

Dewatering

Dewatering of the area within the cofferdam/s would be required to provide a dry worksite. Dewatering discharge could result in discharge of saline water (due to groundwater intrusion at low flow) or highly turbid water which could impact on visual amenity and aquatic ecosystems. Piling could also result in saline displaced groundwater which would need to be disposed of. To minimise the impact of this, dewatering discharge would be directed into temporary construction sediment basins where available for treatment prior to release. Treatment of the water prior to discharge, together with measures outlined in **Section 8.5** would not result in any significant impact to water quality of the Darling River (Baaka), particularly as these activities would only occur during construction.

Disturbance of saline soils

Saline soils are known to occur within the construction footprint. Saline soils may become exposed, erode or leach salt into runoff and subsequently to the Darling River (Baaka), altering the salinity of the water which can alter instream biodiversity and ecosystem function. Saline soils would be disturbed as a result of earthworks and piling. The risk of this occurring, however, is considered low as water quality controls and management measures will be implemented to ensure that there is minimal runoff from exposed areas and stockpiles, as outlined in **Section 8.5**.

Release of oils and fuels

The release of oils and fuels into the Darling River (Baaka) could occur accidently during construction as a result of vehicle movements, or spills and leaks from construction plant and equipment. This can result in the release of hydrocarbons into the Darling River (Baaka) which could be harmful to aquatic life and could affect river users. Environmental mitigation and management measure SW05 will be implemented to minimise the potential for and impact of spills and leaks (refer to **Section 8.5**),

Release of concrete waste

A mobile concrete and grout batching plant would be required during the construction of the new weir which could mobilise cement dust, concrete slurries and washout water to the downstream Darling River (Baaka). This could increase the pH of the water which could be harmful to aquatic life. Water from the curing of concrete may be high in chromium which can accumulate in the gills of fish affecting the health of aquatic organisms. The Darling River (Baaka) at the new weir is the main area at risk, however the risk of transportation of concrete waste downstream is considered low as the work area would be dry and water quality controls and management measures will be implemented to avoid the release of contaminated water (refer to **Section 8.5**).

Dust and litter

Dust and litter could be generated from a variety of sources during the construction of the proposal including materials transport, stockpiling, concrete works, demolition of existing weir, rock crushing and use of construction sites impacting on the water quality of the Darling River (Baaka). Mobilisation of litter to the Darling River (Baaka) could introduce gross pollutants, heavy metals and hydrocarbons into the waterway which could be harmful to aquatic life and reduce the visual amenity.

Environmental mitigation and management measures will be implemented to minimise dust and litter during construction of the proposal (refer to **Section 8.5**).

8.4.2 Operation

Following completion of the construction phase, much of the proposal area will be rehabilitated, with only the access track on the northern side of the river retained during operation.

The operation of the new weir would result in greater storage capacity (about 17 per cent) when in normal operation mode at the existing full supply level of 65.71 metres AHD due to the new town pool that extends about 4.92 river kilometres between the new and existing weirs, resulting in a weir pool of about 66.71 river kilometres upstream from the new weir. However, during times when there is a need to store more water, the weir gates would be raised to a new full supply level of 66.71 metres AHD. This would result in an increased storage capacity of about 116 per cent and an extension of the weir pool by about 18.81 river kilometres to about 85.52 river kilometres.

The operational impacts are associated with:

- Initial filling of the weir pool
- Hydrological changes
- Normal weir pool operations
- Recreation
- Downstream erosion
- Weir/fishway maintenance.

Initial filling of the weir pool/Inundation of previously exposed land

The operation of the new weir would result in the formation of the about 4.92-river kilometre-long new town pool between the new and existing weirs, and, when the weir is in drought security operation mode, also inundate about 18.81 kilometres of the river that is upstream of the existing weir pool to a depth of up to one metre. The inundation of these reaches of the river has the potential to trigger blackwater events, increase salinity and mobilise nutrients.

Blackwater events occur when large amounts of plant matter partially broken down by bacteria are inundated and the decaying matter is transported into the river resulting in the leaching of high loads of dissolved organic nutrients from the floodplain to the river channel, decreasing water quality. This can result in low levels of dissolved oxygen, which when combined with the toxic components of some organic matter can result in death of aquatic organisms. Chemicals released from organic material can also make water bodies more alkaline or acidic, potentially disrupting normal pH balances and resulting in toxic effects on some aquatic organisms (ANZG, 2018). Additionally, water may require additional treatment prior to being used for drinking water purposes (MDBA, 2020b). Despite the short term negative affect, there are benefits to blackwater events including supply of additional carbon and nutrients to drive overall production in river and wetlands which boosts food supplies and supports breeding cycles (ANZG, 2018).

Increases in the salinity of the Darling River (Baaka) has the potential to occur as a result of inundation due to mobilisation of surface salts, however the impact on this would be dependent on groundwater salinity and rate of drawdown. Increased mobilisation of nutrients may also occur with inundation which could be assimilated by phytoplankton and result in increased algal blooms.

Therefore it is expected that some reduction in water quality would occur during the first filling periods, particularly with respect to nutrients (total nitrogen and total phosphorous) and subsequently turbidity and dissolved oxygen. This could present an issue at the water treatment plant when drawing water for drinking water purposes, however the quality of extracted water is unlikely to be any worse than that which occurs when there is a significant rainfall event in the catchment. Also, the new town pool is downstream of the town water intake, which makes it unlikely that water quality issues due to the initial inundation of this reach of the river would impact the town water supply, and the depth of inundation of the extended weir pool when the new weir is in drought security operation mode is a maximum of one metre so much of the temporarily inundated area would normally be under flowing water.

There are no specific water quality issues associated with the reset phase.

Hydrological changes

Weir reservoirs create distinct physical conditions that differ from free flowing natural reaches. They result in hydrological changes including water level, river flow, water velocity and hydraulic retention time all of which can affect aquatic ecosystems, including habitat fragmentation, changes in nutrient cycling and primary productivity.

The commencement of operation of the new weir would result in a weir pool which under different climatic and hydrological conditions can impact on surface water quality by way of stratification, variable dissolved oxygen, increased nutrients and sediment and algal blooms.

As a result of hydrological changes, chemical and thermal differences may be observed at the weir. Thermal stratification occurs when the surface water heats up more rapidly than the deeper water during the day. The surface water becomes less dense and can result in minimal to no mixing with the deeper water, which over time can result in stratification. In addition to clear temperature differences between the surface and deeper water, stratified water bodes also tend to result in different dissolved oxygen levels, where the surface water is continually replenished with oxygen from the atmosphere, but due to lack of mixing and consumption of oxygen from respiring microorganisms the bottom waters become depleted of oxygen (anoxic). Thermal stratification of the new weir pool is more likely to occur when the flows are reduced and the weir pool is stagnant. This scenario would occur when the new weir is in drought security operation mode. At the existing weir, the onset of stratification occurred about two to three months after the onset of drought conditions. Given the new weir would have a higher storage level compared to the existing weir (one metre higher), the onset of thermal stratification would occur between six and eight months after it enters drought security operation mode.

As weir pools are deeper than free flowing sections of the river but have the same volume of water, just at a slower velocity, they are conducive to stratification. However, given weir pools are usually not deep, destratification can occur with climatic changes (Baldwin, 2019). Additionally, due to the low flow velocity, weir pools tend to be deposition zones where the bottom sediments accumulate carbon. This results in a higher sediment oxygen demand in the weir pool compared to free-flowing sections of the river which can contribute to anoxic waters.

Weir pools are also susceptible to algal blooms. The likelihood of algal blooms is dependent on a number of factors including nutrient concentrations, flow/weir height and thermal stratification and therefore more likely to occur during summer/warmer months and/or when the weir is in drought security operation mode. Algal blooms can impact on the uses of the weir pool, including its suitability for recreation and visual amenity as algae can cause skin and eye irritations and blooms can result in discolouration and unsightly scums. It can cause taste and odour issues for the drinking water supply and reduce the effectiveness of the treatment process. Just as algal blooms when present impact on water quality, as the blooms subside, the dead and decaying algae can significantly reduce the oxygen levels in the water, causing stress and sometimes death of aquatic animals.

Dissolved oxygen, temperature and electrical conductivity would be measured at an existing gauging station at Rock Bar (gauging station no. 425008 (Wilcannia Main Channel)) located between the new weir and the existing weir. This would assist in monitoring water quality and implementing measures such as opening the weir gates to prevent or minimise stratification and deterioration in water quality.

Recreation

The existing weir pool is currently used for primary recreation. As mentioned in **Table 8-1** the key indicators for determining recreational suitability is cyanobacteria and enterococci however, to date, only cyanobacteria appear to be monitored. Despite the lack of monitoring data, the existing weir pool would be at risk of contamination with faecal matter from the agricultural area draining the catchment upstream of the existing weir. The origin of faecal matter in agricultural areas include deposition directly into the waterway by livestock and wild/native animals (during dry weather), from farm waste such as manure that can be washed into the river via runoff either directly or from deposition of faecal materials to the soil which is remobilised following rainfall. Literature suggests that enterococci numbers from agricultural sources could range between 1200-4350 colony forming units (cfu) per 100 millilitres (cfu/100mL) which exceeds category D and present a greater than 10 per cent change of illness to a person recreating (Jacobs, 2018). The existing weir pool under current environmental and operating conditions can experience low flow and warm water which can provide favourable conditions for bacteria to multiply.

Locating the proposed new weir two kilometres downstream of the Wilcannia township introduces additional risks of faecal contamination. Whilst the risk from agricultural inputs is still prevalent, the new weir pool is also at risk of:

- pathogens from sewage system overflows/leaks
- pathogens from on-site sewage management system discharges/failures contaminating source water (Public Works Advisory, 2020).

Any sewage related discharge presents a significant risk to human health as enterococci, a key indicator of contamination are estimated to be in the order of 1,000,000 cfu/100mL (NHRMC, 2008). As noted in **Section 3.3.1**, there are also four stormwater drains that discharge into the river upstream of the new weir in what would become the new town pool. Currently these stormwater drains contain runoff during rainfall events, but at times may also contain sewer overflows that are conveyed to the stormwater drains during outages and overflows from the two sewage pumpstations.

Rainfall is required for sewage overflows to pose a risk of entering the river. Sufficient rainfall is required for overflowing sewage to be transported from the town into the river. Although the town receives low rainfall as noted in **Section 3.1.3**, the short distance between the town and the river means that rainfall that generates runoff has the potential to transport pathogens into the river if a sewage overflow occurs just prior to or during the rainfall and is not contained.

Works to reduce or eliminate the risk of sewer overflows entering the stormwater and river are proposed and include augmentation of the Wilcannia Sewerage System by Water Infrastructure NSW to protect raw water quality and a proposed upgrade to the towns sewerage scheme by Central Darling Shire Council (refer to **Section 8.4.3**). These proposed works would greatly reduce the risk of pathogens from sewer overflows, leaks and outages. As such the key risks to the water quality of the new weir with respect to recreational suitability is the same as the existing weir; agricultural land use inputs, but will also be influenced by stormwater and other sources from the Wilcannia township. Enterococci numbers in urban areas/towns can vary and depending on how urbanised the area is, the size of the urban area draining to stormwater and the presence of domestic animals all of which can introduce enterococci and other pathogens into the system. Typically these numbers are greatest directly following rainfall. Generally, stormwater from small urban areas can have enterococci numbers between 84 and 33,800 cfu/100mL and residential areas between 700 and 2,600 cfu/100mL (Jacobs, 2018). The proposed design and operation of the new weir however will likely reduce the impacts as the weir gates will allow water to be discharged and the greater volume of water may provide increased dilution.

Given the lack of existing data on enterococci the following recommendations should be considered:

- Collection of water quality data at various locations under different conditions (wet and dry) to gain an understanding of existing enterococci numbers and how this fluctuates between rainfall events of varying intensities
- Undertaking a detailed risk assessment of the new weir as per the NHMRC (2008) *Guidelines for Managing Risks in Recreational Waters.* This risk assessment should be undertaken by the relevant stakeholder/s responsible for managing recreation within the weir pool. The approach to assessing risks and managing hazards in recreational water is based on a preventative strategy which focuses on developing an understanding of all potential influences on a recreation water body and developing a monitoring program that can provide real time indication of water quality.

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 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 from 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.

Normal weir pool operations

The commencement of operation of the new weir would result in a weir pool which under different climatic and hydrological conditions can impact on surface water quality by way of stratification, variable dissolved oxygen, increased nutrients and sediment and algal blooms.

As a result of hydrological changes, chemical and thermal differences may be observed at the weir. Thermal stratification occurs when the surface water heats up more rapidly than the deeper water during the day. The surface water becomes less dense and can result in minimal to no mixing with the deeper water, which over time can result in stratification. In addition to clear temperature differences between the surface and deeper water, stratified water bodes also tend to result in different dissolved oxygen levels, where the surface water is continually replenished with oxygen from the atmosphere, but due to lack of mixing and consumption of oxygen from respiring microorganisms the bottom waters become depleted of oxygen (anoxic).

As weir pools are deeper than free flowing sections of the river but have the same volume of water, just at a slower velocity, they are conducive to stratification. However, given weir pools are usually not deep, destratification can occur with climatic changes (Baldwin, 2019). Additionally, due to the low flow velocity, weir pools tend to be deposition zones where the bottom sediments accumulate carbon. This results in a higher sediment oxygen demand in the weir pool compared to free-flowing sections of the river which can contribute to anoxic waters.

Weir pools are also susceptible to algal blooms. The likelihood of algal blooms is dependent on a number of factors including nutrient concentrations, flow/weir height and thermal stratification and therefore more likely to occur during summer/warmer months. Algal blooms can impact on the uses of the weir pool, including its suitability for recreation and visual amenity as algae can cause skin and eye irritations and blooms can result in discolouration and unsightly scums. It can cause taste and odour issues for the drinking water supply and reduce the effectiveness of the treatment process. Just as algal blooms when present impact on water quality, as the blooms subside, the dead and decaying algae can significantly reduce the oxygen levels in the water, causing stress and sometimes death of aquatic animals.

In summary the risks to surface water quality from the operation of the new weir may include:

- Thermal stratification
- Variable dissolved oxygen levels through the water column at the weir itself, that are likely to be lower than the free flowing parts of the Darling River (Baaka)
- Elevated turbidity at the weir itself and a portion of the weir pool immediately upstream of the wall due to sediment build from upstream sources and land use practice
- Elevated nutrient concentrations, particularly following initial fill and rainfall
- Increased occurrence of blue-green algal blooms at the weir itself due to low flow, elevated nutrients and stratification.

Dissolved oxygen, temperature and electrical conductivity would be measured at an existing gauging station at Rock Bar located between the new weir and the existing weir. This would assist in monitoring water quality and the implementing measures should as opening the weir gates to prevent or minimise stratification and deterioration in water quality.

Downstream erosion

There is potential for localised erosion immediately downstream of the new weir which could contribute sediment loading to the Darling River (Baaka) which could deteriorate water quality. As mentioned in **Section 8.3**, scour protection by way of rockfill would be provided minimising the risk of erosion and increased sediment loads.

8.4.3 Cumulative impacts

Cumulative water quality impacts may arise from the interaction of construction and operation activities of the proposal, and other approved or proposed projects in the area. When considered in isolation, specific impacts of the proposal may be considered minor. These minor impacts may, however, be more substantial, when the impact of multiple projects on the same receivers is considered.

This section provides an assessment of cumulative surface water quality impacts based on the most current and publicly available information for projects within the vicinity of the proposal that are in varying stages of delivery and planning. There is potential for cumulative surface water quality impacts from the proposal and four nearby projects:

- New Wilcannia Water Filtration Plant
- Wilcannia Township Gravity Sewer Scheme
- Wilcannia Sewerage System Augmentation Works
- Victory Park Caravan Park Amenities Block Refurbishment.

These projects are outlined in the following sections.

New Wilcannia Water Filtration Plant

A new water filtration plant is proposed to be built in Wilcannia as the existing plant has reached the end of its service life. The project is funded by the NSW State Government's Safe and Secure Water Program. A contract for construction of the project was awarded in July 2021 (Central Darling Shire Council, 2021).

The new water filtration plant would consistently produce treated water that is safe to drink and protects public health, including algal blooms, and associated taste, odour and toxins due to stagnation of water in the weir pool, high colour and turbidity in the raw water extracted from the weir pool which is exacerbated during wet weather events and prolonged dry periods.

Wilcannia Township Gravity Sewer Scheme

Central Darling Shire Council proposes to construct a gravity sewerage system for the Wilcannia township to avoid the problems associated with the current common effluent drainage system and to bring the level of sewerage services to the town's residents and businesses to the same standard as is now provided to the residents of Malle and Warrali Aboriginal estates (refer to **Section 3.3.1**). The Wilcannia Township Gravity Sewer Scheme project will be funded by the NSW State Government's Safe and Secure Water Program. The project is not expected to commence operation until after the proposal commences operation.

Wilcannia Sewerage System Augmentation Works

The existing Wilcannia sewerage system comprises of seven sewage pumping stations, with two of these being central to the system: effluent from the north-eastern side of the town is collected at pumping station number 1 (PS1) and effluent from the south-western side is collected at pumping station number 2 (PS2) (Public Works Advisory, 2020). To address the risk of sewage overflows entering the stormwater system and the new town pool Water Infrastructure NSW proposes to augment the existing sewerage system by installing diesel-powered back-up pumps at both PS1 and PS 2 to provide redundancy in the event of pump station failure to avoid untreated effluent waste overflowing into the stormwater system. These stormwater mitigation works do not form part of the Wilcannia Weir Replacement project and would be subject to a separate environmental impact assessment. The works are proposed to start in late 2022 so that they are completed prior to commencement of construction of the new weir.

Victory Park Caravan Park Amenities Block Refurbishment

Central Darling Shire Council proposes to replace the amenities block located at the centre of Victory Park Caravan Park. The proposed works include building a new amenities block alongside the existing amenities block, demolishing the existing amenities block, replacing perimeter drainage and sewerage services including installing a new sewage pumping station and storage tank, and installing disabled facilities next to the amenities block. The works are expected to start in about April 2022 and be completed by about August 2022.

Cumulative impact assessment

Potential cumulative impacts to surface water quality with respect to nearby projects are summarised in **Table 8-3**.

Table 8-3 Assessment of potential cumulative impacts for relevant identified projects

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
New Wilcannia Water Treatment Plant	Located on the right riverbank just upstream of the existing weir (near Ross Street). Likely to be some overlap in construction program with the proposal.	Construction of the New Wilcannia Water Treatment Plant is likely to have some overlap with the construction of this Proposal. During timeframes where construction activities are concurrent, there is potential for minor surface water quality impacts to the Darling River (Baaka) at the existing weir on the south bank. Given measures such as cofferdams, silt curtains and sediment basins will be implemented during construction of this proposal, any sediment generated is unlikely to enter downstream Darling River (Baaka). It would be expected that construction activities and discharges associated with the new Water Treatment Plant would be managed to avoid downstream water quality impacts and erosion and

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
		sedimentation. During construction of the new Water Treatment Plant, drinking water will be sourced from groundwater bores. During operation, there are unlikely to be any cumulative impacts to surface water quality as both sites would be rehabilitated and water quality impacts are not expected from operation of the new Water Treatment Plant nor proposal.
Wilcannia Township Gravity Sewer Scheme	Located on the right riverbank in Wilcannia township. Unlikely to be an overlap in construction program with the proposal.	The proposed Wilcannia Township Gravity Sewer Scheme project would reduce the likelihood of sewage overflows occurring and therefore the risk of sewage entering the new town pool.
Wilcannia Sewerage System Augmentation Works	Located on the right riverbank in Wilcannia township. No overlap in construction program expected as Water Infrastructure NSW would complete this project before starting construction of the proposal.	The proposed Wilcannia Sewerage System Augmentation Works project would reduce the likelihood of sewage overflows occurring and therefore the risk of sewage entering the new town pool.
Victory Park Caravan Park Amenities Block Refurbishment	Located on the left riverbank next to the existing weir. No overlap in construction program expected as Central Darling Shire Council is expected to complete this project before the start of construction of the proposal.	The proposed Victory Park Caravan Park Amenities Block Refurbishment project would reduce the likelihood of sewage overflows occurring and therefore the risk of sewage entering the new town pool.

8.5 Management and mitigation measures

Environmental management and mitigation measures would be an integral part of the construction activities and are proposed with the objective of minimising any short term impacts to water quality in the Darling River (Baaka) downstream of work sites. This section provides an overview of the measures that will be incorporated into the design of the proposal to minimise potential impacts to water quality from the construction and operation of the proposal and are detailed in **Table 8-4**. The implementation of these measures is likely to result in the nominated water quality objectives being met and that any changes in water quality are minimised and temporary.

Table 8-4 Proposed surface water quality management and mitigation measures

Ref	Impact	Environmental management measure	Timing
SW1	General	A construction soil and water management plan (CSWMP) will be developed as a sub plan of the construction environmental management plan and will outline measures to manage soil and water impacts associated with the construction works. The CSWMP will include but not be limited to: ▪ Measures to minimise/manage erosion and sediment transport within the construction footprint and offsite including requirements for the preparation of erosion and sediment control plans for all progressive stages of construction ▪ Measures to manage stockpiles including locations, sediment controls and stabilisation ▪ Measures to manage accidental spills including the requirement to maintain materials such as spill kits ▪ Measures to manage potential tannin leachate ▪ Concrete waste management procedures ▪ A surface water quality monitoring program to monitor the performance of management measures.	▪ Pre-construction
SW2	Erosion and sedimentation	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". Erosion and sediment control measures will be identified in the CSWMP and will likely consist of sediment fencing and sediment basins and include: ▪ 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 after installing instream structures ▪ Undertake construction and demolition during low or no flow in the watercourse to minimise sediment loads downstream. 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.	▪ Pre-construction ▪ Construction
SW3	Working in watercourses	The CSWMP will include details of the design, construction method and sequencing and management of cofferdams used to control flows past dry in-stream work sites. The plan will detail: ▪ How flows past in-stream work sites will be maintained at all times	▪ Pre-construction ▪ Construction

Ref	Impact	Environmental management measure	Timing
		▪ The flow rates at which inundation of work sites would occur ▪ How flow rates will be monitored ▪ Procedures to secure in-stream work sites and prevent water pollution when high flows occur.	
SW4	Dewatering	Any water collected from work sites will be treated before being discharged to avoid contaminants from entering the Darling River (Baaka). A dewatering management plan will be prepared as a sub plan of the CSWMP and it will outline: ▪ The method for dewatering the cofferdams as well as discharges from sediment basins/water quality ponds ▪ 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	The CSWMP 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 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).	▪ Pre-construction ▪ Construction
SW6	Impacts of stockpiles	Stockpiles will be managed to minimise the potential for mobilisation and transport of dust, sediment and leachate in runoff. This will include : ▪ Minimising the number of stockpiles, area used for stockpiles and time that they are left exposed	▪ Construction

Ref	Impact	Environmental management measure	Timing
		▪ Locating stockpiles away from drainage lines, waterways and areas where they may be susceptible to wind erosion ▪ Stabilising stockpiles, establishing appropriate sediment controls and suppressing dust as required.	
SW7	Water quality	The location and details of all water quality controls (including but not limited to temporary sediment basins) will be further considered during the detailed design phase. Diversion drains and erosion and sediment control measures will include but not limited to: ▪ Temporary drainage to construction sediment basins ▪ Inclusion of silt curtains around the work site. Control measures will be in place prior to commencement of any work.	▪ Detailed design ▪ Construction
SW8	Concrete works	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
SW9	Construction discharges	Prior to releasing construction water collected in sediment basins, water should be repurposed on site wherever possible. For instance, for dust suppression activities. Water that cannot be repurposed on site should be treated if necessary, prior to discharge. Water quality monitoring should occur to confirm the suitability for any proposed reuse of water on site or prior to it being discharged downstream.	▪ Detailed design ▪ Construction
SW10	Water quality monitoring – construction	A construction surface water monitoring program will be developed in accordance with the ANZG (2018) and included in the CSWMP to establish baseline conditions, to observe any changes in surface water quality that may be attributable to construction of the proposal and inform appropriate management responses. Monitoring during pre-construction and construction will occur at various locations along the Darling River (Baaka). Monitoring sites will be located upstream and downstream of the key construction activities and will include sampling for key indicators of concern. Should the results of monitoring identify that the water quality management measures are not effective in adequately mitigating water quality impacts, additional mitigation measures will be identified and implemented as required.	▪ Pre-construction ▪ Construction

Ref	Impact	Environmental management measure	Timing
SW11	Water quality monitoring – operation	Operational surface water monitoring will occur following completion of construction until work sites have been rehabilitated to an acceptable condition and water quality issues associated with initial inundation of the new town pool have subsided.	▪ Commissioning

9. Flooding impact assessment

A flooding impact assessment has been carried out to determine the likelihood and extent of any upstream flooding impact caused by the proposal. The assessment addresses the requirements of SEAR number 3. **Table** 1-1 outlines how this assessment addresses the requirements of SEAR number 3.

9.1 Assessment methodology

A desktop upstream flooding impact assessment of the proposal has been carried out. Key inputs to this assessment have been provided by Public Works Advisory and include:

- Weir pool extent mapping
- Drown-out assessment. An initial conservative drown-out assessment was undertaken for a one-metre raised fixed crest weir structure with allowance for a vertical slot type fishway on the left abutment. The preliminary concept design of the proposal represents a lesser waterway obstruction and therefore would result in a lower drown-out
- An afflux assessment.

Public Works Advisory initially provided the above items in the business case addendum for a new weir located at site A2. Since the business case addendum was prepared, the proposed new weir has been moved to a refined location about 325 metres upstream of site A2. Public Works Advisory has generally updated the above mapping and assessments for a weir at the currently proposed site and this information has been accounted for in this flooding impact assessment.

The overarching methodology for assessing the potential upstream flooding impacts of the proposal is to compare any potential flooding impacts of the proposal to the existing situation i.e. the continued operation of the existing weir.

The key steps in the assessment methodology were to:

- Review the weir pool extent mapping prepared by Public Works Advisory to confirm that the weir pool would be contained within the river channel and that related upstream changes in inundation extents are minimal
- Review the findings of the hydraulic analysis undertaken to estimate the indicative weir drown-out flow and assess the underlying potential for upstream impacts at higher flows. Review was also undertaken of the estimated Darling River (Baaka) flow at which the increase in upstream water level (afflux) that may be caused by the new weir would diminish to less than 50 millimetres, which was aimed at assessing the underlying potential for upstream flood impacts by confirming whether afflux would reduce to an assumed minimal amount at an in-channel flow level below the top of the low (left) riverbank.

9.2 Risks

The purpose of a weir is to create an increase in upstream river levels to enable flow diversion or, in the case of Wilcannia, to provide an instream raw water supply storage source for extractive use. Weirs have the potential to cause hydrologic and hydraulic impacts both upstream and downstream. Flooding related impacts are typically associated with potential changes in conditions upstream of the weir. Potential upstream impacts include:

- Changes in the extent and depth of upstream inundation
- Changes in upstream flood levels and flood frequency
- Changes in the frequency and duration of upstream inundation
- Changes in flood flow distributions
- Increased riverbank overtopping and breakouts

- Reductions in the stability of the riverbanks and bed due to operation of the weir, particularly if this results in upstream weir pool/river levels that fall at faster rates than historical conditions
- Inundation of private property and property access roads
- Reduction in upstream flow velocities due to increased depths with potential impacts on flowing water habitats
- Potential issues for extraction pumping infrastructure, particularly if sited between riverbanks
- Potential issues related to performance of stormwater drainage and floodplain levee systems.

The potential upstream flooding impacts of the proposal have been considered as have the relative vulnerability of the community living within the weir pool floodplain area.

Construction of a new weir downstream of the existing Wilcannia Weir has the potential to result in increased upstream water levels compared to existing due to both an increased obstruction of the river cross-sectional waterway area and operation of the structure gates. This has the potential to impact upstream flood levels and to inundate areas both in-channel and surrounds either permanently and/or more frequently. The increase in upstream water levels is referred to as 'afflux'. When the new weir is in normal operation mode, afflux would be greatest at weir commence-to-flow conditions and would progressively diminish as river flows increase.

9.3 Avoidance and minimisation of impacts

The key factor influencing the potential for a weir to cause upstream flooding is the weir height and the area of the river channel cross-section that it obstructs. The higher the crest level of a weir and the greater the area of the river channel cross-section that it obstructs, the more likely it is to cause the potential impacts identified in **Section 9.2**.

Public Works Advisory, on behalf of Water Infrastructure NSW, has investigated different crest levels for the proposed new weir. These investigations are documented in the *Wilcannia Weir Replacement Business Case* (Department of Primary Industries (Water), 2016) and *Wilcannia Weir Upgrade, Addendum to Business* Case (Department of Industry – Water, 2019). The investigations considered the relationships between weir crest height and the water supply secure yield provided by the additional weir pool storage capacity and the likelihood of upstream and/or downstream impacts. Of the three heights considered (existing, +0.5 metres and +1.0 metres), only the one-metre raising provided an adequate secure yield hence was the only viable weir height investigated.

9.4 Assessment of impacts

9.4.1 Weir pool extents

A new weir located downstream of the existing weir and with a design full supply level matched to the existing weir crest level of 65.71 metres AHD would maintain the existing weir pool while also providing a new additional section of weir pool between the new and existing weirs (the 'new town pool'). This would add about 4.92 river kilometres to the length of the existing weir pool, which is about 61.79 river kilometres long, to create a combined weir pool length of about 66.71 river kilometres.

As noted in **Section 4.2.1**, the new weir would have dual operating modes. When the new weir is in drought security operation mode, the full supply level would increase by one metre to 66.71 metres AHD and the maximum upstream weir pool extent would increase by about 18.81 river kilometres beyond the upstream limit of the existing weir pool extent to create a total weir pool length of about 85.52 river kilometres.

A longitudinal schematic profile of the new weir pool in normal and drought security operation modes is provided in **Figure 4-2**.

Public Works Advisory has mapped the new weir pool extents when the new weir is in normal operation mode and the weir pool level is at the existing full supply level of 65.71 metres AHD (refer to **Figure 4-1**). Mapping of the new weir pool extents at the existing full supply level has been compared to the existing weir pool extents and it shows that:

- The weir pool inundation extents are well confined within the banks of the main river channel with no breakouts and insignificant extents of water backing up into tributaries and/or drainage watercourses
- Upstream of the existing weir the inundation extents are essentially the same as those for the existing weir, assuming the existing crest breach on the right abutment is remediated (refer to **Section 4.1.2** and **Photo** 4-1**)**
- The greatest change in river conditions would occur within the new town pool segment created along the length of river between the new and existing weirs. Conditions along this about 4.92 river kilometre section of the river would change from existing natural flowing (lotic) conditions to weir pool (lentic) for the majority of time with consequent effects including permanent inundation of the riverbed and riverbanks up to 65.71 metres AHD, reduced river flow velocities and increased water depths. These impacted conditions within the new town pool would generally continue for flows up until afflux becomes negligible (assumed to be less than 50 millimetres) at a flow above weir drown-out
- The upstream extent of the weir pool would remain the same at about 61.79 river kilometres upstream of the existing weir, or about 66.71 river kilometres upstream of the proposed new weir.

Public Works Advisory has also mapped the new weir pool extents when the new weir is in drought security operation mode and the maximum weir pool level increases by one metre up to a full supply level of 66.71 metres AHD (refer to **Figure 4-1**). Mapping of the weir pool extent at this raised full supply level has been compared to the existing weir pool extents and it shows that:

- There would be no substantial increases in lateral weir pool extents and no weir pool breakout of the main river channel. This indicates that there is no topographical impediment to the proposed one metre increase in the design full supply level when the weir is in the drought security operation mode
- Increases in the lateral extent of the weir pool are greatest where the riverbanks are flatter and where there are in-channel riverbank and bed features, such as bank benches above 65.71 metres AHD (and below 66.71 metres AHD)
- There would only be minor intrusion of the weir pool into tributaries and/or drainage watercourses. The greatest intrusion would occur into Kallyanka Creek, where the weir pool would backup about 100 metres. The weir pool would also backup into Paroo River by about 100 metres. Elsewhere, the weir pool would backup tributaries and/or drainage watercourses by less than 30 metres, and typically less than 10 to 15 metres
- Based on the mapping, there would be no out-of-channel impacts to private property.

9.4.2 Weir drown-out and afflux

General

The new weir would obstruct a greater proportion of the river channel waterway area in both normal operation mode and drought security operation mode than the existing weir and as a consequence cause upstream river water levels to increase. The new weir would obstruct more of the river channel waterway area when it is in drought security operation mode than normal operation mode, however, the weir would only be in drought security operation mode when there are drought conditions. Therefore, at times of high flow, the weir would be in normal operation mode.

To assess the potential impact of the new weir, the extent of any upstream water level increase caused by the new weir is compared to what the upstream water level would be if a new weir were not to be built and the existing weir were to remain in place. Consideration is also given to what the water level would be in the river if there were no weir.

The water levels upstream of the proposed new weir would depend on the design of the weir structure, the operating mode, the position of the weir and fishway gates, operational settings and the river flow conditions:

- *Low flow* — When there are near cease-to-flow river conditions (i.e. less than one megalitres per day, as per **Table 2-1**) the new weir is likely to be in drought security operation mode and upstream water levels in the new town pool and existing weir pool would be up to one metre above the current full supply level. There would also be up to about 18.81 river kilometres of additional weir pool upstream of the existing weir pool. If cease-to-flow conditions persist, the water level in the weir pool (and also the upstream extent of the weir pool) would reduce due to water extraction for town water use, evaporation and infiltration
- *High flow* — When flows return to the river, the reset phase would be triggered and the new weir would transition from drought security operation mode to normal operation mode and the full supply level would return to being the same as the existing weir pool. As river flows increase, the water level upstream of the new weir would increase if inflows to the weir pool exceed the design capacity of the fishway at the weir, which is 1,000 megalitres per day. Once inflows to the weir pool exceed 1,000 megalitres per day, water would start to flow over the top of the weir crest. If flows continue to increase, the difference between existing upstream river levels compared to those for the new weir would diminish as the weir becomes first submerged and then drowned-out
- *Weir drown-out* —Weir drown-out occurs when river flow is sufficiently high to cause the weir structure to cease being the main hydraulic influence on upstream river water levels. This occurs when passing flow produces a high water level immediately downstream of the weir that results in the weir structure becoming completely submerged and the difference in water levels from downstream to upstream becoming typically 0.15 metres or less.

The difference between existing and proposed upstream river levels at a particular location is referred to as the afflux. A typical design requirement is to ensure that the afflux has diminished to an amount deemed to be insignificant at some point, such as before significant upstream infrastructure, property access or environmentally sensitive areas are affected, and particularly before riverbank overtopping and breakouts occur.

The likelihood of potentially significant upstream impacts increases with waterway area obstruction and weir height. **Figure 9-1** shows diagrammatically this hydraulic behaviour and the reduction of afflux with increasing flows. Afflux diminishes moving upstream away from the structure causing the afflux.

Based on the *Wilcannia Weir Upgrade, Addendum to Business Case* (Department of Industry – Water, 2019), the proposed new weir would obstruct the natural river waterway area relative to a top of low (left) bank level of 72.11 metres AHD by 25 per cent at a level near the existing full supply level (65.65 metres AHD) and by 35 per cent for the associated one metre raised drought full supply level (66.65 metres AHD), or an incremental increase in obstruction of the river channel of 10 per cent.

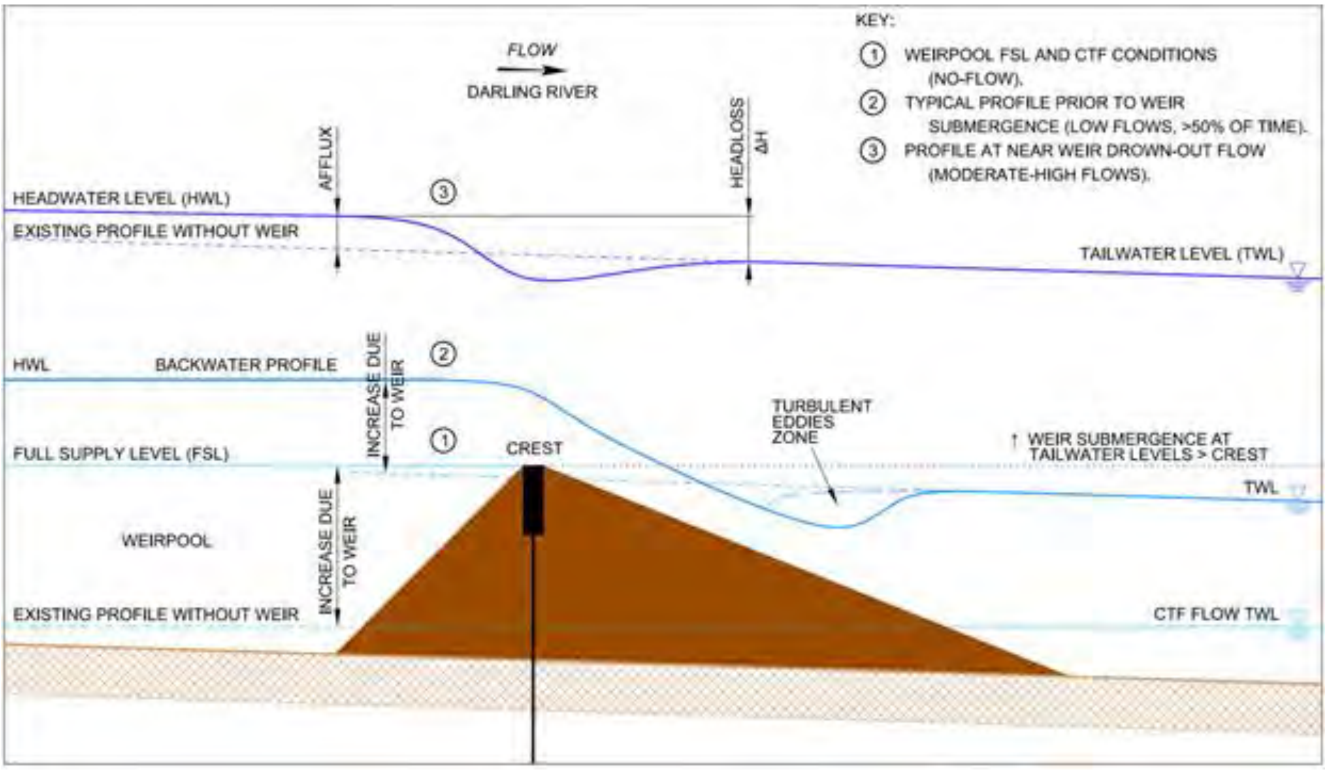


Figure 9-1 Progressive change in weir flow profiles with a change in flow (Ref: Public Works Advisory, 2019)

Drown-out assessment

Drown-out assessments were undertaken by Public Works Advisory using a conservation of energy approach (Bernoulli's principle) with allowance for contraction and expansion losses and accounting for an initial tailwater rating based on normal depth calculations using the Manning's open channel flow equation.

Table 9-1 shows the drown-out assessment results. These are applicable for a tailwater rating based on a downstream river slope of 1V:15,000H and Manning's roughness coefficient (n) of 0.035, with sensitivity assessed using values of 0.03 and 0.04.

The drown-out flow water levels shown in **Table 9-1** are substantially below the top of low riverbank level. This indicates that the new weir is unlikely to produce any apparent significant upstream flooding impacts as flows increase and approach top of low bank level. For the initially assessed weir drown-out flow of 12,070 megalitres per day, future upstream water levels would be about 0.16 to 0.20 metres higher than existing river levels and based on an initially assessed fixed crest weir with a crest level of 66.65 metres AHD (as mentioned above).

Additionally, the afflux values at weir drown-out would diminish moving away from the weir site in the upstream direction due to backwater effects.

It is important to note that the proposed new weir with fully opened weir gates and a high flow fishway would have a lesser flow obstruction than the initially assessed wholly fixed crest weir. Accordingly, the assessments undertaken are expected to be conservative.

Table 9-1 Key results of the drown-out flow assessment

Item	One metre raised weir design FSL 66.65 metres AHD
Weir drown-out flow (megalitres per day)	12,070 (n=0.035) (sensitivity range 14,920 (n=0.03) to 10,110 (n=0.04))

Item	One metre raised weir design FSL 66.65 metres AHD
Weir drown-out flow time duration exceedance frequency (%)*	17
Headwater Level (metres AHD)	68.09
Tailwater Level (metres AHD)	67.91
Structure head loss (metres) – representative of afflux	0.18 (sensitivity range 0.16 to 0.20, respectively)
Depth over weir crest (metres)	0.95
Headwater level below top of low riverbank (metres)	4.01

* Estimated from historic data for gauge no. 425008 (Wilcannia Main Channel) over the period 10/10/1972 to 06/07/2020.

Changes to upstream flood water levels (afflux)

Compared to the results for the above weir drown-out assessment, the increase in upstream water levels due to the weir obstruction is expected to diminish to a negligible value prior to flows reaching the top of low (left) riverbank level of 72.11 metres AHD (refer to **Figure 9-2**).

The increase in flow rate needed to reduce afflux to 50 millimetres results in only a relative minor increase in headwater level that is estimated to be about 0.87 metres higher than those for weir drown-out conditions (sensitivity range 1.35 metres (n=0.03) to 0.061 metres (n=0.04). These additional figures reaffirm the expectation that the proposed new weir is unlikely to produce any apparent upstream flooding impacts out of the main river channel.

The flow associated with the above assessment of a 50 millimetre afflux is 16,200 megalitres per day (187.5 m^3/s) past the weir obstruction. This provides an indicative river flow above which the potential for upstream impacts is anticipated to be insignificant before becoming negligible with further flow increases. The above flow corresponds to a headwater level of 68.96 metres AHD (refer to **Figure 9-2**), which is 2.31 metres above the assessed one-metre raised fixed crest level of 66.65 metres AHD and 3.15 metres below the top of low (left) riverbank level.

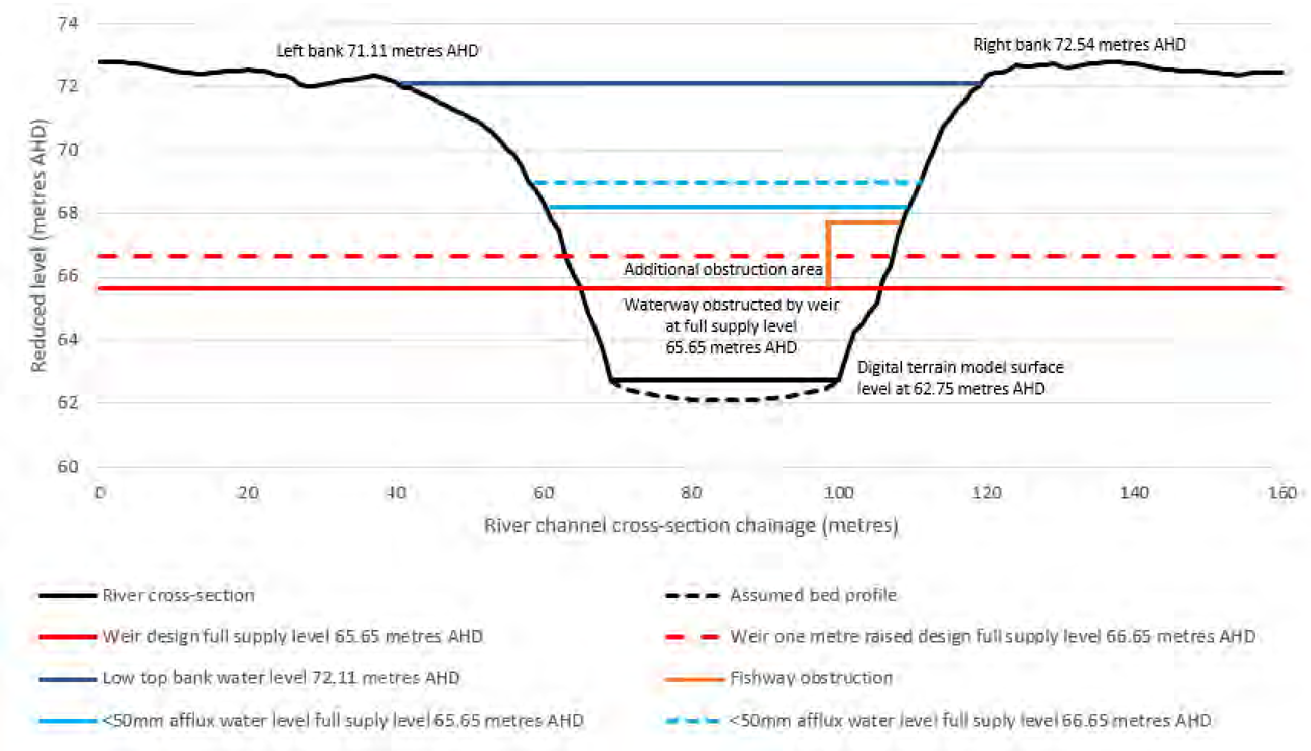


Figure 9-2 Indicative new weir (assumed fixed crest) and fishway obstruction of the natural river channel

To provide insight to the river flow at near top of low (left) riverbank level, **Photo 9-1** shows a photo taken on 04 May 2021 at the proposed new weir site. The average daily flow recorded at the Wilcannia gauge (no. 425008, Wilcannia Main Channel) was 24,122 megalitres per day, which has a time duration exceedance frequency of eight per cent based on the period 10 October 1972 to 06 July 2020. At the time of the photo the water surface was surveyed, and the level was found to be 71.65 metres AHD.

Photo 9-1 Darling River (Baaka) flood flow of 24,122 megalitres per day at the proposed new weir site on 04 May 2021

The flood frequency of the 04 May 2021 event was estimated to have an annual exceedance probability of more than 20 per cent (one in five years). Given that this flow is well above the 16,200 megalitres per day assessed for a 50 millimetre afflux and that flows greater than the observed event would have lower annual exceedance probabilities then it is clear that the proposed new weir would have a negligible effect on any flood levels that are out of channel and for any flood flow event with a smaller annual exceedance probability (e.g. one per cent annual exceedance probability (1 in 100 years)).

9.4.3 Construction impacts

There is potential for flooding of the Darling River (Baaka) at Wilcannia during construction of the proposal, which would have the potential to result in damage to construction equipment and materials, injury to construction people and water quality impacts due to erosion/scouring of construction sites and related river channel areas. These potential impacts could occur due to changes in flow patterns and water levels during construction related to flow diversion, cofferdamming and potential flood damage to work sites.

The risk of flood impacts would be significantly reduced through ongoing monitoring of upstream catchment and weather conditions so as to provide early warning of an impending flood and to allow preparatory response actions to be implemented with the aim of minimising impacts and financial risk. This would be documented in a flood monitoring and preparedness response plan, which would include appropriate response actions to ensure the protection of construction equipment, materials and personnel along with any construction works at both the existing and new weir sites. Effective monitoring of catchment conditions would provide up to 10 days' warning of flood events. This would provide a reasonable lead-time period to undertake flood mitigation tasks such as protecting construction equipment, materials and personnel.

Cofferdams comprising a combination of rock, earth, and steel sheet piling materials would be constructed across only about half the river channel at any one time during construction. This would allow flows to pass downstream via the remaining open portion of the river channel as a flow diversion around the construction site(s). The Stage 1 and Stage 2 cofferdams proposed during construction of the new weir are anticipated to be designed to cater for a minimum flood diversion capacity of 7,000 megalitres per day (81 m^3/s).

9.4.4 Operation impacts

Upstream impacts

The incremental upstream impacts of the proposed new weir during normal operation mode would be the increased weir pool area at the new town pool along the about 4.92 river kilometre reach between the new weir and the existing weir. The weir pool area upstream of the existing weir would remain unchanged during normal operation mode. Localised impacts including bank stability and erosion protection for the new town pool would need to be addressed during the detailed design of the weir and fishway.

Flooding

An examination of the range of flows in the Darling River (Baaka) up to top of bank flows was undertaken to assess the difference in water levels (afflux) between existing and proposed conditions at the new weir site. As discussed in **Section 9.4.2**, it has been assessed that once top of bank flows are reached, with the weir completely submerged during large flood events, the change in flood levels (afflux) is expected to be negligible and accordingly, so too the potential for flood impacts.

The hydrology investigation presented in **Section 5** examined available river gauge data over a period of 48 years, which allowed for flow time duration and flood frequencies to be determined. This information combined with the findings of the hydraulic assessments presented above in **Section 9.4.2**, provide further insight to the potential for flood impacts.

At the indicative weir 'drowns-out' flow of 12,070 megalitres per day (140 m^3/s), the water level difference has been estimated to be 0.18 metres across the initially assessed fixed crest weir (with crest level of 66.65 metres AHD). This flow has a time duration frequency of about 83 per cent (17 per cent exceedance) and corresponds to an annual exceedance probability flood event of about 57 per cent (i.e. one in less than two years).

At the indicative weir flow of 16,200 megalitres per day (188 m^3/s), the water level difference has been estimated to be 0.05 metres across the initially assessed fixed crest weir (with crest level of 66.65 metres AHD). This flow has a time duration frequency of about 87 per cent (13 per cent exceedance) and corresponds to an annual exceedance probability flood event of less than one in two years).

Figure 9-3 show the Darling River (Baaka) water level variability at river gauging station no. 425008 (Wilcannia Main Channel) across time overlaid with the levels for cease-to-flow, the new weir full supply crest level during normal operation mode (65.71 metres AHD) and drought security operation mode (66.71 metres AHD), weir drown-out level (conservatively based on a fixed crest weir at 66.65 metres AHD),level when afflux is anticipated to diminish to 50 millimetres, and the top of low riverbank level at the new weir site.

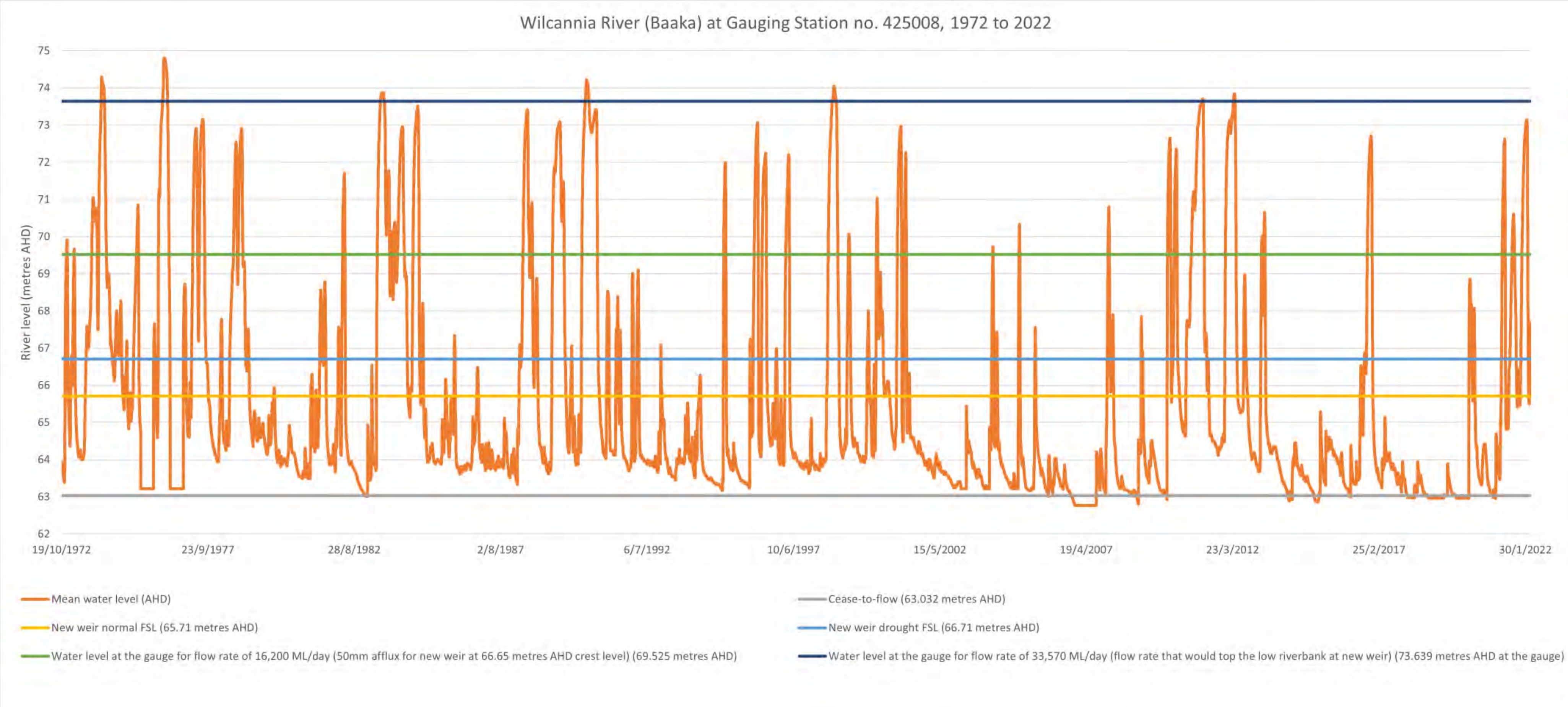


Figure 9-3 Darling River (Baaka) variability at streamflow gauging station no. 425008 (Wilcannia Main Channel), 1972 to 2022

9.5 Mitigation and management measures

Measures to mitigate and manage the potential flood impacts associated with construction of the proposal are detailed in **Table 9-2**. No flood mitigation and management measures are proposed, or considered necessary, for the operational phase of the proposal.

Table 9-2 Proposed flooding management and mitigation measures

Ref	Impacts	Mitigation and management measures	Timing
F1	Localised flooding due to construction activities	The design of temporary flow diversion works within the river will take into consideration and make clear reference to available hydrological data and clearly identify the assumptions and criteria adopted.	▪ Construction
F2	Localised flooding due to construction activities	The design and crest level of the proposed cofferdams will take into consideration and make clear reference to hydrological data and clearly identify the assumptions and criteria adopted.	▪ Construction
F3	Flood impacts to temporary and permanent works	The construction contractor will develop a monitoring and flood preparedness response plan that will: ▪ Detail procedures for monitoring catchment rainfall, river system flows (including tributaries), river water levels, and flow conditions at the construction sites ▪ Identify subsequent response actions that will be taken to ensure the protection of personnel, equipment, materials, the existing weir structure (including as modified), the new weir works, the river channel and environment, and any other aspects/items ▪ Establish contingencies such as, for example, provisions for the removal or pre-flooding (filling) of cofferdams if a response action flow trigger is reached and designated temporary cleared storage locations to standby equipment and materials.	▪ Construction
F4	Flood impacts to temporary and permanent works	River gauges in the Darling River (Baaka) nos. 425008 (Wilcannia Main Channel) at Rock Bar and 425058 (Moorabin) will be monitored to gain an understanding of prevailing flows at the new and existing weir sites. Upstream gauges on both the main river and tributaries will also be monitored for upstream flow conditions in advance of flows arriving at Wilcannia. Monitoring will be used to identify current and predicted flow conditions in the river at Wilcannia and to provide notification of likely significant flow events that may impact the progress of the works or trigger implementation of appropriate response actions.	▪ Construction
F5	Flood impacts to temporary and permanent works	Rainfall within the catchment will be monitored to identify significant events to provide early warning of the potential for increased river flows.	▪ Construction
F6	Flood impacts to temporary and permanent works	The construction contractor will establish suitable temporary provisions for monitoring the level of any weir pool and how these levels correlate to flows past the construction sites.	▪ Construction

Ref	Impacts	Mitigation and management measures	Timing
F7	Flood impacts to temporary and permanent works	Response actions are to include the timing and duration of all key activities expressed in relation to river flows, weir pool levels, and/or other relevant measures.	▪ Construction
F8	Flood impacts to temporary and permanent works	Response actions may involve, but not be limited to, the withdrawal and later return of personnel, equipment, materials, temporary works and other items from the river and/or adjacent construction sites.	▪ Construction
F9	Flood impacts to temporary and permanent works	Provisions will also be made for out-of-hours implementation of response actions.	▪ Construction

10. Conclusion

Water Infrastructure NSW proposes to replace the existing Wilcannia Weir with a new weir and demolish the existing weir. The new weir has been designed with dual operation modes for normal and drought periods with the weir crest level only being raised above the existing full supply level during drought periods. Dynamic storage rules would apply when the new weir is in normal operation mode and a translucency rule would apply when the new weir is in drought security operation mode. These design features and operating rules would enable the new weir to provide adequate water security to Wilcannia while minimising impacts to flows in the Darling River (Baaka).

This assessment has considered the potential impacts of the proposal on hydrology, geomorphology, groundwater, surface water and flooding and identified that:

- The operation of the new weir would result in an increase in short duration (less than five days) cease-to-discharge events due to the new weir not discharging when it is in the weir filling phase. Due to the short duration of these events their effect on flows downstream of the new weir is likely to dissipate, which would limit their effect on downstream cease-to-flow characteristics
- The operation of the new weir proposal would also result in what would otherwise be long duration cease-to-flow spells being broken into two shorter duration cease-to-flow spells due to the application of the translucency rule when the new weir is in drought security operation mode. This results in a reduction in the mean duration of cease-to-flow spells, from 57 days to 36 days
- There would be an increase in the number of very-low-flow spells but the duration of events would decrease due to these events being interrupted due to the filling phase being triggered and the weir being in drought security operation mode for brief periods
- The number of base flow 2 spells would increase by about one-third, but the mean duration of these spells would only decrease by about 10 per cent, resulting in an increase in the total duration of base flow 2 spells due to the application of the translucency rule during drought security operation mode, which would result in discharges from the new weir when there are inflows to the new town pool and Pool1, whereas some of these flows would not have passed the existing weir
- The operation of the new weir would have only a minor impact on larger flows as the weir would be in normal operation mode and would be operated to optimise downstream flows
- The operation of the new weir would result in a long-term local groundwater level increase near the new town pool to a level similar to the normal full supply level in the weir pool
- As the emergency town water supply bores are not directly connected to the Darling River (Baaka), the risk to the town water supply bores from the construction of the weir is considered low
- Construction of the new weir and partial removal and decommissioning of the existing weir would involve works within the Darling River (Baaka), which presents several risks to surface water quality from erosion and sedimentation, release of tannin leachate, dewatering, disturbance of saline soils, release of oils and fuels, release of concrete waste, and dust and litter. A comprehensive range of management and mitigation measures are proposed to address these risks to surface water quality
- Drown-out flows are substantially below the top of the low riverbank level, indicating that the new weir is unlikely to produce any apparent significant upstream flooding impacts
- Once drown-out of the weir occurs for larger flood events such as the one per cent annual exceedance probability event and the probable maximum flood the new weir would not produce any incremental impact in terms of affluxes.

These impacts of the proposal would be minimised by implementing a range of environmental management and mitigation measures that are designed to minimise changes in downstream flows compared to the existing weir, avoid water pollution, particularly during the construction phase of the proposal, and identify whether impacts to groundwater are greater than predicted.

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Appendix A. Secure yield analysis report

NUWS

WILCANNIA WEIR REPLACEMENT

Yield Study Report

Prepared for NSW Public Works Advisory
on behalf of Water Infrastructure NSW

Report No. 20014 - Final 2.0
July 2022
NSW Urban Water Services Pty Ltd

Summary

This report provides *Secure Yield* estimates for the Wilcannia Weir Replacement Project with assessment undertaken in general accordance with DPIE-Water/NSW Office of Water[1] (NOW) draft guidelines *"Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities"* (Ref 1).

It is noted '*secure yield'* is a defined term (see Chapter 1, Section 1.7) based on the accepted methodology.

It is noted the secure yield estimates are dependent on the operating rules, data and assumptions as discussed in detail in the main body of this report.

It was not feasible to employ the full methodology in the *draft guidelines* (Ref 1) for assessing the effects of climate change on *secure yield* due to the very large catchment (about 570,000 km^2) upstream of Wilcannia. The methodology was used for assessing the storage net evaporation losses, however, to assess inflows the historical critical drought was extended by additional days of zero flows as suggested during liaison with DPIE-Water.

Different historic flow time series datasets were considered (See Section 2.3) and the series considered appropriate for *secure yield* purposes was that utilising observed data when available, which included the reported observation that there were zero inflows to the Wilcannia weir pool during January to December 1902 (for 362 days).

This drought featured as the influencing critical drought. In the future with improved regulation of upstream water use through water sharing plans and the like, this may not occur, thereby providing implicitly some potential conservatism to allow for uncertainty in the upstream flow modelling. Figure S1 compares the daily flows from the different flow series considered and identifies the adopted Wilcannia inflow time series that was judged to be more appropriate for secure yield estimation.

Table S1 provides resulting *estimates* for secure yield using historical data and future secure yield with 1 degree Celsius (°C) climate warming[2] for the modelled proposed[3] new weir storage and new Wilcannia weir structure located about 5km downstream of the existing weir. The proposed new weir provides for a 1m higher crest level and a combined total pool storage of about 6200 ML at the raised FSL of RL 66.65 with about 5300 ML being accessible above the dead storage level of RL 63.65.

1. *NSW Office of Water (NOW) roles migrated to NSW Department of Planning, Industry and Environment (DPIE) during the period 2017-2019.*
2. *The 1 °C climate warming assessment methodology in the draft guidelines relates to changes from 1990. It is noted that climate warming is often quoted elsewhere as referring to what has occurred since 1900 or post industrialisation rather than 1990.*
3. *It is understood since completion of the secure yield modelling the details of the proposed new weir at Refined Site A2 (Ch -4.92km downstream) and associated enlarged storage have been further defined to account for supplementary field survey in 2021 that adopted a revised weir FSL of RL 65.71/66.71 km (dual operating mode) and better represented the dead storage in both Pool 3 (Ch ~30.12 to 49.20 km upstream) and the End Pool (Pool 4, Ch ~49.20 to 61.79 km upstream at FSL 65.71 or Ch ~80.6 km at FSL 66.71).*

Table S1 Proposed new Wilcannia weir secure yield estimates (Rev Site A2, FSL 66.65)

Run No. Conditions	Historic Secure Yield ML/a	1 °C Climate Warming	
		Basis: Increased Net Evaporation and Critical Drought extended by	Secure Yield ML/a
802	**728**	**15% (55 days)**	**225**
807	**728**	**10% (37 days)**	**371 (adopted)**
806	**728**	**5% (18 days)**	**561**
802	**728**	**0 (0 days)**	**654**
Wilcannia Weir Inflow Series: IQQM merged with observed flows and selected historic flows set to zero.			

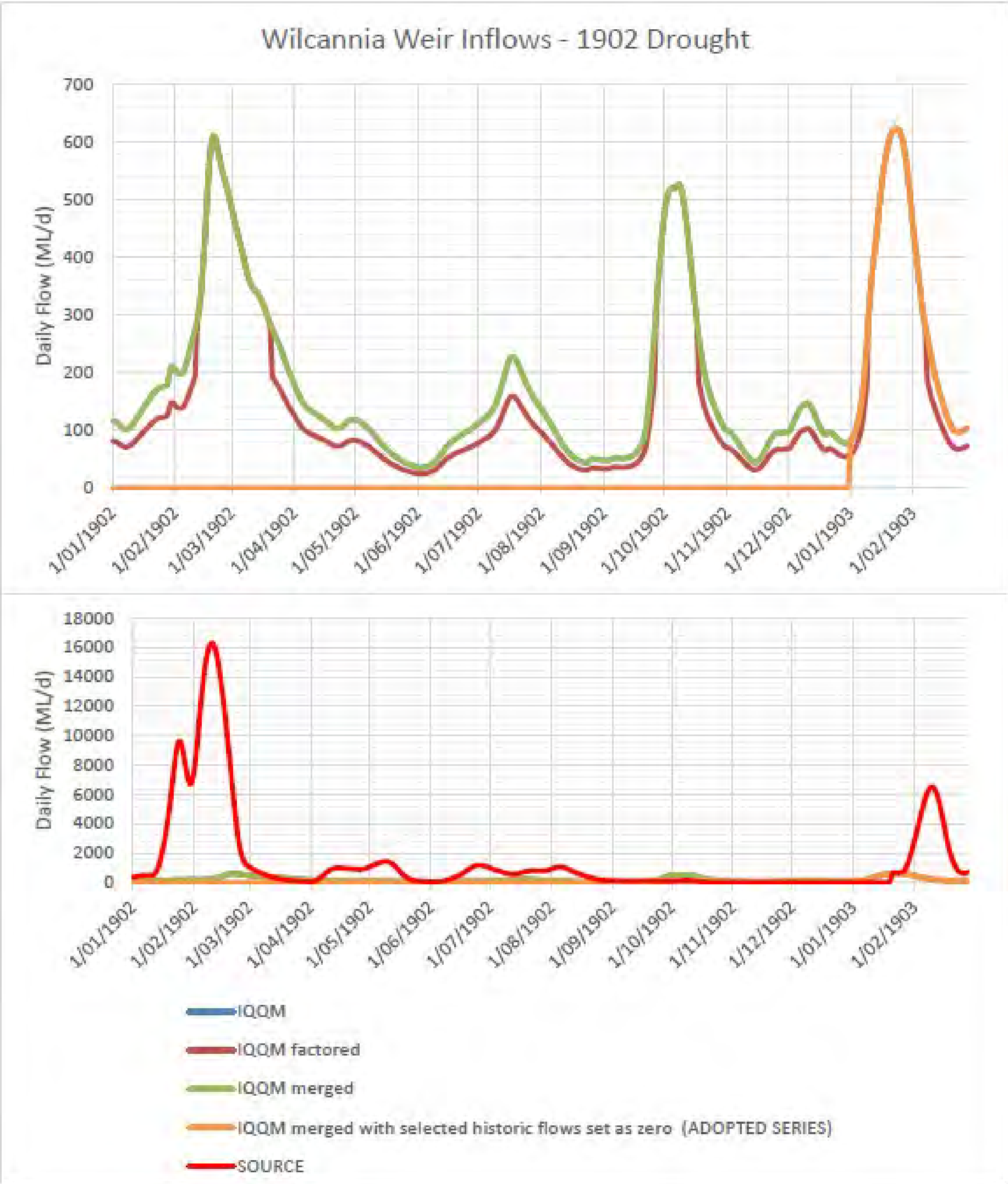
From consideration of assessed reductions in historic secure yield, from other projects, compared to climate warming effected secure yield where the draft guidelines (Ref 1) methodology could be fully employed, the case with the 10% increase in the number of days of zero inflow for the critical drought was judged to be the more appropriate of the four results in Table S1. The approach for Run 807 conditions resulted in an estimated climate warming effected secure yield (371 ML/a) that is 49% less than the historic climate secure yield (728 ML/a).

For the above adopted approach, the proposed new Wilcannia weir with a 1m raised crest compared to the existing weir would be expected to meet the nominated PWA assessed future target (2050) annual unrestricted dry year demand of 362 ML/a on a secure yield basis.

Further studies

The initial trial dual operating mode assessment with 100 / 200 ML/day triggers (passing downstream of Bourke Town Weir) demonstrated that there was merit in the preliminary concept of a dual mode of operation for the proposed new Wilcannia weir, however, it needed to be further developed. The further work was subsequently undertaken as a separate study that included, for example:

- updated WaterNSW SOURCE model flows for the Barwon-Darling River with selected DPIE-Water updated tributary inflows,
- additional bathymetric survey (2021) to better define the dead storages within Pool 3 and Pool 4,
- account for a minor 0.06m higher revised full supply level of RL 65.71 and 1m raised level of RL 66.71, and
- more detailed operating rules aimed at minimising environmental impacts associated with a proposed new 1m raised (dual mode) weir at Revised Site A2 (current 2022 site).



For clarity the much larger SOURCE modelled inflows are not shown on the top plot with the larger scale y-axis.

The IQQM (blue trace) is the same as IQQM merged (green trace) as recording daily flows at the gauging station did not commence until 1913.

Figure S1 Comparison of supplied drought inflow data for 1902/1903

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1. Introduction

1.1 Background

In 2016 Central Darling Shire Council undertook IWCM (Integrated Water Cycle Management) studies. As part of these studies, secure yield assessments were required by Central Darling Shire Council for three of their water supply schemes in accordance with the requirements of DPIE-Water/NSW Office of Water (NOW)[4] draft guidelines "*Assuring future urban water security – Assessment and adaption guidelines for NSW local water utilities"* (Ref 1).

One of the three water supply systems required to be assessed was for the town of Wilcannia.

The existing Wilcannia water supply headworks system consists of:

- Wilcannia weir on the Darling River from which raw water is pumped to supply dual reticulated water supply systems via two separate treatment systems. The weir has a catchment area of about 570,000 km^2. Additional backup supply is provided by multiple bores located at Union Bend, about 3 km to the south of the town.

1.2 Scope of Work

Central Darling Shire Council commissioned in 2016 NSW Public Works Advisory (PWA) to undertake the IWCM studies with NSW Urban Water Services (NUWS) engaged as specialist sub-consultants to:

- Estimate the '*secure yield'* of the existing Wilcannia surface water supply headworks system in accordance with the draft guidelines "*Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities"* (Ref 1). (*This study is generally referred herein as the '**2016 study**'*).

Later the NUWS work was extended in 2018/2019 by PWA to assess the yield of a proposed new Wilcannia weir to provide input to Technical Investigations as an Addendum (Ref 2) to the Business Case for the proposed new weir. (*This study is generally referred herein as the '**2019 BCA study**'*).

The NUWS work was then further extended in 2020/2021 by PWA to determine the secure yield of the proposed new weir based on updated bathymetric survey and storage details. PWA were commissioned by Water Infrastructure NSW (*transferred from WaterNSW*) to develop functionality requirements, prepare a preliminary concept design, provide advice, and undertake related assessments for a new weir. (*This study is generally referred herein as the '**2021 WWR study**'*).

It is noted '*secure yield*' is a defined term as provided by *Best-Practice Management of Water Supply and Sewerage Guidelines* (Ref 3), the *NSW Water Supply Investigation Manual* (Ref 4) and more recently by the NOW draft guidelines *"Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities"* (Ref 1).

Use of the term '*secure yield*' provides a practical, consistent basis for assessing the yield of a system on a security of supply basis. Details of the basis of 'secure yield' are provided in Section 1.7.

As the Wilcannia secure yield work progressed, various aspects were refined including storage details, demands and river inflows.

4. NSW Office of Water (NOW) roles migrated to NSW Department of Planning, Industry and Environment (DPIE) during the period 2017-2019.

1.3 Objectives

This report contains a summary of the modelling undertaken to provide secure yield estimates for the existing Wilcannia weir and the proposed new weir for specified operating and flow conditions.

The outcomes from this modelling were required to provide the required secure yield analysis to assist with planning to meet future water demand.

1.4 Methodology

Estimating the yield of a headworks system involves two important stages:

- Streamflow estimation:

  Developing an appropriate sequence of streamflows

- System Behaviour Modelling:

  Modelling the behaviour of the headworks system subject to operating constraints using the streamflows to assess what demand subject to reliability or security criteria can be satisfied.

For this study required streamflows were provided initially by DPIE-Water from their IQQM (Ref 5) modelling of the Darling River catchment (Ref 6) and then from WaterNSW from their SOURCE (Ref 7) modelling of Darling River catchment. It is noted both models are underpinned by the Sacramento Rainfall Runoff model (Ref 8 & 9). Figure 3 in Chapter 7 provides a schematic of the rainfall runoff model.

For the behaviour modelling a purposely developed system behaviour model to determine yield in terms of 'secure yield' previously was set up for the water supply headworks system. The underlying methodology used in the model arises from the definition of *Secure Yield* and has been successfully used on many other water supply headworks systems. The model logic has been developed and tested through many uses over two decades. A schematic of the model is provided in Figure 4, also in Chapter 7.

1.5 Climate Change

While secure yield allows for meeting demand with restrictions through a much worse drought than has occurred since about 1890 with the historic climate, additional consideration needs to be given to possible changes from climate warming.

For this study additional consideration was given by using the general approach proposed in the draft guidelines (Ref 1). Chapter 4 provides details of the assessment undertaken for this project for the historic climate and also provides details of the how historic climate secure yield estimates were adjusted to allow for climate warming.

1.6 Qualifications

The work contained in this report is considered valid within the context of the study purposes, but caution should be exercised if aspects of this report, including data and estimates, are abstracted out of context or are to be used for some other purpose.

Hydrology is not an exact science and necessarily involves some uncertainty and the results should be regarded as estimates within both the limitations of the study and available data for the purposes of providing assisting guidance within an overall project development process.

The yield of a headworks system is dependent on the assumed streamflows and operating constraints. For this study observed streamflows were provided by others and the operating constraints are as specified. While the yield estimates are based on established methodology, NSW Urban Water Services Pty Ltd does not warrant or accept any liability in relation to the quality or accuracy of the yield estimates that are reliant on provided information and no responsibility is accepted by NSW Urban Water Services Pty Ltd for the accuracy, currency, reliability, and correctness of any information in this publication provided by the client or third parties.

1.7 Yield Model

Secure Yield

For about the past 30 years most urban water supply headworks in country NSW have been sized on a robust Security of Supply basis. This security of supply basis was developed to cost-effectively provide sufficient dam storage capacity to allow the water utility to effectively manage its water supply in future droughts of greater severity than experienced over the past 100 or more years. '*Secure yield*'' is the water demand that can be expected to be supplied with only moderate restrictions during a significantly more severe drought than has been experienced since about 1895 (from when generally reliable rainfall records are available). The required water restrictions must not be too severe, not too frequent, nor of excessive duration. It has been argued that the definition of '*secure yield*' in effect allows meeting demand with moderate restrictions through a severe drought akin to a '1 in 1000 year' drought[5].

Under the NSW Security of Supply basis (commonly referred to as the '5/10/20' rule), water supply headworks systems were normally sized so that:

a. Duration of restrictions does not exceed 5% of the time;

b. Frequency of restrictions does not exceed 10% of years (i.e. 1 year in 10 on average);

c. Severity of restrictions does not exceed 20%. Systems must be able to meet 80% of the unrestricted water demand (i.e. 20% average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy both (a) and (b) above.

'Secure yield' was hence defined as the highest annual water demand that can be supplied from a water supply headworks system while meeting the above '5/10/20' rule.

Over the last 20 years there has been a significant reduction in residential water consumption per property and thus it is considered it will be difficult to achieve a 20% reduction in consumption as implied by the earlier '5/10/20' rule. Consequently, DPIE-Water (*formerly NOW*)) recommends that future planning should be based on a 10% reduction in consumption through a repetition of the worst drought commencing with the storage already drawn down to satisfy the 5% duration and 10% frequency criteria. Thus the '5/10/20' rule has now become a '5/10/10' rule.

It is also noted that more recently the 10% frequency rule has been slightly refined by DPIE-Water/NOW from frequency of restrictions occurring 1 in 10 years on average to only being applied in 10% of years. For a sample of test cases this was of little consequence and was desired to fit in with DPIE-Water/NOW requirements for Performance Reporting of restrictions and thus was also based on the financial year.

5. It is noted that '1 in 1000 year drought' does not mean it only occurs once every thousand years but means it has a 0.1% probability of occurring any year.

The current procedures to determine secure yield are illustrated in Figures 1 and 2 in Chapter 7, which have been taken from material provided by DPIE-Water/NOW.

Model

Essentially the model is a computer program that balances on a daily basis continuity equations between all the water sources and demands while incorporating the procedures (as illustrated in Figures 1 and 2) to determine secure yield. The model simulates the behaviour of the system by accounting for and balancing the available water. The hydrological cycle is modelled external to the model and the required hydrometeorological data is provided as input to the system behaviour model. In essence the system model is driven by operating conditions such as the need to meet a particular demand while satisfying constraints and available flow.

2. Hydrometeorological Data

2.1 Introduction

In general estimates of daily rainfalls, streamflows and daily evaporation and evapotranspiration for as long a historical period as possible is desirable.

Satisfying the '5/10/10' rule for determining secure yield requires more than 100 years of daily streamflows to be a sufficiently long data sample for testing the rules and to include the significant Federation drought (1895-1903) and other known major droughts.

In addition to daily streamflows, accompanying daily rainfalls and evaporation are required for input to the system behaviour model for determining the net loss or gain from or to the storage's water surface area due to evaporation or rainfall.

The daily rainfalls are also usually required as input to the rainfall runoff models as well as daily evapotranspiration to obtain streamflows when no observed streamflows are available.

For this study the modelled inflows were provided.

The details of the models are provided in References 5 to 8 and illustrated in Figure 3.

For this study historic flow data series were provided from the IQQM model for 1895 to 2014/2016 and from the SOURCE model for 1900 to 2019.

2.2 Meteorological Data

The daily rainfall and daily evaporation data were obtained from the SILO Data Drill for the grid points to represent the weir storage water area. The SILO Data Drill is a service provided by the Science Delivery Division of Queensland Department of Science, Information Technology, Innovation and the Arts (DSITIA). The Data Drill accesses grids of data at 0.05° intervals derived from interpolation of point Bureau of Meteorology station records. Interpolations are calculated by Splinning and Kriging techniques. Further details of the processes are given in Ref 9.

The daily evaporation and rainfall data obtained from the SILO Data Drill was used to represent losses from the storages based on the grid points provided in Table 2.1.

Table 2.1 SILO grid points – Wilcannia weir

Grid Point	Latitude	Longitude
1	-31.55°	143.40°

2.3 Flow Data

The key input for determining *secure yield* is a historic daily inflow sequence going back to about 1890 to cover all observed significant droughts particularly the Federation drought. Thus historic daily inflow sequences were required for the location:

- Wilcannia Weir on the Darling River

As the study evolved different historic inflow series were used to examine the sensitivity of the secure yield to various aspects inherent to the flow series. All the flow series required to be used were based on rainfall runoff modelling undertaken by DPIE-Water (*or their predecessors*) and WaterNSW.

The historic flow series used included:

Initial Inflow Series (2016 study)

For the initial modelling undertaken in 2016 the historic inflow series were based on the historic flow series provided by DPIE-Water from their IQQM modelling of the Darling River catchment. The period of flows was from 30/6/1895 to 30/6/2014 based on the current operating conditions and water sharing plans as of 2016. From this data three cases were modelled:

1. Use of the IQQM flows unmodified (IQQM).
2. Use of the IQQM flows with flows below 280 ML/d factored by 0.7 as the NOW IQQM model report (Ref 6) suggested from calibration low flows (below about 90%'ile) appear to be overestimated by up to about 30% (IQQM factored).
3. Use of the IQQM flows merged with the observed flows to present at the time (2016, i.e. observed flows used in preference to modelled flows - IQQM merged).

Initial Flow Series Adjusted for Zero Flows (2016, 2019 BCA, and 2021 WWR studies)

Flows were available for the two gauging stations:

i. 425008 Darling River at Wilcannia Main Channel,
ii. 425018 Talyawalka Creek at Barrier Highway (Wilcannia).

The total flow at Wilcannia being a combination of the two gauging station flows.

For the secure yield modelling only the main channel flows were used as it was considered these better represented the inflows to the weir pool. The other gauging station appears to record flows on the floodplains that may bypass the weir.

The main channel gauging station (*based on information on the current Realtime Water Data website*) is located just downstream of the existing Wilcannia weir. Observed daily flows were available for the station from 6/6/1913 to 30/5/2016 including supplementary available data from Pinneena but with missing data as indicated in Table 2.2.

Table 2.2 Missing daily flows (gauge 425008)

Days of Missing Daily Flows
1/11/1913 – 28/2/1914
1/10/1914 – 30/4/1915
1/7/1915 – 31/7/1915
1/12/1915 – 1/2/1916
1/6/1918 – 31/8/1918
1/12/1918 – 31/12/1918
1/4/1919 – 31/8/1919
1/4/1920 – 31/5/1920
1/3/1923 – 30/9/1923
1/12/1943 – 31/12/1943

Days of Missing Daily Flows
1/10/1947 – 31/12/1947
1/9/1948 – 31/10/1948
1/4/1949 – 30/6/1949
20/10/2004 – 7/11/2004
6/12/2004 – 1/1/2005
1/7/2011 – 21/7/2011

The 1987 report "*Wilcannia Water Supply, Darling River Weir Water Security Study*" (Ref 11) reported periods of more than two months when the flow ceased at Wilcannia. These are reproduced in Table 2.3.

Table 2.3 Periods greater than two months with no flow

Year	Months	Number of Months
1888*	June 1888 to January 1889	8
1902*	January to December (362 days)	11
1919	January to March	3
1919	September 1919 to March 1920	7
1923	February to June	4
1940	October to December	3
1945	January to March	3
1982/83	September 1982 to February 1983	6

** Denotes period before actual gauge readings were taken and the no flow conditions here are estimated.*

These periods of zero flows were replaced in the IQQM flow series and the IQQM flow series that were merged with the data recorded at the gauging station (425008). This resulted in a fourth historic flow series (*IQQM merged/selected historic flows set to zero)* and through a process of consideration became the adopted historic climate inflow series.

It is noted that the extent of the periods of no flows were different to that for the gauging station. For example, the gauging station for the 1982/83 drought only 79 days of zero flows were recorded. *This may be a reflection that if the weir was leaking the downstream gauge may have been recording that leakage. Furthermore, for the purposes of estimating secure yield it would be conservative to adopt the zero flows.*

Additional Inflow Series (2021 WWR study)

In 2020 WaterNSW provided a historic inflow series based on their recent SOURCE modelling of the Darling River catchment that reflected the July 2020 Water Sharing Plans and was requested to be examined in providing an additional basis for secure yield estimates for the proposed new weir. The weir inflow time series was complemented by a second SOURCE data series of flows past Bourke Town Weir that were to be used as trigger flows associated with an initial trial assessment of a dual operating mode for a proposed new 1m raised weir with a variable full supply level (FSL) of RL 65.65 (matched to the existing weir) and RL 66.65 (1m raised).

3. System Behaviour Modelling

3.1 Introduction

Modelling of the behaviour of the water supply headworks system is required to determine the *secure yield* of that system. The aim of the modelling is to determine the maximum annual demand that satisfies the '5/10/10' rules. This is done using a computer storage and system behaviour model using an iterative process to satisfy all the requirements implied by the rules and available water from the various sources.

A system behaviour model was set up for the Wilcannia raw water storage scheme and progressively modified to suit the requirements of each stage of the work. Essentially the system behaviour model involved a storage behaviour model to determine secure yield using model logic developed and tested over many years and incorporating refinements to reflect current requirements.

The model is essentially driven by operating conditions such as the need to meet a specified demand whilst satisfying constraints such as available water from streamflows and accounting for losses. Figure 4 shows a schematic of the general model.

In addition to the hydrometeorological data that must be input into the computer simulation model, other data such as identified in the respective sections below has also been input to produce a complete model. The system behaviour modelling included the following data and assumptions based on NUWS experience and as informed by the information provided by PWA, which was progressively updated.

3.2 Headworks System

Wilcannia water supply existing headworks system consists of:

- Wilcannia weir storage on the Darling River from which water is pumped to supply. The bore water supply was not required to be included in the model for any stage as the bores have been considered to represent backup supply provisions.

The Wilcannia water supply headworks system used for secure yield assessment has been modified during each stage of the work as follows:

- 2016 (Initial) Study: Existing weir storage without off-stream storage (2 cases), and plus off-stream storage (1 case).
- 2019 BCA Study: Proposed new weir with 0, 0.5 and 1m raisings.
- 2021 WWR Study: Proposed new weir with 1m raising.

3.3 Demand Pattern

Whilst secure yield provides the system annual demand that can be met, the annual demand for modelling purposes needs to be broken down into monthly patterns to reflect seasonality and if practical and feasible into daily patterns if daily pumping from river direct to supply.

Table 3.1 provides the monthly demand patterns used. For the initial modelling, the pattern was based on Nyngan town water supply (TWS) taken from the NUWS 2016 Nyngan-Cobar yield study (Ref 12). This pattern was later updated for subsequent stages by PWA (Ref 13) after they completed their demand analysis for Wilcannia.

It is NUWS experience that generally the secure yield is not that sensitive to the monthly demand pattern if seasonality is shown by the differentials and that the storage can meet several months demand.

Table 3.1 Monthly Demand Patterns

Pattern	Monthly Demand % of Total Annual Demand											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Nyngan TWS	5	6	7	9	11	11	13	10	9	7	7	5
Wilcannia Potable	6.4	6.4	7.18	9.20	10.61	11.38	12.62	8.76	9.20	6.87	5.77	5.63
Wilcannia Raw Water	5.0	5.0	6.49	9.67	12.20	13.29	15.37	9.48	9.67	5.97	3.96	3.90

3.4 Storage

Various storage sizes were modelled to cover the respective headworks schemes and cases within each progressive stage of the work. The secure yield is dependent on the amount of water that can be pumped from the respective operational storage volume during droughts.

Also evaporation losses (or rainfall gain) associated with the operational water storage(s) water surface area(s) were modelled according to the fluctuation in storage volume and input daily evaporation and daily rainfall. Tables 3.3 to 3.8 provide the storage volume and corresponding water surface area data used.

Initial Storage Modelling (2016 study) - PWD 1987 storage ratings

The initial existing weir pool storage size requested to be modelled was 470 ML (FSL 65.2 for original crest with spillway). It was understood that the 470 ML storage was the pool immediately upstream of the weir to the first upstream rock bar (Bar 1) such that in droughts raw water was only pumped from this pool (Pool 1). *However, it was proposed if augmentation was required then consideration should be given to accessing the next upstream pool (Pool 2).*

Table 3.2 provides the initial modelled storage characteristics for the existing weir pool (Pool1) between the weir and Bar 1 at the original FSL of 65.2.

Table 3.2 Initial Existing Weir Pool 1 Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km2
468	0.23
423.8	0.212
319.8	0.204
227.5	0.1652
146.9	0.1572
84.5	0.0924
40.3	0.0844
7.8	0.0456
0	0.0456
Based on Table B.1.1 PWD1987 and initial top water surface area.	

Pool 2 located immediately upstream of the existing weir pool rock Bar 1 was advised by PWA to be 1297 ML and the additional storage characteristics modelled are provided in Table 3.3.

Table 3.3 Initial Additional Pool 2 Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km^2
1380	0.84
992	0.713714
667	0.588304
405	0.462227
205	0.340849
87	0.144909
18	0.131205
0	0.05435
Based on Table B.1.2 PWD1987 and initial top water surface area.	

As part of the initial (2016) requested analysis, modelling was undertaken to estimate the offstream storage required in addition to the existing weir (Pools 1 and 2) to meet the future demand on a secure yield basis. The off-stream storage size was assumed to be 500m x 500m with 1:3 side slopes and to have a depth of 10m. The modelled water surface areas are provided in Table 3.4.

Table 3.4 Initial Offstream Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km^2
2212	0.25
1964.988	0.244036
1723.904	0.238144
1488.676	0.232324
1259.232	0.226576
1035.5	0.2209
817.408	0.215296
604.884	0.209764
397.856	0.204304
196.252	0.198916
0	0.1936
Estimated from geometry.	

Initial New Weir Storage Modelling (2019 BCA study) - DTM and PWD 1987 ratings

In early 2019 undertook revised secure yield modelling for PWA NUWS to assist informing the Addendum to the Business Case for the Wilcannia Weir Upgrade Project (Ref 2).

The project proposed that a new weir with a potentially raised weir crest would be located at Site A2 about 5.25 km downstream of the existing weir.

For this work, PWA provided revised weir pool storage characteristic data for both the existing weir pool and for the new portion of weir pool that was proposed to be created between the existing weir and the proposed new weir. The aim was to significantly improve the accuracy of the storage volume and surface area information that was to be used in the yield study.

For this purpose, reliance on the previous 1987 storage data was limited to only the underwater portions below the respective water levels captured in an available digital terrain model (DTM) of the Darling River (Baaka) at Wilcannia.

The DTM allowed for the identification of two additional main bars (Bar 2 and Bar 3) upstream of the existing weir and Bar 1, mentioned above for the 2016 work.

The full supply level (FSL) for the weir was also updated to account for previous weir refurbishment works that had modified the weir and infilled the central crest spillway section. The adopted FSL applied in the revised (2019) yield study was RL 65.65 based on available information.

In the model, the weir pool storage volume and surface area data for the proposed new weir was divided into storage portions that account for the potential effects of the identified riverbed bars (1, 2 and 3). The separate weir pool portions that are defined by the dividing bars are outlined as follows:

- End Pool (Pool 4): Pool upstream of Bar 3 RL 65.59 - length ~9.87 km at existing FSL 65.65, which becomes longer with any weir raising;
- Pool 3: Pool between Bar 3 and Bar 2 RL 65.52 - length~19.08 km;
- Pool 2: Pool between Bar 2 and Bar 1 RL 65.27 - length ~24.69 km;
- Pool 1: Pool between Bar 1 and existing weir (FSL 65.65) - length ~5.43 km;
- New additional (town) pool: Pool between existing and proposed weirs (raised FSL varies) - length ~5.25 km.

For the 2019 BCA study, the End Pool (Pool 4) was not included since the accessible storage depth was very shallow at only 0.06 m between the existing weir FSL 65.65 and the cease-to-flow level of Bar 3 at RL 65.59.

The storage volume within Pool 3 below the cease-to-flow level of the downstream bar (Bar 2) has been treated as isolated dead storage.

The storage volume within Pool 2 below the cease-to-flow level of the downstream bar (Bar 1) has been generally treated as isolated storage, which is accessible via pumped transfer.

The dead storage level for Pool 2, Pool 1 and the New Town Pool was RL 63.65 as advised by PWA. Separate yield assessments cover both cases of ignoring or accounting for dead storage.

The maximum level at which the 1987 storage data was used for existing weir Pool 2 was RL 65.02 (existing FSL-0.63 m) and for Pool 1 was RL 64.91 (existing FSL-0.74). For the New Town Pool the DTM was used above RL 62.76 (existing FSL-2.89m). Not all the dead storage volume within each weir pool portion could be fully accounted for due to having no available bathymetric survey data at the time.

The proposed decommissioning of the existing weir would effectively combine Pool 1 and the New Town Pool above the dead storage level.

In the 2019 BCA yield model the inflows flow into Pool 3 and then spills into Pool 2 and then into the combined Pool 1 and New Town Pool (i.e. Combined Pool 1). Evaporation losses and any rainfall gains are applied to all the pools water surface area. Water is extracted from Combined Pool 1, which in effect draws water from the upstream pools until the disconnects occur when water is below the respective rock bar crest levels. However, for Pool 2 it was assumed water can be pumped into Pool 1 (*and the model kept track of this*) when the Pool 2 storage level was below the downstream Bar 1 cease-to-flow level.

Table 3.5 provides the modelled storage characteristics for Pool 3.

Table 3.5 Pool 3 Storage Volume - Surface Area

Storage Level RL (mAHD)	Storage Volume ML	Water Surface Area km^2
66.65	1011.2	0.733887
66.15	657.38	0.680605
65.65	332.63	0.616593
65.59	295.94	0.60735
65.52	253.85	0.596059
65.27	110.59	0.550147
65.18	62.15	0.528862
Water accessible down to 65.52 when rock bar disconnect occurs		

Source: PWA

Table 3.6 provides the modelled storage characteristics for Pool 2.

Table 3.6 Pool 2 Storage Volume - Surface Area

Storage Level RL (mAHD)	Storage Volume ML	Water Surface Area km^2
66.65	2947.48	1.046495
66.15	2437.04	0.996046
65.65	1952.96	0.94003
65.59	1896.82	0.932561
65.52	1831.92	0.923664
65.27	1605.6	0.88935
65.18	1526.46	0.874402
65.02	1390.08	0.827104
64.91	1303.75	0.801804
64.65	1102.54	0.75646
64.5	986.45	0.73300
64.15	759.46	0.615860

Storage Level RL (mAHD)	Storage Volume ML	Water Surface Area km^2
64	662.18	0.56680
63.65	479.06	0.50576
Water accessible down to 65.27 when rock bar disconnect occurs and then pumping to Pool 1 occurs		

Source: PWA

Table 3.7 provides the modelled storage characteristics for the combined Pool 1 and New Town Pool.

Table 3.7 Combined Pool 1 Storage Volume - Surface Area

Storage Level RL (mAHD)	Storage Volume ML	Water Surface Area km^2
66.65	1582.022	0.524132
66.15	1326.13	0.499777
65.65	1082.776	0.473322
64.65	640.6301	0.413094
63.65	268.4905	0.322161
63.15	27.84188	0.102611
63.05	18.15925	0.093528
62.95	10.67487	0.062263
62.85	4.68125	0.058409

Source: PWA

Revised New Weir Storage Modelling (2021 WWR study) - DTM and 2020 survey ratings

The storage data for the existing weir and the proposed new weir were updated in 2020 to account for river cross-sectional bathymetric survey undertaken within the New Town Pool, Pool 1, and Pool 2. The new survey superseded the need to use the previous 1987 storage data for the bathymetric storage components of both Pool 1 and Pool 2. The non-bathymetric storage components above the respective captured water level for all pools remained based on the available DTM.

The available 2020 survey, including the existing weir crest, identified that the actual FSL was RL 65.71 rather than the previously used level of RL 65.65. This represented a relatively small increase of only 0.06m. For consistency with the 2019 BCA yield modelling work, the 2021 yield update modelling maintained the existing weir FSL at RL 65.65. However, the accessible volume within the End Pool (Pool 4) above the cease-to-flow level of Bar 3 was included in the 2021 modelling rather than be excluded as for the 2019 work.

Additionally, the site for the proposed new weir had been recently shifted upstream to ~4.92 km downstream of the existing weir from ~5.25 km downstream previously. This represented a small upstream shift distance of ~0.33 km from ‘Site A2’ to ‘Revised Site A2’.

Figure 5 shows a plot of updated total and accessible storage volume for both the existing and proposed new weir at Revised Site A2.

Table 3.8 provides the modelled overall weir pool storage characteristics for the proposed new weir at Revised Site A2. The overall rating accounts for the separate weirpool portions and dividing rock bars that cause progressive pool isolation.

Table 3.8 Overall Weir Pool Rating for Proposed New Weir at Revised Site A2

Storage Level RL (mAHD)	Water Surface Area m^2	Total Storage Volume ML	Accessible Storage Volume ML
69.65	4,760,003	18,451	17,552
69.15	4,530,673	16,129	15,230
68.65	4,306,827	13,920	13,021
68.15	4,091,288	11,821	10,922
67.65	3,870,286	9,830	8,931
67.15	3,636,617	7,953	7,054
66.65	3,370,711	6,200	5,301
66.15	3,013,523	4,592	3,693
65.71	2,684,159	3,333	2,434
65.65	2,516,432	3,176	2,277
65.59	2,459,845	3,027	2,128
65.52	1,972,037	2,715	1,989
65.27	1,326,364	2,124	1,652
65.18	1,305,656	2,005	1,534
65.14	1,295,275	1,954	1,482
65.02	1,246,956	1,801	1,329
64.91	1,181,086	1,669	1,197
64.65	1,091,931	1,377	905
64.5	1,055,515	1,216	744
64.15	929,236	864	392
64	857,095	731	259
63.65	655,274	472	0
63.5	583,900	380	
63.39	529,504	321	

Source: PWA

3.5 Environmental Flows

There were generally no requirements to make releases for any of the yield studies undertaken.

It is noted the adopted secure yield was in effect controlled by a period of about 12 months of zero inflows thus any requirements for translucency to weir inflows would have little influence on the secure yield.

3.6 Operating Rules

Table 3.9 provides the main operating rules modelled.

Table 3.9 Operating Rules

System	Operating Rules
Wilcannia	Water pumped from river weir pool storage to supply. If Pool 1 became disconnected from Pool 2 then it was assumed Pool 2 water was still immediately (*within daily time step*) available by pumping from Pool 2 to Pool 1. Water that could be pumped was based on water accessibility and daily inflow. Pumping was based on modelled daily time step.

4. Modelling Results

4.1 Introduction

The secure yield estimates determined from the historic climate behaviour modelling for the weir storages are presented in this chapter along with a limited number for climate warming conditions.

Secure yield determination is based on a defined methodology (see Section 1.7) and uses historic climate data and allows for supply to be met through a much more severe drought than has occurred in about the last 130 years. Most of the results presented in this chapter are based on historic climate. Adjustments to some nominated case results were made to allow for projected climate change scenarios using the methodology as far as practical from the NOW draft guidelines (Ref 1).

While secure yield is reliant on the available streamflows, it is also dependent on transfer capacities, environmental flow conditions, annual demands and their monthly distribution, level of security expected and the schemes operating rules. The conditions used have been described in Chapter 3.

The expected level of security arises from the 5/10/10 rules, which provides for 10% restrictions occurring in 10% of the years for 5% of the time.

4.2 Initial Results

(2016 study - Pre-existing weir with central spillway FSL 65.2 and three initial inflow series)

Table 4.1 provides the initial secure yield results based on the pre-existing weir storage with FSL of RL 65.2 and three initial inflow series.

Comments made in 2016 on the initial results were:

1. The secure yields for Wilcannia using just IQQM flows or factored IQQM flows are higher than when using observed flow data merged with the IQQM data (so that observed data is used in preference to IQQM modelled data).
2. Use of the observed data was used to examine the effect of the 2016 drought, however, this was found not to be the critical drought.
3. Use of the observed data is more of a reflection of the secure yield for the historic climate if past upstream operations repeated themselves. Use of the IQQM data provides a reflection of the secure yield for the historic climate expected for current upstream operations with water sharing plans. The water sharing plans in effect are expected to provide all stakeholders with *necessary* regulated water.
4. The observed Darling River flows are necessarily for the gauging station at Wilcannia (425008). The gauging station is just downstream of the existing weir and thus their use will be slightly conservative as in effect only record flows that have spilled over or leaked through the weir. The expected differences are judged to be less than the differences arising from modelling a catchment upstream of the gauge and existing weir, which is reported to be about 570,000 km^2.

Table 4.1 Initial Secure Yield Results (Historic Climate) with pre-existing weir FSL 65.2

Storage ML	Run No.	Flow Series	Secure Yield ML/a	Transfer from Storage ML/d (30 l/s)	Restrictions			Critical Drought	
					Applied at storage (% full)	Duration (%)	% of Years	From	To
470	Set110	IQQM	**618**	2.592	-	-	-	-	-
	Set111	IQQM factored	**618**	2.592	-	-	-	-	-
	Set120	IQQM merged	**193**	2.592	60	0.93	7.38	16/09/2006	19/08/2007

Discussion:

1. IQQM flows below 280 ML/d factored by 0.7 as NOW IQQM model report suggests from calibration low flows (below about 90%ile) appear to be overestimated by up to about 30%.
2. IQQM flows merged with observed flows to present 2016 (i.e. observed flows used in preference to modelled flows).
3. Runs Set110 and Set111 secure yield constrained by the 30 l/s transfer capacity from the weir to supply.

Assumptions:

1. 470 ML storage size nominated by PWA in 2016 based on PWD1987.
2. Top Water Surface Area 0.23 km^2 estimated from satellite photo and bottom surface area 0.03135 km^2.
3. Monthly seasonal % demand pattern assumed same as used for Nyngan.
4. Only considered 470 ML river pre-existing weir storage (i.e. Pool 1 between pre-existing weir and the upstream Bar 1) -Pre-existing weir FSL 65.2.

Figure 6 provides the storage behaviour diagram for a repeat of the modelled historic climate while meeting the demand equivalent to the secure yield *(with restrictions in accordance with the 5/10/10 rule*) for the IQQM merged flow series.

4.3 Additional Initial Results

(2016 study- fourth initial inflow series (IQQM merged adjusted for selected zero flows))

Additional modelling was undertaken with the IQQM merged flow series with selected historic flows set to zero based on the periods of zero flows reported in PWD1987 (Ref 11) and reproduced in Table 2.3.

Table 4.2 provides secure yield estimates with the previously used (*Nyngan)* demand pattern and with the recently (*15/8/2017*) provided Wilcannia potable demand pattern. The comparison suggests the secure yield is not sensitive to the differences in the two demand patterns however there are some slight differences in the expected performance.

Table 4.2 Secure Yield Estimates (Historic Climate) - Sensitivity to Demand Pattern

Storage ML	Run No.	Demand Pattern	Secure Yield ML/a	Max Transfer from Storage ML/d	Restrictions			Critical Drought	
					Applied at storage (% full)	Duration (%)	% of Years	From	To
470	Set241	Nyngan	**114**	0.478	60	1.44	6.5	31/12/1901	31/12/1902
	Set341	Wilcannia Potable	**114**	0.464	65	1.77	9.76	31/12/1901	31/12/1902

Assumptions:
1. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987.
2. 470 ML storage size nominated by PWA.
3. Top Water Surface Area 0.23 km^2 estimated from satellite photo and bottom surface area 0.03135 km^2.

Table 4.3 provides the secure yield estimates from considering the pre-existing weir and both Pool 1 (470 ML) and Pool 2 (the next upstream pool past Bar 1) along with the addition of an off-stream storage.

Table 4.3 Secure Yield Estimates (Historic Climate) with Additional Storages

Storage ML	Run No.	Flow Series	Secure Yield ML/a	Max Transfer from Storage ML/d	Restrictions			Critical Drought	
					Applied at storage (% full)	Duration (%)	% of Years	From	To
Pre-existing weir pool (470 ML) plus upstream Pool 2 (1297ML)									
1767	Set342	*See 1 below*	**352**	1.433	55	1.56	7.32	26/08/1901	31/12/1902
Pre-existing weir pool (470 ML) plus upstream Pool 2 (1297 ML) plus offstream storage (2212ML), unconstrained transfer to off-stream storage									
3979	Set343	*See 1 below*	**1772**	2.592 from weir, 6.492 from offstream	60	1.54	7.32	15/07/2006	19/08/2007
Pre-existing weir pool (470 ML) plus upstream pool (1297 ML) plus offstream storage (2212ML), 20 ML/d transfer to offstream storage									
3979	Set344	*See 1 below*	**1772**	2.592 from weir, 5.854 from offstream	60	1.54	7.32	15/07/2006	19/08/2007

Assumptions:
1. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987. 2. Wilcannia Potable Demand Pattern (*15/8/2017*). 3. Storage sizes nominated by PWA. 4. Pre-existing Weir Pool Top Water Surface Area 0.23 km^2 estimated from satellite photo and lower levels estimated from PWD1987.

Figures 7 to 9 provide the storage behaviour diagrams for the above three modelled storage cases for a repeat of the modelled historic climate while meeting the demand equivalent to the secure yield *(with restrictions in accordance with the 5/10/10 rule*) for the IQQM merged flow series with the selected historic flows set for zero.

4.4 Results Initial New Weir

(2019 BCA study – New downstream weir at Site A2 with raisings 0, 0.5 and 1m)

Historic Climate

Table 4.4 provides secure yield estimates for the initial proposed new downstream weir replacing the existing weir resulting in one large weir pool that becomes disconnected to three separate pools as the storage level draws down below the proposed new weir crest full supply level (FSL) and the upstream riverbed bars. For the proposed new weir, raising options of 0, 0.5 and 1m have been assessed relative to the existing weir FSL of RL 65.65 (mAHD).

Table 4.4 Secure Yield Estimates (Historic Climate) - Initial new weir Sensitivity to Raising

Total Weir Storage ML	Run No.	New Weir Crest RL mAHD	Secure Yield ML/a	Max Transfer from Storage ML/d	Restrictions			Critical Drought	
					Applied at storage (% full)	Duration (%)	% of Years	From	To
5540	600	**66.65**	**636**	2.59	65	1.45	6.50	31/12/1901	31/12/1902
4420	601	**66.15**	**636**	2.59	60	1.51	7.32	31/12/1901	31/12/1902
3368	604	**65.65**	**399**	1.62	60	1.78	9.76	30/12/1901	31/12/1902
Discussion: 1. Runs 600 and 601 secure yield constrained by the 30 l/s (2.59 ML/d) transfer capacity from the weir to supply. Assumptions: 1. No releases required from weir. 2. Wilcannia Potable Demand Pattern. 3. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987. 4. Initial new weir storage details as provided by PWA (Tables 3.5 to 3.7).									

For the 0.5 and 1m raising cases (Runs 600 and 601 respectively) it was found that the *secure yield* was constrained by the specified existing transfer capacity and thus these two cases were rerun with *unconstrained* transfer capacity to establish the potential benefits in yield between the two raisings. The results are provided in Table 4.5.

Table 4.5 Secure Yield Estimates (Historic Climate) - Raising with Unconstrained Transfer

Total Weir Storage ML	Run No.	New Weir Crest RL mAHD	Secure Yield ML/a	Max Transfer from Storage ML/d	Restrictions			Critical Drought	
					Applied at storage (% full)	Duration (%)	% of Years	From	To
5540	602	**66.65**	**1632**	6.64	60	1.66	8.13	31/12/1901	31/12/1902
4420	603	**66.15**	**1052**	4.28	60	1.82	9.76	31/12/1901	31/12/1902

Assumptions:

1. No releases required from weir.
2. Wilcannia Potable Demand Pattern.
3. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987.
4. Initial new weir storage details as provided by PWA (Tables 3.5 to 3.7).

Figures 10 and 11 provide for the cases in Table 4.5 storage behaviour diagrams for a repeat of the historic climate supplying annual demands (*with restrictions applied in accordance with the 5/10/10 rules*) that equate to the secure yields for the modelled storage cases using the IQQM merged flow series with the selected historic flows set to zero. Figure 12 provides a similar plot for the case of nil raising (crest RL 65.65) in Table 4.4.

Climate Change

The historic climate secure yields would be reduced by climate warming. However, it was not feasible to employ the procedures to assess the reduction in secure yield for 1 °C climate warming scenario as given in the draft guidelines *"Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities"* (Ref 1).

It was beyond the scope of the original study to do climate change flow modelling due to the flows being provided from the IQQM model, which encapsulated several models and covered a catchment area of some 570,000 km^2.

It is noted as the catchment upstream is heavily regulated and subject to water sharing plans it may be that the potentially reduced inflows from climate change may be mitigated as suggested by the IQQM modelled flows (both unmodified and factored) providing higher secure yields than with the IQQM modelled flows merged with the observed historic flows.

Towards making an assessment of potential reduction as suggested by DPIE-Water, the critical drought of no inflows was extended by a preliminary additional 15% (55 days) and modelling was undertaken using the historic climate flow series but with the extended critical drought plus considering changes in evaporation and rainfall over the storages water surface areas for 1 °C climate warming.

Table 4.6 provides the historic secure yields (with unconstrained transfer) adjusted for 1 °C climate warming based on the above, which somewhat follows the concepts in the draft guidelines *"Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities*" (Ref 1). The individual results for the 15 GCMs (*Global Climate Models*) and corresponding historic data base are provided in Appendix A.

Table 4.6 Preliminary Secure Yield Estimates Adjusted for Climate Change

Case	Proposed New Weir with Crest 65 .65 RL m AHD	Historic Secure Yield ML/a	Adjustment Factor for Climate Change	Secure Yield with 1 °C Climate Warming ML/a
Run 602	1 m raising	**1632**	0.95977	**1566**
Run 603	0.5 m raising	**1052**	0.82995	**873**
Run 604	No raising	**399**	0.9507	**379**

It was judged the results in Table 4.6 following in effect the draft guideline procedures did not fully capture the influence of reduced flows from climate change. This was because while the extended critical drought was included in all 15 sets of time series data, the derived A*djustment Factor* in effect only reflected the changes in increased evaporation and reduced rainfall on the storage from climate warming. The draft guidelines (Ref 1) process involves applying the adjustment factor to the historic secure yield. Thus, it was considered that it would be more appropriate to use a historic secure yield based on the extended critical drought as shown in Table 4.7 for the historic climate to fully capture the effects of the extended critical inflow drought.

Table 4.7 Refined Preliminary Secure Yield Estimates Adjusted for Climate Change

Case	Proposed New Weir with Crest 65 .65 RL m AHD	Historic Secure Yield using 15% (55 days) extended critical drought ML/a	Adjustment Factor for Climate Change	Secure Yield with 1 °C Climate Warming ML/a
Run 602CCHis	1 m raising	**1243**	0.95977	**1193**
Run 603CCHis	0.5 m raising	**641**	0.82995	**532**
Run 604CCHis	No raising	**203**	0.9507	**193**

4.5 Additional Results Initial New Weir

(2019 BCA study - New downstream weir at Site A2 with raisings 0.5 and 1m, and dead storage)

Further modelling was undertaken as requested similar to that in Section 4.4 above but with an added consideration of dead storage:

> *Any volume that is lower than 2m below the FSL of RL 65.65 to be inaccessible for the combined New Town Pool and Pool 1, along with that for Pool 2.*

Historic Climate

Table 4.8 provides secure yield estimates for the initial proposed new downstream weir replacing the existing weir resulting in one large weir pool that becomes disconnected to three separate pools as the storage level draws down below the proposed new weir crest full supply level (FSL) and the upstream riverbed bars. For the proposed new weir, raising options of 0.5 and 1m have been assessed here relative to the existing weir FSL of RL 65.65 (mAHD).

Table 4.8 Secure Yield Estimates (Historic Climate) - Sensitivity to Raising with Dead Storage

Weir Storage ML		Run No.	New Weir Crest RL mAHD	Secure Yield ML/a	Max Transfer from Storage ML/d	Restrictions			Critical Drought	
Total*	Use-able					Applied at storage (% full)	Duration (%)	% of Years	From	To
5540	**4539**	700	**66.65**	**636**	2.59	65	1.45	6.50	31/12/1901	31/12/1902
4420	**3419**	703	**66.15**	**344**	1.40	65	1.72	8.13	31/12/1901	31/12/1902

** Dead Storage 1001 ML.*

Discussion:

1. Run 700 secure yield constrained by the 30 l/s (2.59 ML/d) transfer capacity from the weir to supply.

Assumptions:

1. No releases required from weir.
2. Wilcannia Potable Demand Pattern.
3. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987.
4. Initial new weir storage details as provided by PWA (Tables 3.5 to 3.7).

For the 0.5m raising case (Run 703) with the dead storage it was found that the secure yield was now not constrained by the specified existing transfer capacity. Table 4.9 provides the results for the 1m raising (Run 700) but with *unconstrained* transfer (Run 702) capacity to establish the potential yield.

Table 4.9 Secure Yield Estimates (Historic Climate) - Unconstrained Transfer

Weir Storage ML		Run No.	New Weir Crest RL mAHD	Secure Yield ML/a	Max Transfer from Storage ML/d	Restrictions			Critical Drought	
Total*	Use-able					Applied at storage (% full)	Duration (%)	% of Years	From	To
5540	4539	**702**	**66.65**	**997**	**4.06**	65	1.68	8.13	31/12/1901	31/12/1902

** Dead Storage 1001 ML.*

Assumptions:

1. No releases required from weir.
2. Wilcannia Potable Demand Pattern.
3. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987.
4. Initial new weir storage details as provided by PWA (Tables 3.5 to 3.7).

Figures 13 to 15 provide storage behaviour diagrams for a repeat of the historic climate supplying annual demands (*with restrictions applied in accordance with the 5/10/10 rules*) that equate to the secure yields for the modelled storage cases (allowing for dead storage) using the IQQM merged flow series with the selected historic flows set to zero.

Climate Change

The historic climate secure yields would be reduced by climate warming. However it was not feasible to employ the procedures to assess the reduction in secure yield for 1 °C climate warming scenario as given in the draft guidelines *"Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities*" (Ref 1).

It was beyond the scope of the original study to do climate change flow modelling due to the flows being provided from the IQQM model, which encapsulated several models and covered a catchment area of some 570,000 km^2.

It is noted as the catchment upstream is heavily regulated and subject to water sharing plans it may be that the potentially reduced inflows from climate change may be mitigated as suggested by the IQQM modelled flows (both unmodified and factored) providing higher secure yields than with the IQQM modelled flows merged with observed historic flows.

Towards making an assessment of potential reduction as suggested by DPIE-Water, the critical drought of no inflows was extended by a preliminary additional 15% (55 days) and modelling was undertaken using the historic climate flow series but with the extended critical drought plus considering changes in evaporation and rainfall over the storages water surface areas for 1 °C climate warming.

Table 4.10 provides the historic secure yields (with constrained Run 700) and unconstrained (Run 702 and 703) transfers) adjusted for 1 °C climate warming based on the above, which somewhat follows the concepts in the draft guidelines *"Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities"* (Ref 1). The individual results for the 15 GCMs and corresponding historic data base are provided in Appendix B.

Table 4.10 Preliminary Secure Yield Estimates Adjusted for Climate Change

Case	Proposed New Weir with Crest 65 .65 RL m AHD	Max Transfer Capacity ML/d	Historic Secure Yield (*from specified run*) ML/a	Adjustment Factor for Climate Change	Secure Yield with 1 °C Climate Warming ML/a
Run 700	1 m raising	**2.59**	**636**	0.92296	**587**
Run 703	0.5 m raising	**1.40**	**344**	n/d*	**n/d***
Run 702	1 m raising	**4.06**	**997**	0.86706	**864**

** n/d – the model could not determine any secure yield as when doing critical run with reduced storage sizes to allow for worse droughts then in last 130 years or so, the available stored water was less than the evaporation losses for the critical drought.*

It was judged the results in Table 4.10 following in effect the draft guideline (Ref 1) procedures may not fully capture the influence of reduced flows from climate change. This is because for all 16 flow series (*15 GCMs and historic*) the flows were the same and thus there was *no relativity* in flow differences when determining the ratio for climate change factor. Thus, it may be more appropriate to use a historic secure yield based on the extended critical drought as shown in Table 4.11

Table 4.11 Refined Preliminary Secure Yield Estimates Adjusted for Climate Change

Case	Proposed New Weir with Crest 65 .65 RL m AHD	Historic Secure Yield using extended critical drought ML/a	Adjustment Factor for Climate Change	Secure Yield with 1 °C Climate Warming ML/a
Run 700CCHis	1 m raising	**636**	0.92296	**587**
Run 703CCHis	0.5 m raising	**n/d***	n/d*	**n/d***
Run 702CCHis	1 m raising	**677**	0.86706	**587**

** n/d – the model could not determine any secure yield as when doing critical run with reduced storage sizes to allow for worse droughts in last 130 years or so, the available stored water was less than the evaporation losses for the critical drought.*

4.6 Initial Results Revised New Weir

(2021 WWR Study - New downstream weir at Revised Site A2 with 1m raising (2020 survey))

The proposed new storage details were revised to those given in Table 3.8 in September 2020 based on revised WaterNSW survey data including bathymetric survey data and accounting for dead storage.

Table 4.12 compares results for the 2020 updated new weir pool data with those obtained for the previous (2019 BCA study) pool data.

Table 4.12 Secure Yield Estimates (Historic Climate) Comparison - Revised (2020) Pool Data

Run No.	Case	Max Transfer Capacity ML/d	Secure Yield (5/10/10) ML/a	Restrictions			Critical Drought	
				Applied at storage (% full)	Duration (%)	% of Years	From	To
700	Weir crest 66.65 m RL 2019 pool data	**2.59**	**636***	65	1.45	6.50	31/12/1901	31/12/1902
702		**4.06**	**997**	65	1.68	8.13	31/12/1901	31/12/1902
801	Weir crest 66.65 m RL 2020 updated pool data	**2.59**	**636***	55	1.78	8.13	31/12/1901	31/12/1902
802		**2.96**	**728**	50	1.51	7.32	31/12/1901	31/12/1902

* Secure yield constrained by transfer rate of 30l/s (2.59 ML/d).

Assumptions:

1. No releases required from weir.
2. Wilcannia Potable Demand Pattern.
3. IQQM flows merged with observed flows and selected Historic Flows Set to zero based on periods of zero flows reported in PWD1987.

For the first case (Runs 700 and 801) examined while there were slight changes in expected restrictions there was no change in secure yield as the system was constrained by the existing transfer system. Thus, a second case (Runs 702 and 802) was simulated with the transfer unconstrained. This resulted in a reduction of some 270 ML/a in secure yield from use of the 2020 updated pool storage data.

4.7 Initial Results Revised New Weir with Initial Dual Operating Mode

(2021 WWR study - New downstream weir at Revised Site A2 with 1m raising (2020 survey) and dual operating mode FSL 65.65 / 66.65)

Historic Climate

Table 4.13 provides secure yield results examining the effects of trialling an initial dual operating mode based on trigger flows passing Bourke Town Weir with varying Wilcannia inflows. Flows passing Bourke Town Weir and additional Wilcannia inflows time series data was provided by WaterNSW from their SOURCE modelling of the Darling-Barwon River catchment.

The modelled proposed trial initial dual mode operating rule was:

- During normal flow times the proposed new Wilcannia weir crest is set to RL 65.65.
- If the daily outflow at Bourke weir falls to 100 ML/d the Wilcannia weir crest is raised by 1m to an FSL of RL 66.65.
- Once the Wilcannia weir crest is raised to RL 66.65, it stays at this crest level until the daily outflow at Bourke weir rises to 200 ML/d. When this occurs the Wilcannia weir crest is incrementally lowered at the rate of 0.1m/day until back to the normal FSL of RL 65.65.

Use of the IQQM (adopted series) Wilcannia inflows and the WaterNSW Bourke trigger flows resulted in a major drop in secure yield from use of the trial initial trial operating rule, however, this is expected to be somewhat a reflection of the inconsistent basis of the two flow series.

Use of the WaterNSW Wilcannia inflows and Bourke trigger flows, thus from a consistency basis, resulted in a minor drop in secure yield from use of the trial initial dual mode operating rule. However, if WaterNSW allowances for infiltration and, stock and domestic extractions were applied to the Wilcannia weir inflows the secure yield would be zero for both with and without the trial initial dual mode operating rule.

Table 4.13 Secure Yield Estimates (Historic Climate) - Initial Dual Mode Comparison

Run No.	Flow Case	Max Transfer Capacity ML/d	Secure Yield (5/10/10) ML/a	Restrictions			Critical Drought	
				Applied at storage (% full)	Duration (%)	% of Years	From	To
1m fixed crest weir (FSL 66.65) without proposed initial trial dual operating mode								
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	**2.96**	**728**	50	1.51	7.32	31/12/1901	31/12/1902
810	SOURCE Wilcannia weir inflows	**2.80**	**689**	40	1.45	9.09	11/8/1919	27/5/1920
Proposed initial trial dual operating mode (FSL 65.65 / 66.65) with 100/200 ML/d triggers								
811	SOURCE Wilcannia weir inflows & Bourke weir trigger flows	**2.68**	**659**	55	1.69	9.09	28/10/1914	22/06/1915
821	IQQM merged with selected flows set to zero Wilcannia weir inflows & SOURCE Bourke weir trigger flows	**0.29**	**71**	70	1.98	9.32	31/12/1901	31/12/1902
Weir crest FSL 66.65. 2020 updated pool data as in Table 3.8.								

Figures 16 to 19 provide storage behaviour diagrams for a repeat of the historic climate supplying annual demands (*with restrictions applied in accordance with the 5/10/10 rules*) that equate to the secure yields for the modelled storage cases (allowing for dead storage) for the different combinations of Bourke trigger flows and Wilcannia weir inflows for the initial trial dual operating mode and the comparison baseline of a 1m fixed crest weir.

Despite the issues of inconsistency with the modelled flows, the initial trial dual operating mode assessment (with 100 / 200 ML/day triggers) demonstrated that there was merit in the preliminary concept of a dual mode of operation but that it needed to be further developed.

The further work was subsequently undertaken as a separate study that included, for example, updated SOURCE model flows, additional bathymetric survey (2021) for Pool 3 and Pool 4, revised FSL of RL 65.71 / 66.71, and more detailed operating rules, which were aimed at minimising environmental impacts associated with a proposed new 1m raised (dual mode) weir at Revised Site A2.

4.8 Revised New Weir – Extended Drought

(2021 WWR study - New downstream weir at Revised Site A2 with 1m raising (2020 survey))

To understand the influence on the secure yield of extending the critical drought to allow for climate change additional modelling was requested.

Table 4.14 compares the modelling results based on the historic flows without and with the critical drought extended by 55 days (15%) of zero inflow.

Table 4.14 Secure Yield Estimates (Historic Climate) Without and With Extended Drought

Run No.	Flow Case	Max Transfer Capacity ML/d	Secure Yield (5/10/10 ML/a	Restrictions			Critical Drought	
				Applied at storage (% full)	Duration (%)	% of Years	From	To
Historic Climate								
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	**2.96**	**728**	50	1.51	7.32	31/12/1901	31/12/1902
Historic Climate but with period of zero flows of 31/12/1901 to 31/12/1902 extended to 24/2/1903								
805	IQQM merged with selected flows set to zero Wilcannia weir inflows	**2.80**	**331**	55	1.78	8.13	31/12/1901	24/02/1903
Weir crest FSL 66.65. 2020 updated pool data as in Table 3.8. 1m raised fixed crest weir (FSL 66.65) without proposed initial trial dual operating mode. Modelling period 1/7/1895 to 9/8/2016.								

Table 4.15 compares estimates of the secure yield for 1 °C climate warming based on the GCM evaporation data for 1 °C climate warming with the historic flows with and without the critical drought extended by 15% (55 days) of zero flow.

Table 4.15 Secure Yield Estimates considering 1 °C Climate Warming

Run No. Conditions	Flow Case	Historic Secure Yield ML/a	Secure Yield with 1 °C Climate Warming ML/a
Allowing for extended critical drought (15% / 55 days of more zero flow) and increased net evaporation			
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	**728**	**225**
Only Allowing for increased net evaporation			
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	**728**	**654**
Modelling period 1/7/1895 to 31/12/2008 for 1 °C climate warming due to GCM data.			

The individual results for the 15 GCMs and corresponding historic data base are provided in Appendix C and D. The results incorporate the historical flows but with the 1 °C climate warming evaporation (*and rainfall*) data from the 15 GCMs. The historical GCM case has a higher secure yield (844 ML/a) than the historic climate (728 ML/a) this is a consequence of the two different periods of flows used. The historic climate secure yield includes the effect of the droughts that occurred post 31/12/2008. The GCM data base only goes to 31/12/2008 and the methodology allows for this by applying relative adjustment factors. For this case it was *judged* the factor was 0.9 (i.e. 758 (*the lowest from the 15 GCMs*) divided by 844).

It is noted the relative variability of the GCM secure yield results just considering changes in evaporation (and rainfall) without the extended drought is much less than was obtained when including the extended drought (as shown by the GCM results in Appendix C). The interactions are complex *(and that is why it must be modelled*) but the change in variability infers it relates to the effect of evaporation on that extra 55 days of no inflow.

Figure 20 (Run 805 (802 conditions)) provides the storage behaviour diagram for a repeat of the modelled historic climate but with the extended critical drought, supplying the annual demand (*with restrictions applied in accordance with the 5/10/10 rules*) that equates to the secure yield for case 805 (i.e. 331 ML/a) - refer to Table 4.14.

Figure 21 (Run 802 conditions) provides the behaviour diagram for a repeat of the modelled case for the median GCM case for 1 °C climate warming evaporation with historic flows but with the critical drought extended. The plot is for what is referred to as the *critical* run, i.e. the storage is assumed to be drawn-down to satisfy the 5/10/x rule (i.e. in this case available storage is 2915 ML at the start of the critical drought). Delivering 225 ML/a with 10% restrictions is just satisfied (*thus the 5/10/10 rules have been satisfied*) - refer to Table 4.15.

Towards explaining the evaporation variability Figure 22 compares the storage behaviour diagram for four *determining* cases during the critical drought delivering their respective secure yields (in accordance with 5/10/10 rule). The four cases are:

1 **802CCHis**: Extended drought flows, Historic GCM evaporation: Secure yield 363 ML/a

2 **802CCMed**: Extended drought flows, Median GCM 1 °C climate warming evaporation: Secure yield 225 ML/a

3 **802CC2His**: Historic drought flows, Historic GCM evaporation: Secure yield 844 ML/a

4 **802CC2Med**: Historic drought flows, Lowest GCM 1 °C climate warming evaporation: Secure yield 758 ML/a.

The behaviour for each pair *(i.e. with and without the extended drought flows*) is similar and since the flows are the same for each pair but the demand (as implied from their respective secure yields) being supplied is different, then the similarity in storage behaviour (for each pair) reflects the differences in evaporation (and rainfall). Between 1 and 2 the evaporation thus relates to about 140 ML/a. Between 3 and 4 the evaporation thus relates to about 90 ML/a. Accordingly, this confirmed net evaporation loss during the critical drought was important and that it was appropriately modelled.

4.9 Revised New Weir - Extended Drought Sensitivity

(2021 WWR study - New downstream weir at Revised Site A2 with 1m raising (2020 survey))

The reduction in secure yield for 1 °C climate warming from extending the critical drought by 55 days (15%) of zero flows and allowing for higher evaporation losses was about 69% (Run 802 conditions, Table 4.15). This was judged perhaps on the high side informed from secure yield studies undertaken by NUWS for 8 inland systems (i.e. west of divide) where the reduction varied from about 50% to 20%.

Further modelling was requested to examine the sensitivity to extending the critical drought by different lengths of days of zero inflow.

Table 4.16 compares the modelling results based on the historic flows without and with the critical drought extended by 55 days of zero inflow along with the new cases of extending the critical drought by 18 days (5%) and 37 days (10%) of zero inflow.

Table 4.16 Secure Yield (Historic Climate) Estimates - Extended Drought Sensitivity

Run No.	Flow Case	Max Transfer Capacity ML/d	Secure Yield (5/10/10) ML/a	Restrictions			Critical Drought	
				Applied at storage (% full)	Duration (%)	% of Years	From	To
Historic Climate								
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	2.96	**728**	50	1.51	7.32	31/12/1901	31/12/1902

Run No.	Flow Case	Max Transfer Capacity ML/d	Secure Yield (5/10/10) ML/a	Restrictions			Critical Drought	
				Applied at storage (% full)	Duration (%)	% of Years	From	To
Historic Climate but with period of zero flows of 31/12/1901 to 31/12/1902 extended by 55 days (15%) to 24/2/1903								
805	IQQM merged with selected flows set to zero Wilcannia weir inflows	2.80	**331**	55	1.78	8.13	31/12/1901	24/02/1903
Historic Climate but with period of zero flows of 31/12/1901 to 31/12/1902 extended by 18 (5%) days to 6/2/1903								
806	IQQM merged with selected flows set to zero Wilcannia weir inflows	2.68	**658**	55	1.82	8.94	31/12/1901	18/01/1903.
Historic Climate but with period of zero flows of 31/12/1901 to 31/12/1902 extended by 37 (10%) days to 24/2/1903								
807	IQQM merged with selected flows set to zero Wilcannia weir inflows	1.93	**475**	55	1.79	8.13	31/12/1901	6/02/1903
Weir crest FSL 66.65. 2020 updated pool data updated as in Table 3.8. 1m raised fixed crest weir (FSL 66.65) without initial trial dual operating mode. Modelling period 1/7/1895 to 9/8/2016.								

Figures 23 and 24 and provide the storage behaviour diagrams for a repeat of the modelled historic climate but with the extended critical droughts, supplying the annual demand (*with restrictions applied in accordance with the 5/10/10 rules*) that equates to the secure yield for that case (i.e. 658 ML/a for 18 days (5%) extended drought and 475 ML/a for 37 days (10%) extended drought).

Table 4.17 compares the estimates of the secure yield for 1 °C climate warming based on the GCM evaporation (*and rainfall*) data for 1 °C climate warming with the secure yield for historic flows with and without the critical drought extended by 55 days of zero flow along with the new cases of extending the critical drought by 18 (5%) and 37 (10%) days of zero inflow.

The individual results for the two new cases for the 15 GCMs and corresponding historic data base are provided in Appendix E. The results incorporate the historical flows but with the 1 °C climate warming evaporation (*and rainfall*) data from the 15 GCMs.

Table 4.17 Secure Yield Estimates considering 1 °C Climate Warming

Run No. Conditions	Flow Case	Historic Secure Yield ML/a	Secure Yield with 1 °C Climate Warming ML/a
Allowing for extended critical drought (15% / 55 days of more zero flow) and increased net evaporation			
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	**728**	**225**** *(205)**
Allowing for extended critical drought (10% / 37 days of more zero flow) and increased net evaporation			
807	IQQM merged with selected flows set to zero Wilcannia weir inflows	**728**	**371**** *(410)**
Allowing for extended critical drought (5% / 18 days of more zero flow) and increased net evaporation			
806	IQQM merged with selected flows set to zero Wilcannia weir inflows	**728**	**561**** *(596)**
Only Allowing for increased evaporation			
802	IQQM merged with selected flows set to zero Wilcannia weir inflows	**728**	**654**
Modelling period 1/7/1895 to 31/12/2008 for 1 °C climate warming due to GCM data. ** These values come directly from the median result from the 15 GCMs in the relevant Tables in the Appendices. * These values obtained if applying the ratio suggested by the draft guidelines (Ref 1) as determined from the lowest ratio of either GCM with 10/15/25 divided by historic GCM, or median GCM divided by historic GCM. For example, for Case 802 from Appendix C, the ratio is 225/363 which equals 0.6198, which is then multiplied by 331 from Table 4.14 for Run 805 (i.e. Run 802 conditions but with the critical drought extended by 55 days of zero flow) to give 205. However, due to the basis of the historic GCM it is considered appropriate to adopt directly the lowest of either the median GCM or lowest GCM with 10/15/25.			

From consideration of assessed reductions in historic secure yield, from other projects, compared to climate warming effected secure yield where the draft guidelines (Ref 1) methodology could be fully employed, the case with the 10% increase in the number of days of zero inflow for the critical drought was judged to be the more appropriate of the four results in Table 4.17.

5. Recommendations

The results presented in this report should be used keeping in mind the assumptions on which the estimates are based.

6. References

1 NSW Department of Primary Industries, Office of Water (2013), "Assuring future urban water security - Assessment and adaption guidelines for NSW local water utilities", Draft-December 2013.

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5 Simons M., Podger G., and Cooke R. (1996), "IQQM – A hydrologic modelling tool for water resource and salinity management", Environmental Software, Volume 11, Issues 1-3, 1996, pages 185-192.

6 NSW Office of Water (2011), "Barwon-Darling Valley – IQQM Cap Implementation Report", Version 1, July 2011.

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9 CRC for Catchment Hydrology (2004), Rainfall Runoff Library, User Guide", Geoff Podger.

10 Jeffrey, S.J., Carter,J.O., Moudie, K.M., and Beswick, A.R. (2001), "Using Spatial Interpolation to construct a Comprehensive archive of Australian Climatic data", Environmental Modelling and Software, Vol 16/4 pp309-330, 2001.

11 NSW Public Works Department (1987), "Wilcannia Water Supply, Darling River Weir, Water Security Study", Report No. 871105, February 1987.

12 NSW Urban Water Services (2016), "Nyngan and Cobar Water Security Project, Water Supply System Modelling", prepared for Bogan Shire Council and NSW Office of Water, Report No.14009, May 2016.

13 Blaikie, J. (PWA 2017). Per-com e-mail to Cloke, P. (NUWS), 15 August.

7. Figures

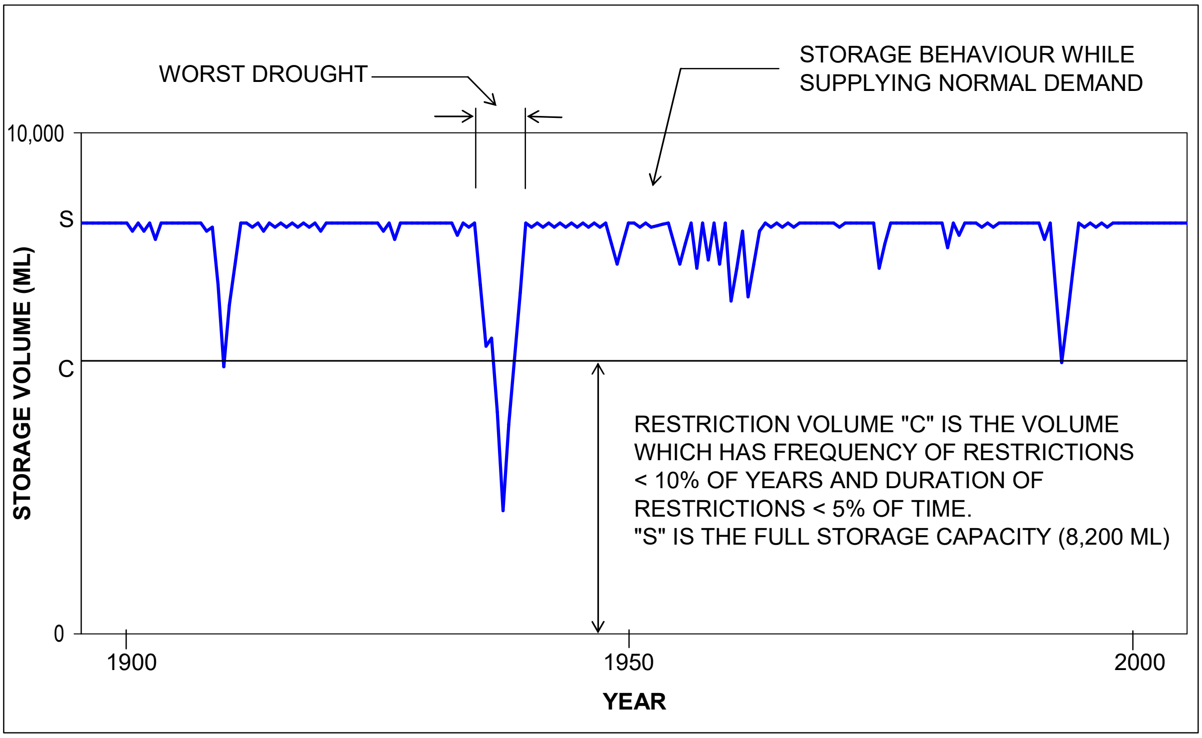


Figure 1 Duration and Frequency of Restrictions

Figure 1 shows the results of simulating an example utility's storage behavior for 120 years of daily streamflow, rainfall and evaporation data and shows that:

- Unrestricted water demand can be supplied for over 95% of the time and over 90% of years (i.e. whenever the storage volume is above the **restriction volume C**). In order to satisfy the 5/10/10 rule, restrictions must be imposed whenever the volume of water in storage falls below the **restriction volume C**
- A 10% reduction in demand is applied when the storage falls below **restriction volume C**
- The worst drought shown in Figure 1 is for approximately the 5-year period January 1939 to December 1943
- The minimum simulated storage volume is approximately 30% of the full storage capacity.

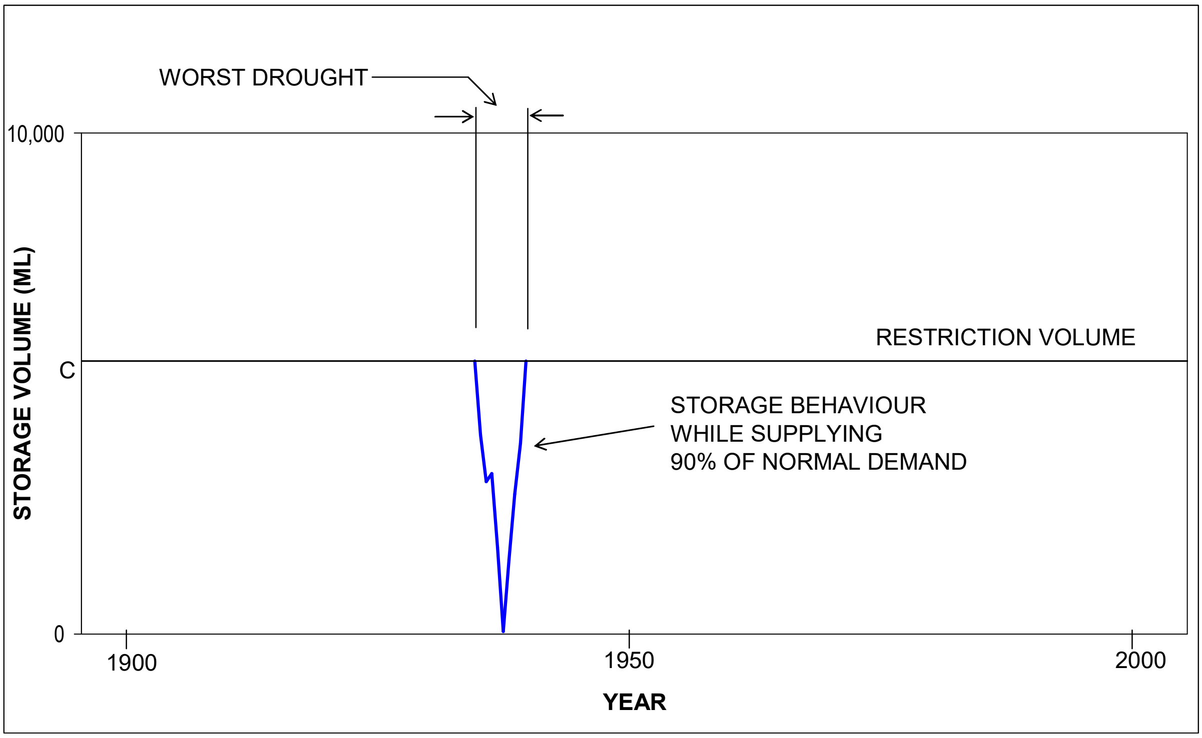


Figure 2 Severity of Restrictions

Figure 2 shows the results of simulating storage behaviour for the worst drought identified in Figure 1 (5-year drought from January 1939 to December 1943) on the following basis:

- A 10% reduction in demand for the full 5-year drought as the storage volume is below the Restriction volume C
- The commencing storage volume for this simulation is the **restriction volume C** and the resulting minimum simulated storage volume is approximately 2% of the full storage capacity.

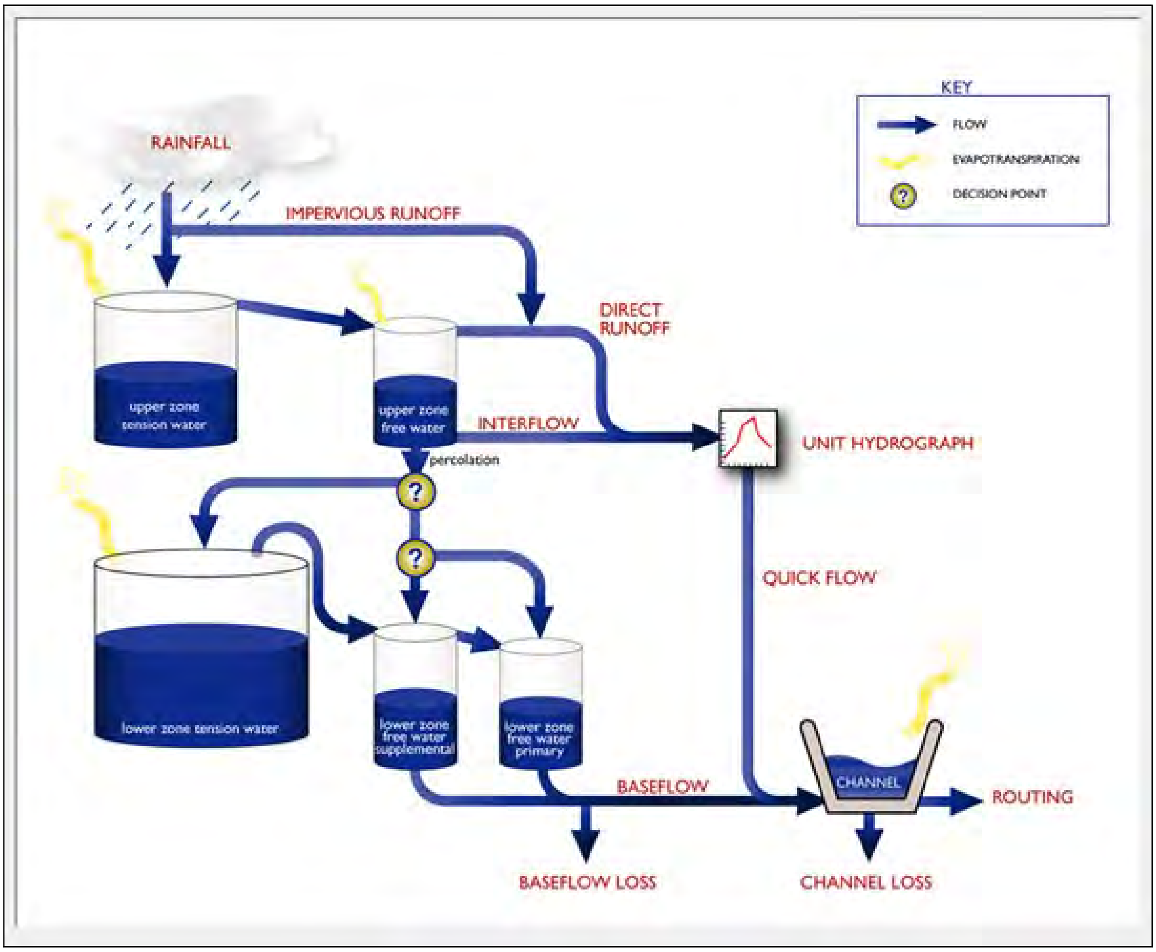
Comment:

Imposition of the requirements of the 5/10/10 rule approximates the severity of a '1 in 1000 year' drought and is necessary in order to enable a utility to manage its system in a drought more severe than the worst drought in the 120 year historical record, with only moderate drought water restrictions.

As the first year of the worst drought for this example utility is simulated in **both Figure 1 and Figure 2**, the water supply system must be able to cope with effectively a 6-year drought, rather than the 5-year worst drought in Figure 1 as it takes about 1-year to drawdown to **restriction volume C.**

It is important to note that the analytical process for the 5/10/10 rule is iterative and that a solution is identified only when all 3 requirements have been met.

A refinement that the NUWS model undertakes and as practiced by NSW Public Works Hydrology Group is to test all droughts for criticality when testing the critical drought with the storage already drawdown at the start of the drought. This is done as it was occasionally found in previous studies that the drought that is critical for the full storage was not necessarily the drought that was critical for in effect a smaller (i.e. drawdown) storage. This is achieved by modelling the full flow series with the reduced storage size and the restricted demand. This also arises from the "1 in 1000 year" security concept.



Source: Ref 9

Figure 3 Sacramento Model

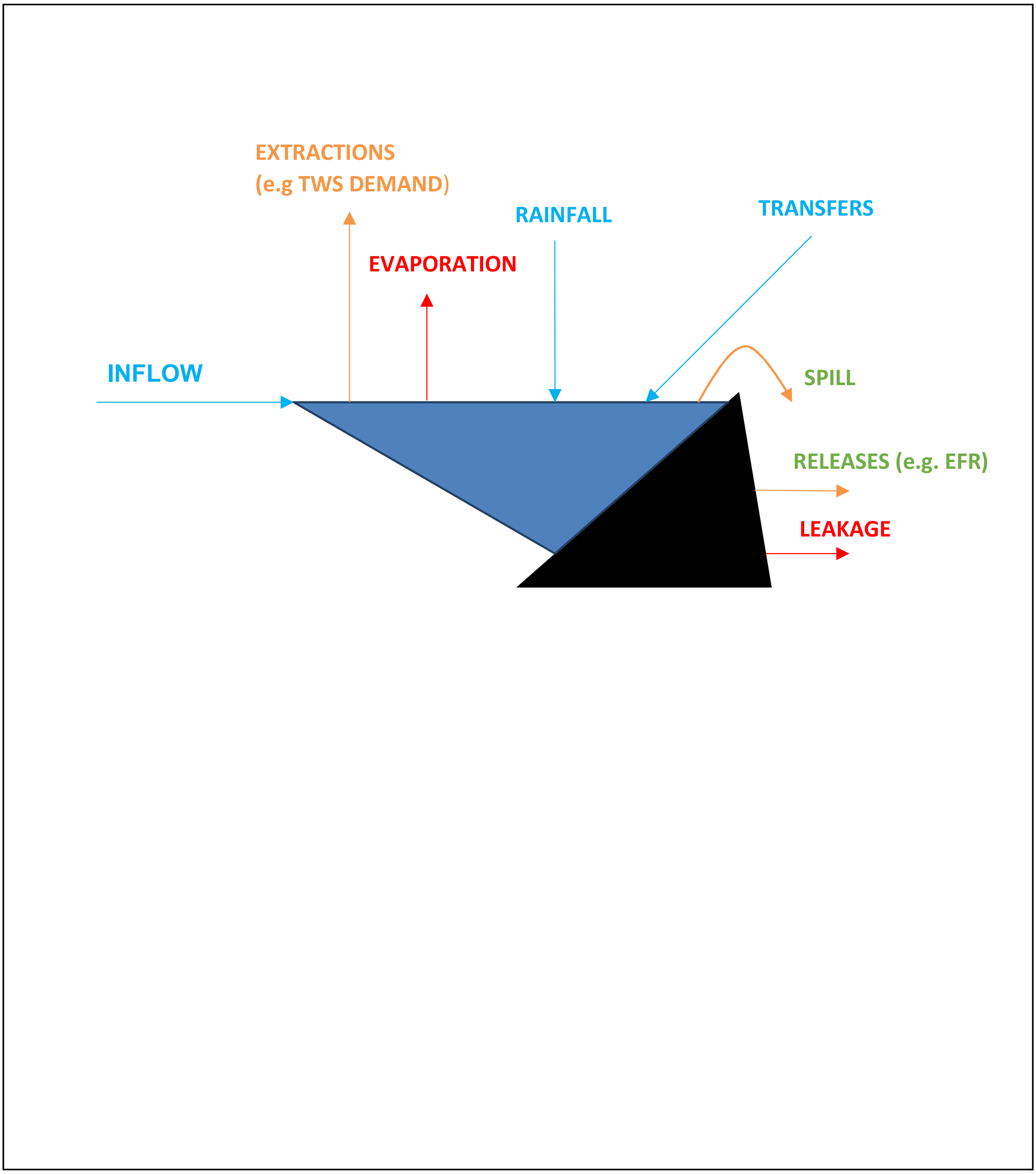
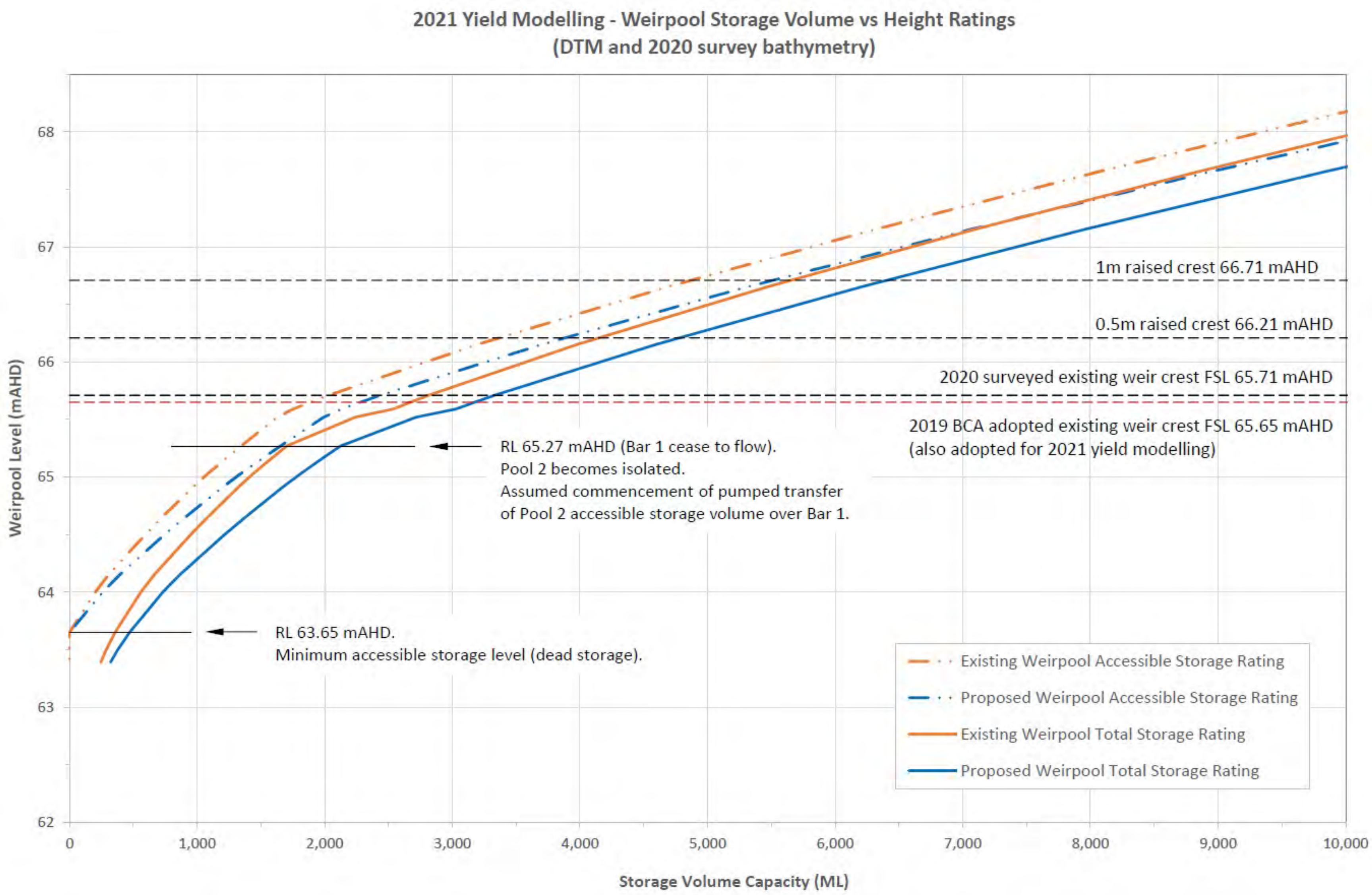
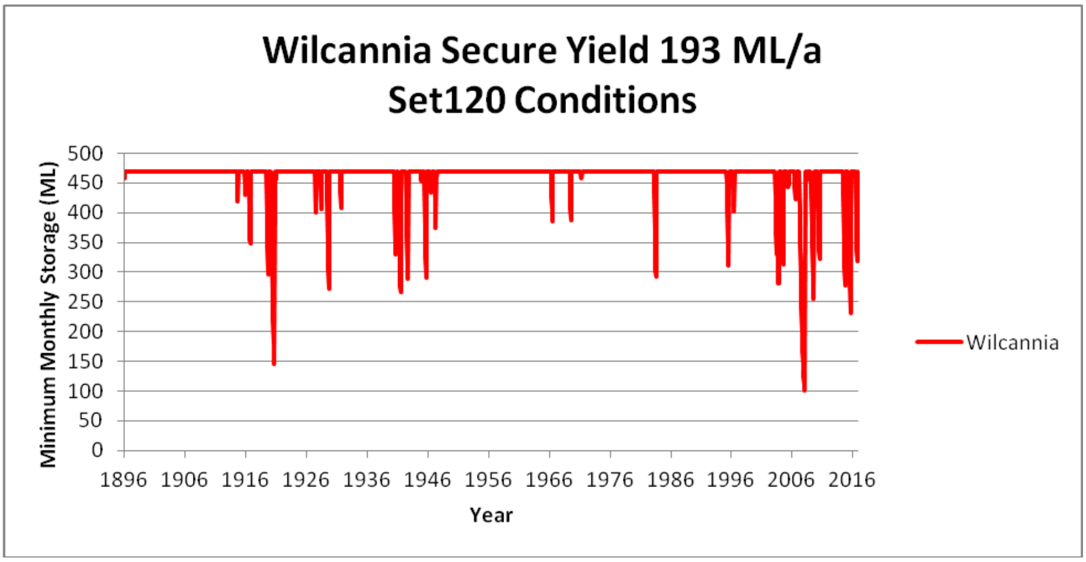


Figure 4 Storage Behaviour Model Schematic



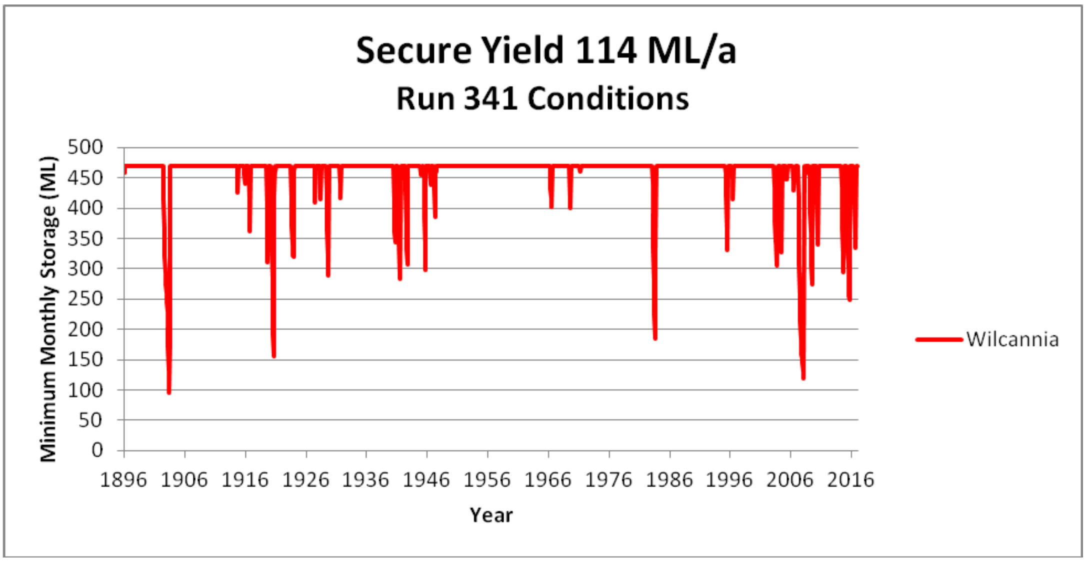
Source :PWA

Figure 5 Pool Storage Rating



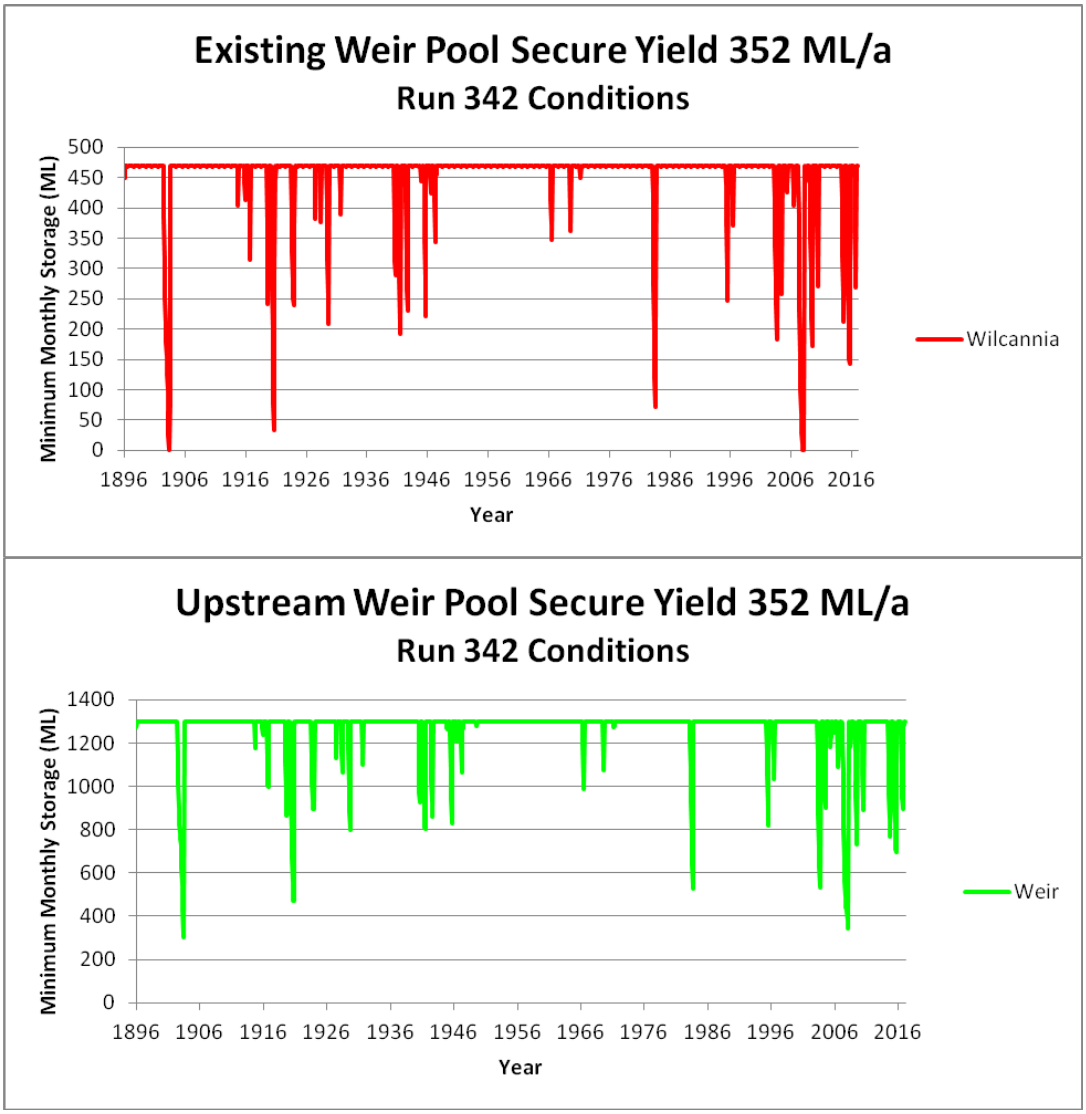
IQQM Merged Flow Series.
Pre-existing weir Pool 1.

Figure 6 470 ML Weir Pool Storage Behaviour - Run 120



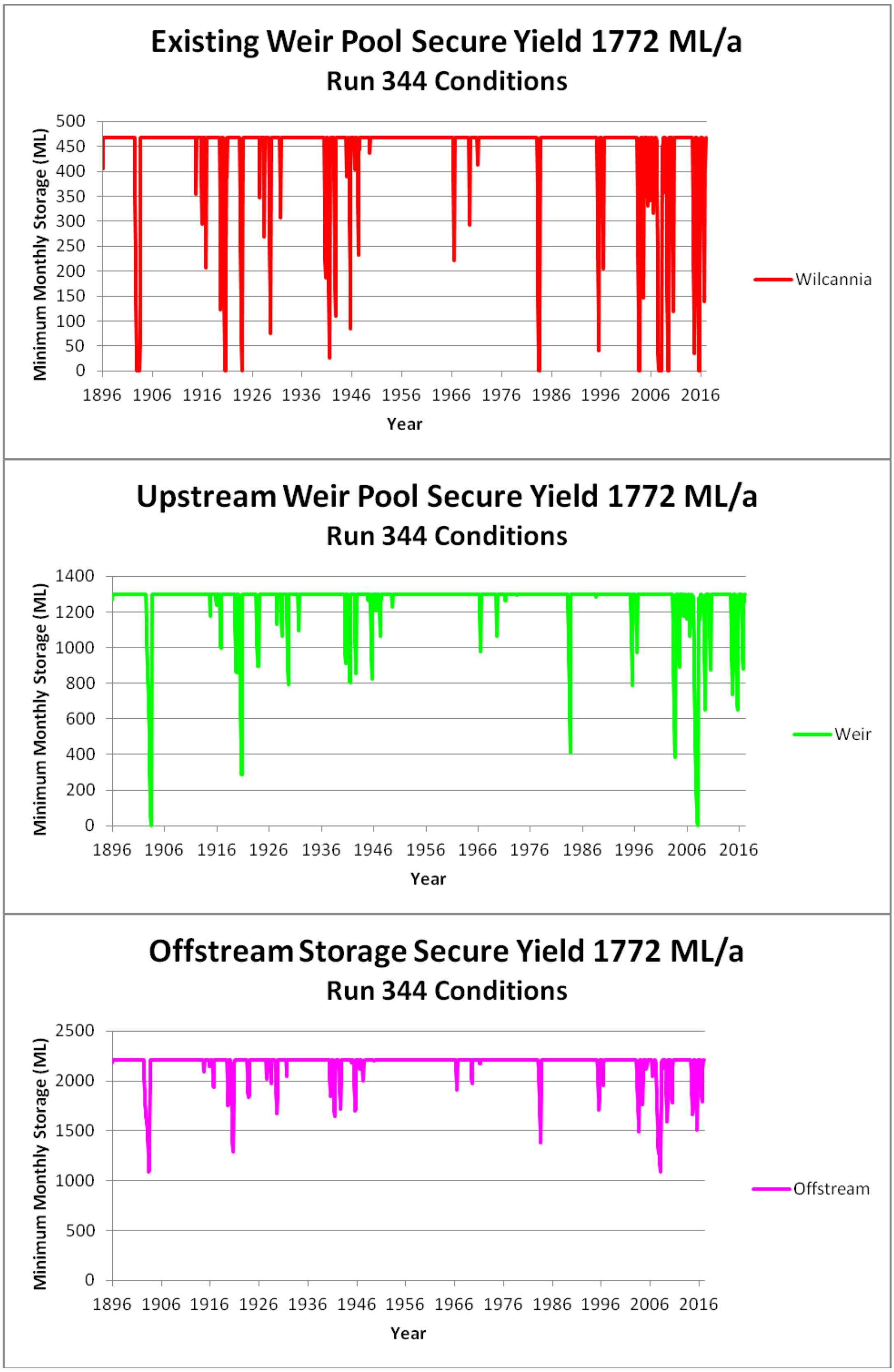
IQQM Merged Flow Series with selected historic flows set as zero.
Pre-existing weir Pool 1.

Figure 7 470 ML Weir Pool Storage Behaviour - Run 341



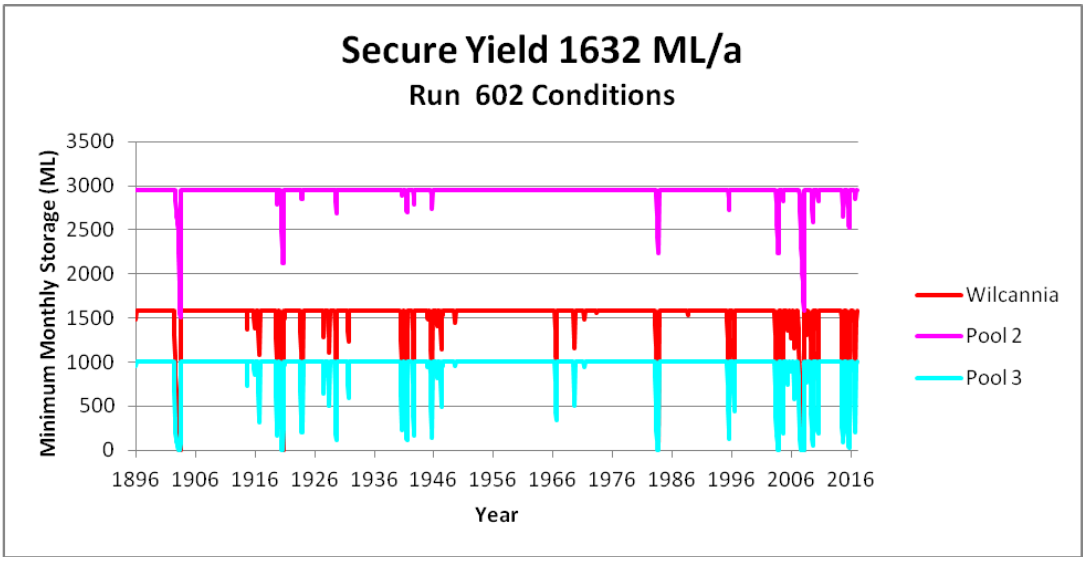
IQQM Merged Flow Series with selected historic flows set as zero.
Pre-existing weir Pool 1 (red) and Pool 2 (green).

Figure 8 Existing Weir and Upstream Pool Storage Behaviour - Run 342



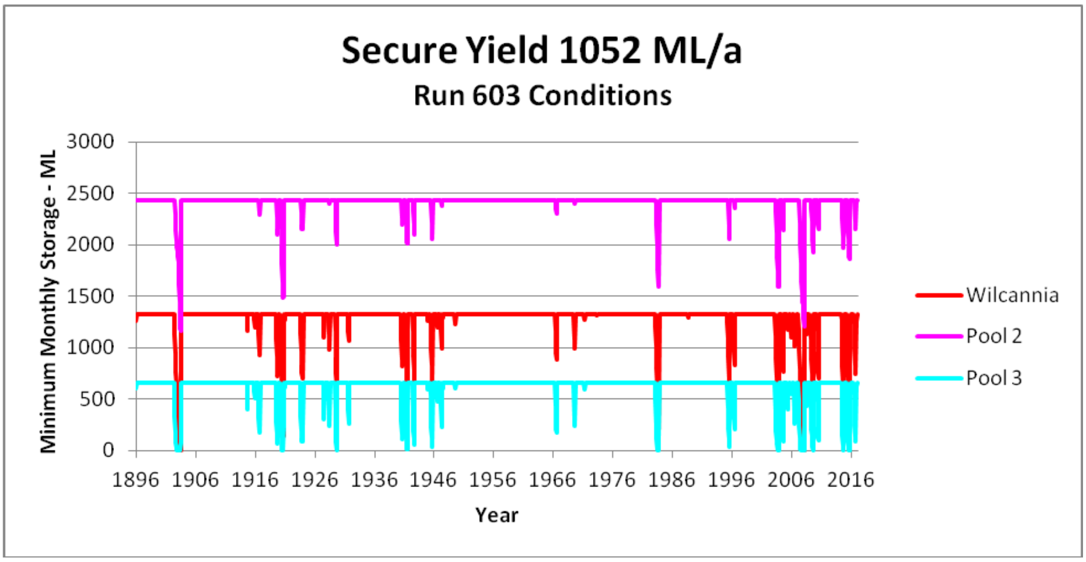
IQQM Merged Flow Series with selected historic flows set as zero.
Pre-existing weir Pool 1 (red) and Pool 2 (green) plus offstream storage (purple).

Figure 9 Existing Weir and Upstream Pool plus Offstream Storage Behaviour - Run 344



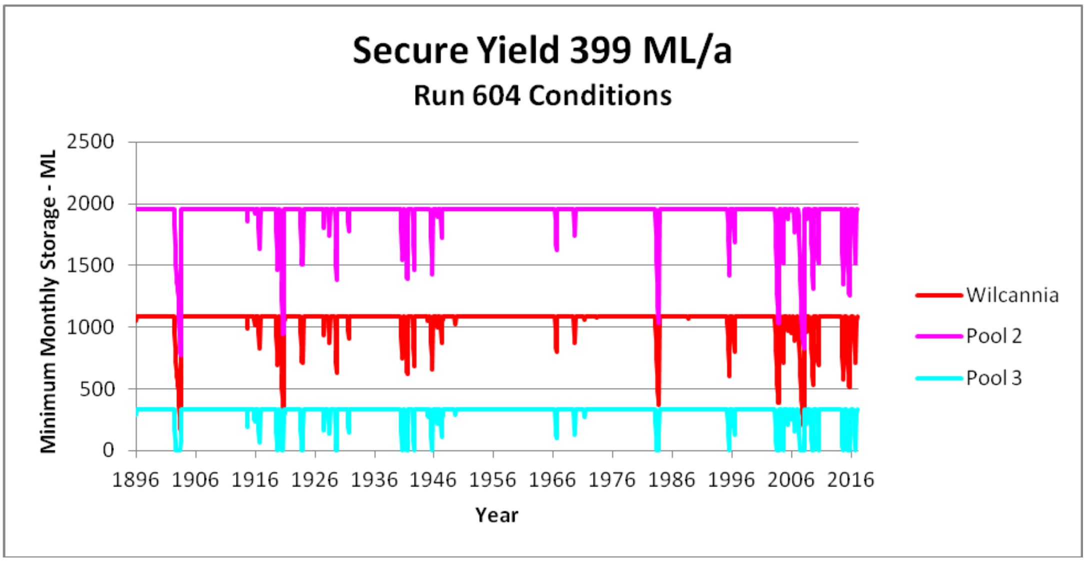
IQQM Merged Flow Series with selected historic flows set as zero.
Initial new weir storage – 1m raising (FSL 66.65).

Figure 10 Storage Behaviour - 1m Raising



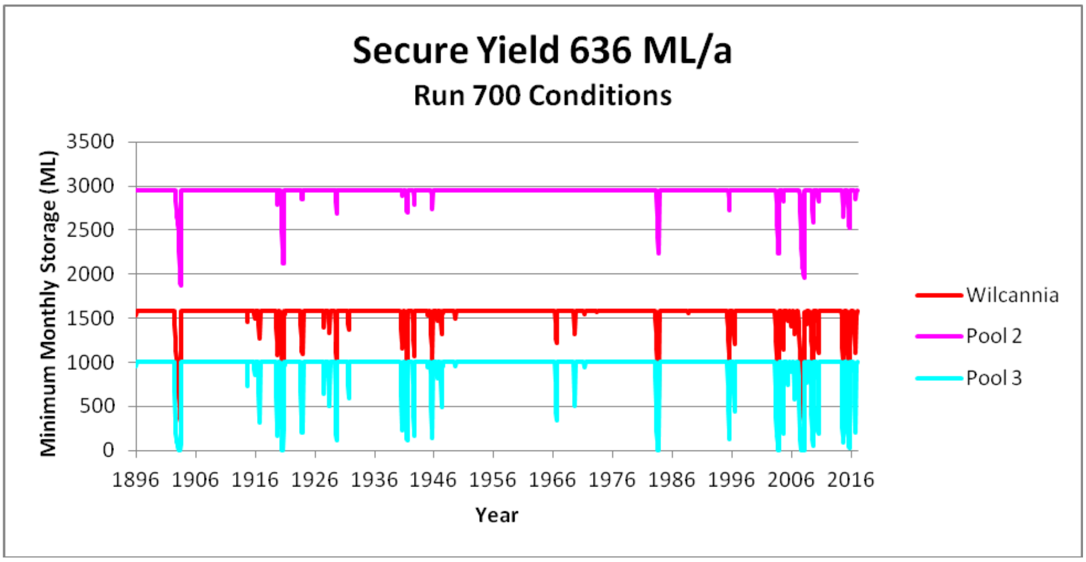
IQQM Merged Flow Series with selected historic flows set as zero.
Initial new weir storage – 0.5m raising (FSL 66.15).

Figure 11 Storage Behaviour - 0.5m Raising



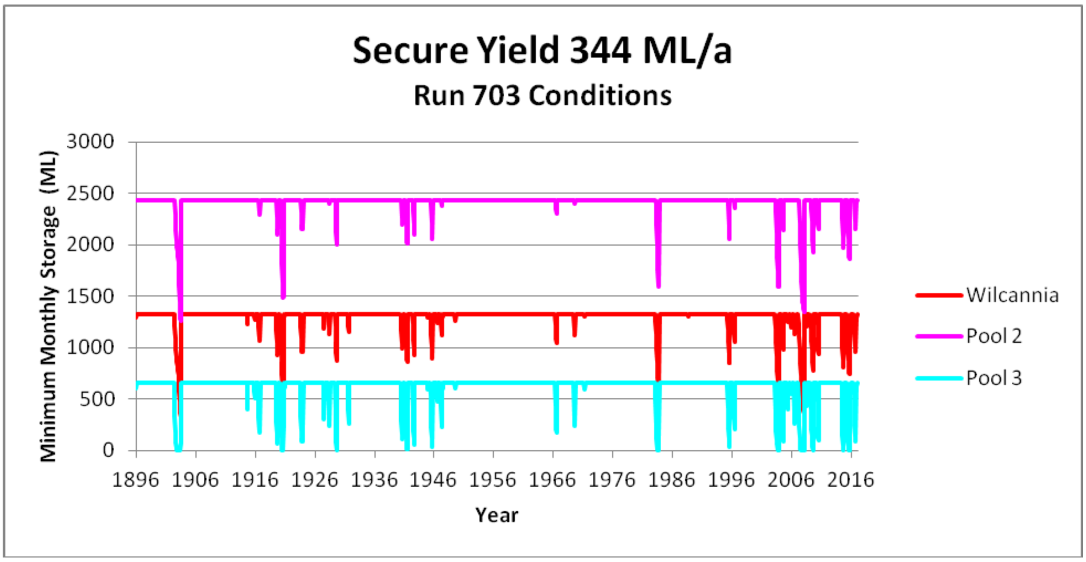
IQQM Merged Flow Series with selected historic flows set as zero.
Initial new weir storage - 0m raising (FSL 65.65).

Figure 12 Storage Behaviour - 0m Raising



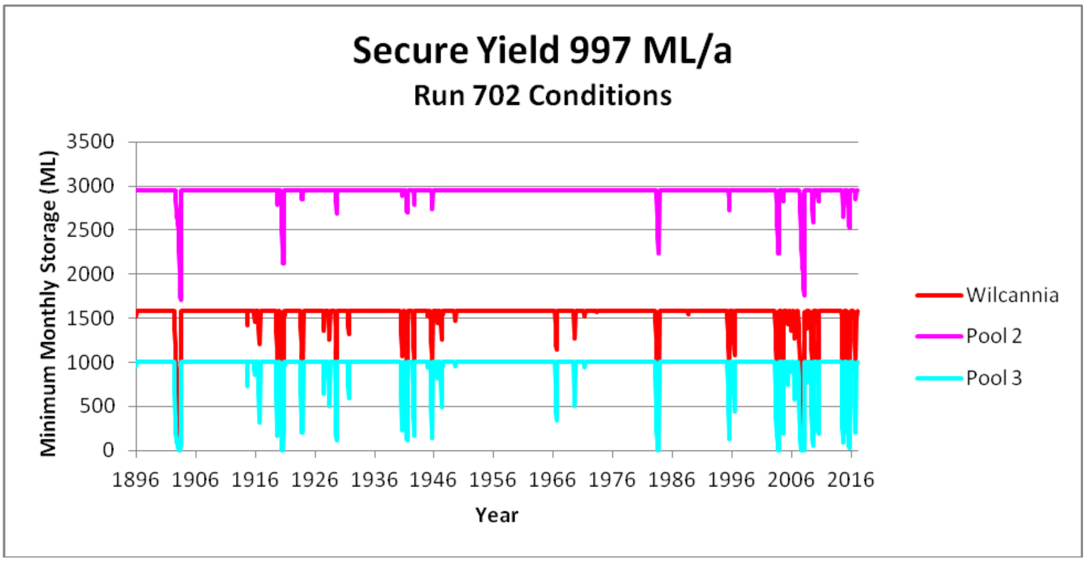
IQQM Merged Flow Series with selected historic flows set as zero.
1001 ML dead storage.
Initial new weir storage – 1m raising (FSL 66.65).

Figure 13 Storage Behaviour - 1m Raising - Constrained Transfer



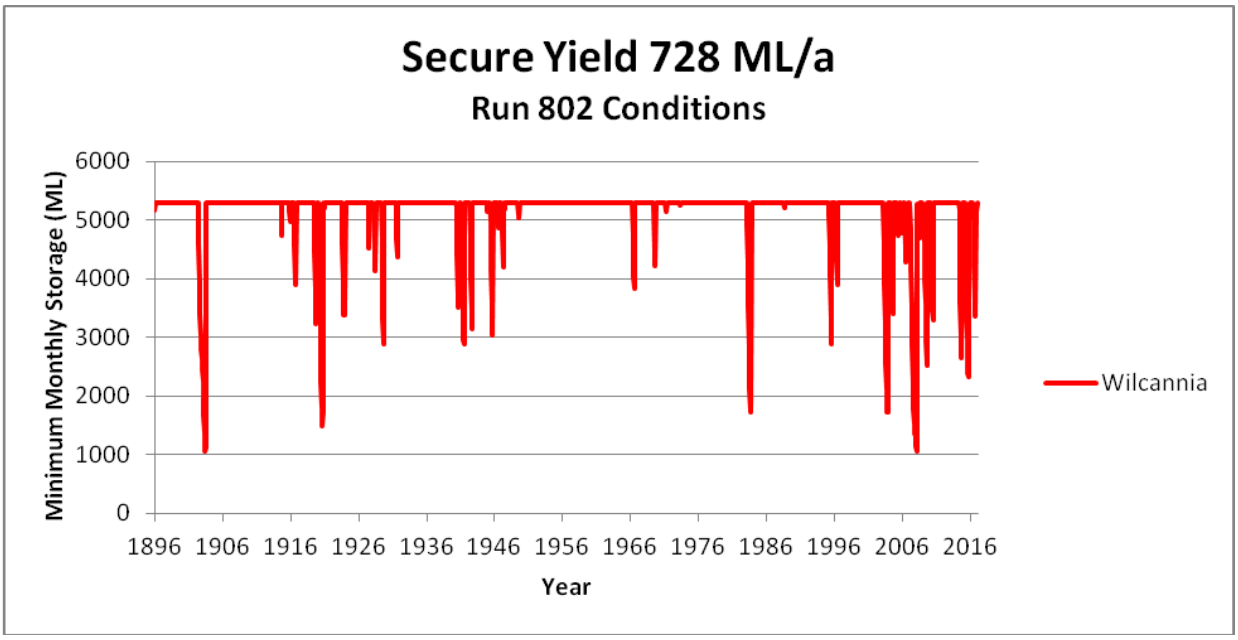
IQQM Merged Flow Series with selected historic flows set as zero.
1001 ML dead storage.
Initial new weir storage – 0.5m raising (FSL 66.15).

Figure 14 Storage Behaviour - 0.5m Raising - Unconstrained Transfer



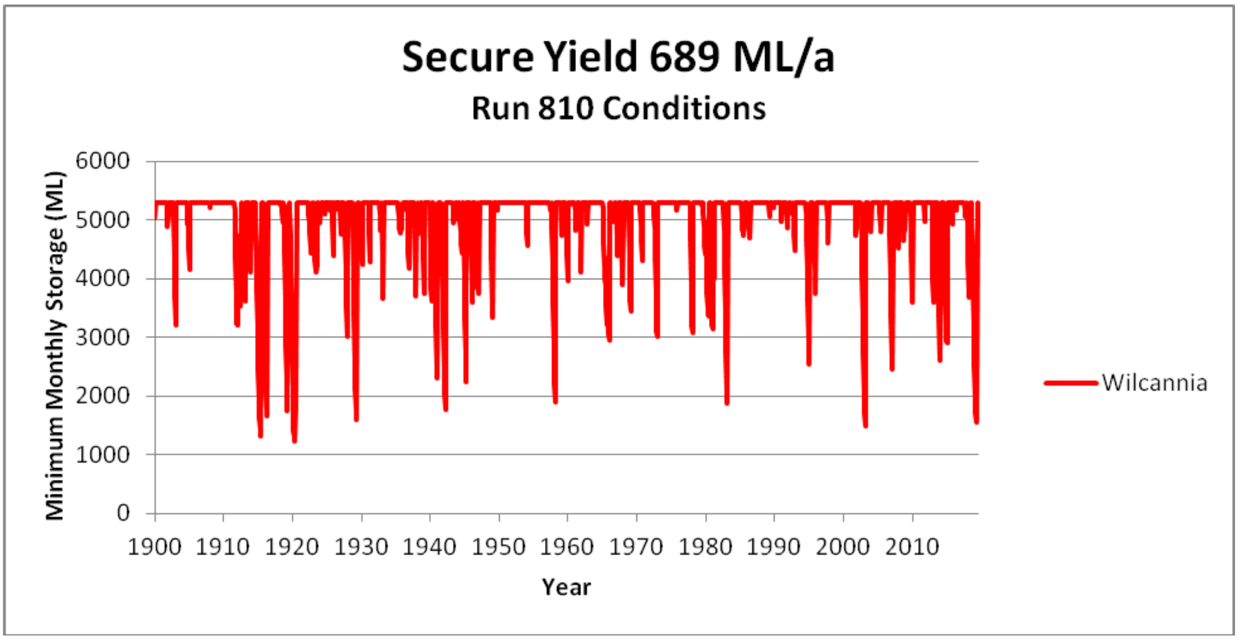
IQQM Merged Flow Series with selected historic flows set as zero.
1001 ML dead storage.
Initial new weir storage – 1m raising (FSL 66.65).

Figure 15 Storage Behaviour - 1m Raising - Unconstrained Transfer



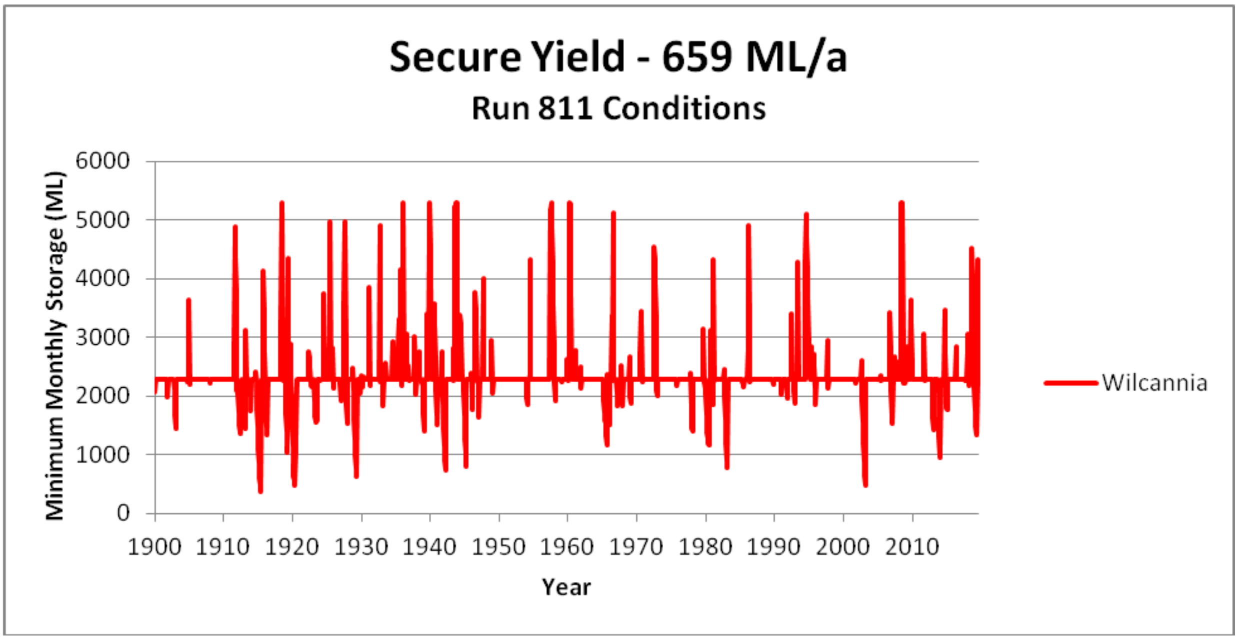
IQQM Merged Flow Series with selected historic flows set as zero.
Revised new weir storage – 1m fixed crest raising (FSL 66.65) - Unconstrained transfer.

Figure 16 Storage Behaviour - No Initial Trial Dual Operating Mode (IQQM Flows)



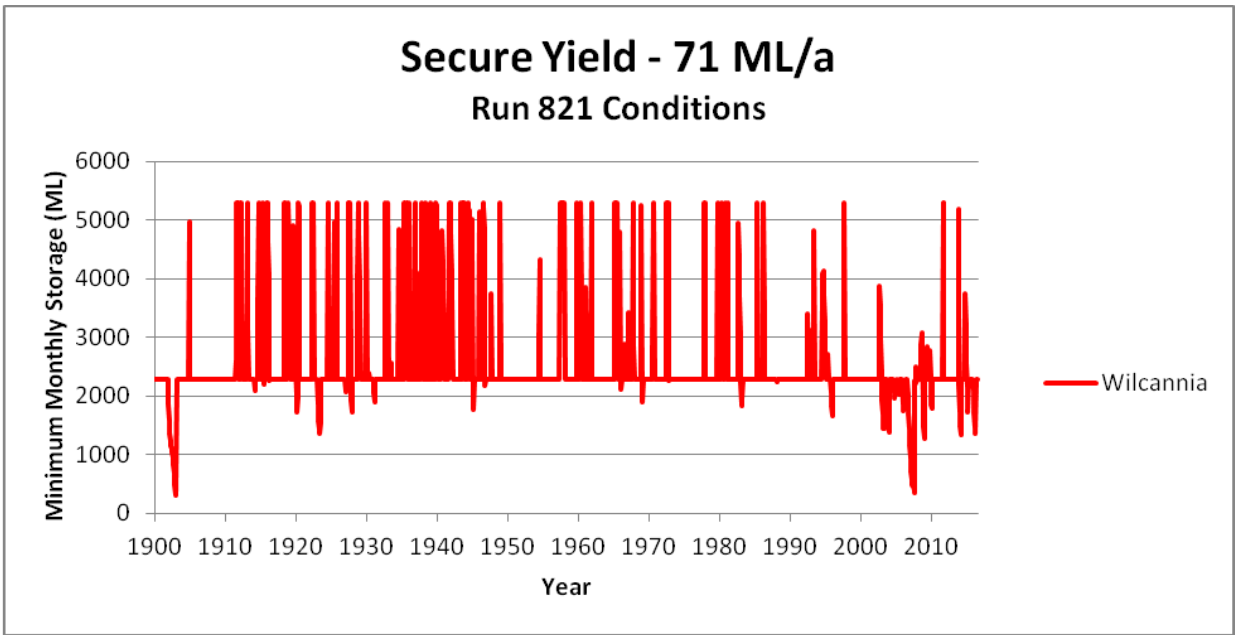
WaterNSW SOURCE Inflows.
Revised new weir storage – 1m fixed crest raising (FSL 66.65) - Unconstrained transfer.

Figure 17 Storage Behaviour - No Initial Trial Dual Operating Mode (SOURCE Inflows)



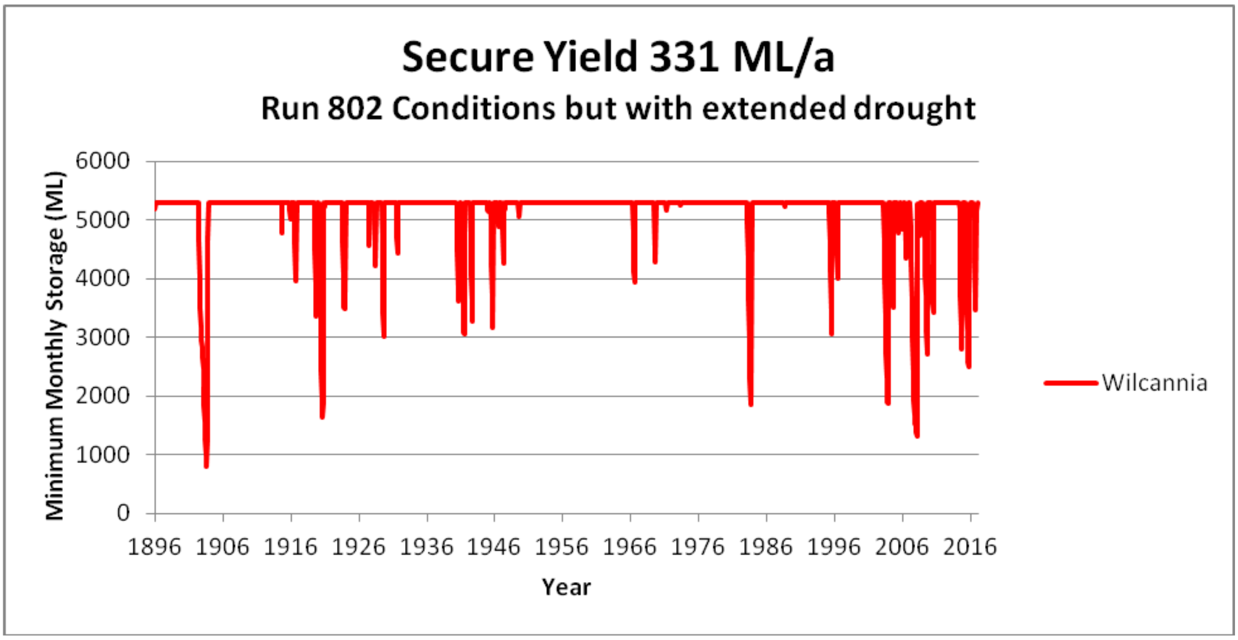
WaterNSW SOURCE for both Wilcannia inflows and Bourke trigger flows.
Revised new weir storage – Initial trial dual operating mode (FSL 65.65 / 66.65) - Triggers 100/200 ML/d.

Figure 18 Storage Behaviour - With Initial Trial Dual Operating Mode (SOURCE flows)



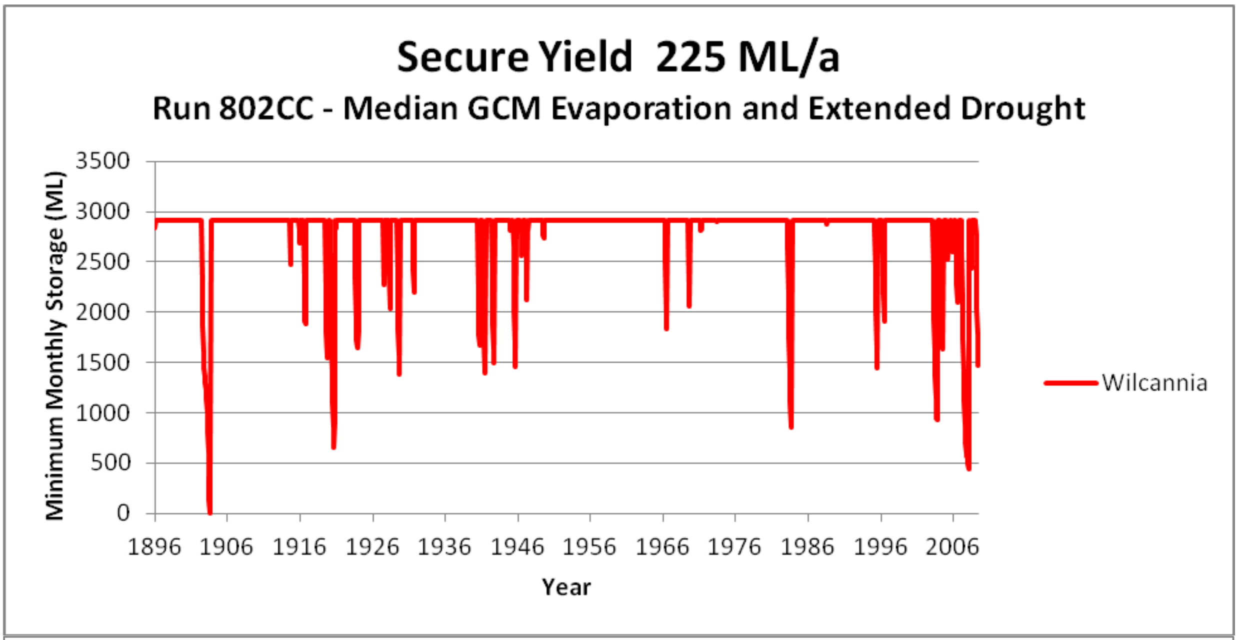
IQQM Merged Flow Series with selected historic flows set as zero for Wilcannia inflows.
WaterNSW SOURCE Bourke trigger flows.
Revised new weir storage – Initial trial dual operating mode (FSL 65.65 / 66.65) - Triggers 100/200 ML/d.

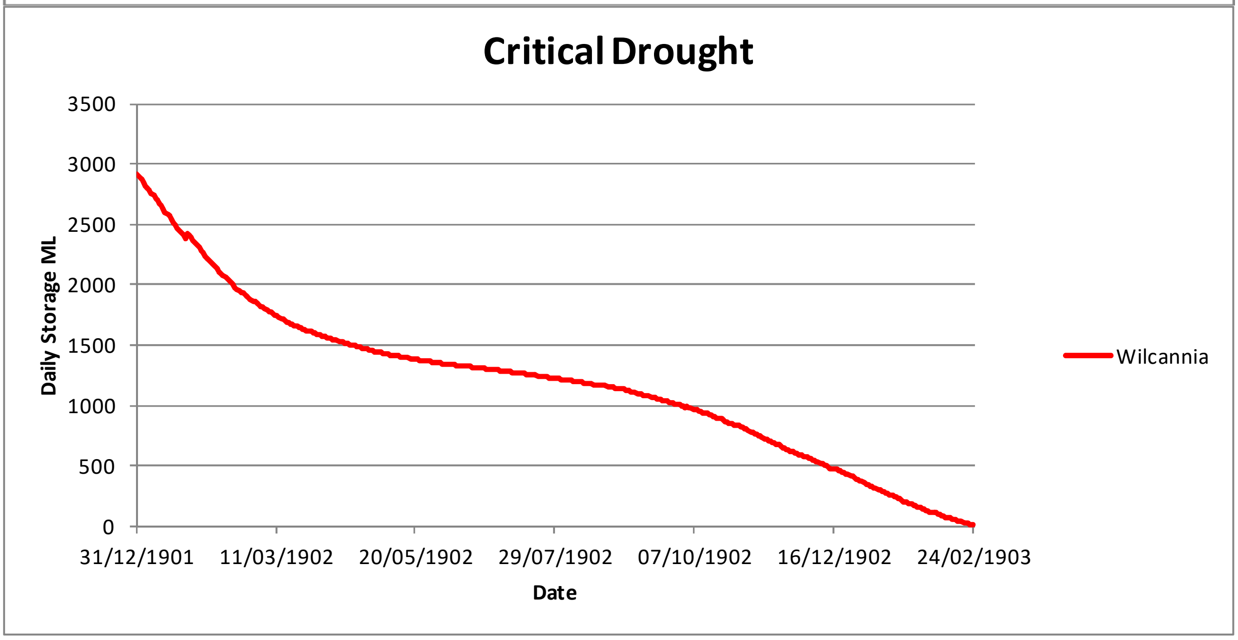
Figure 19 Storage Behaviour - With Initial Trial Dual Operating Mode (IQQM & SOURCE flows)



IQQM Merged Flow Series with selected historic flows set as zero with extended critical drought.
Revised new weir storage – 1m fixed crest raising (FSL 66.65).
Note: The above is Run 805.

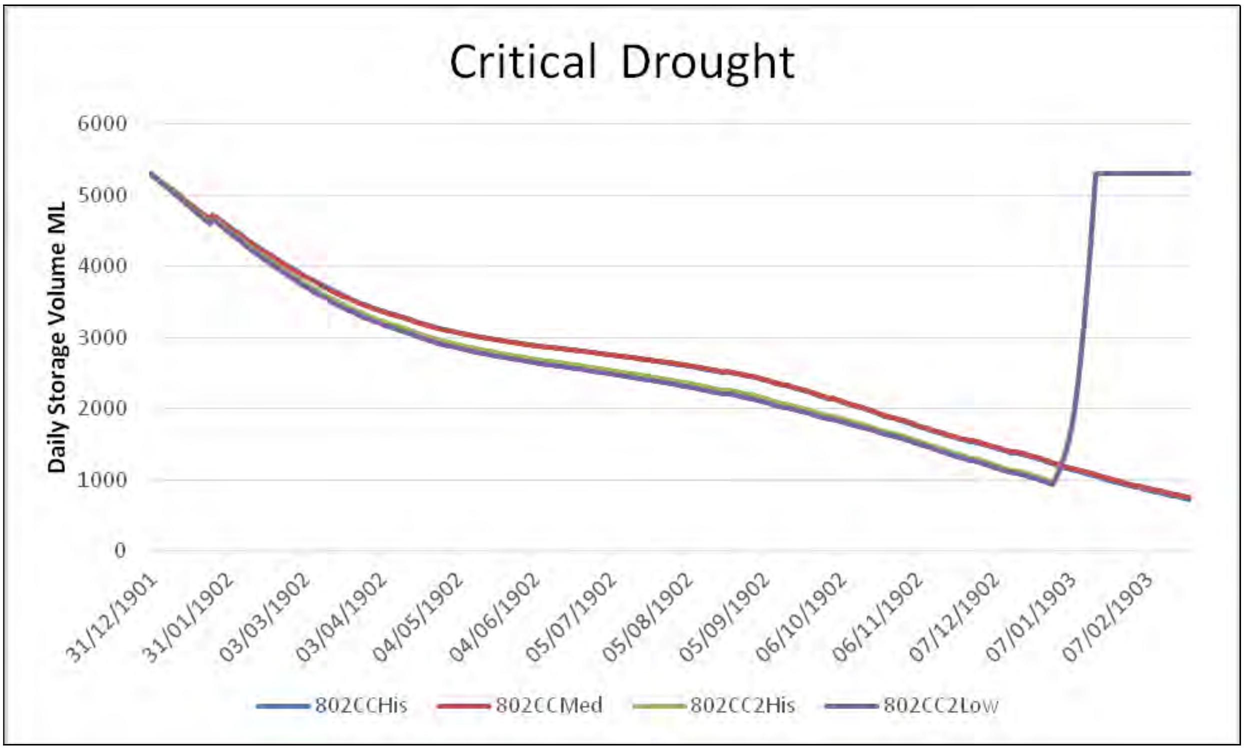
Figure 20 Storage Behaviour - Historic Climate with Critical Drought Extended 55 days (15%)





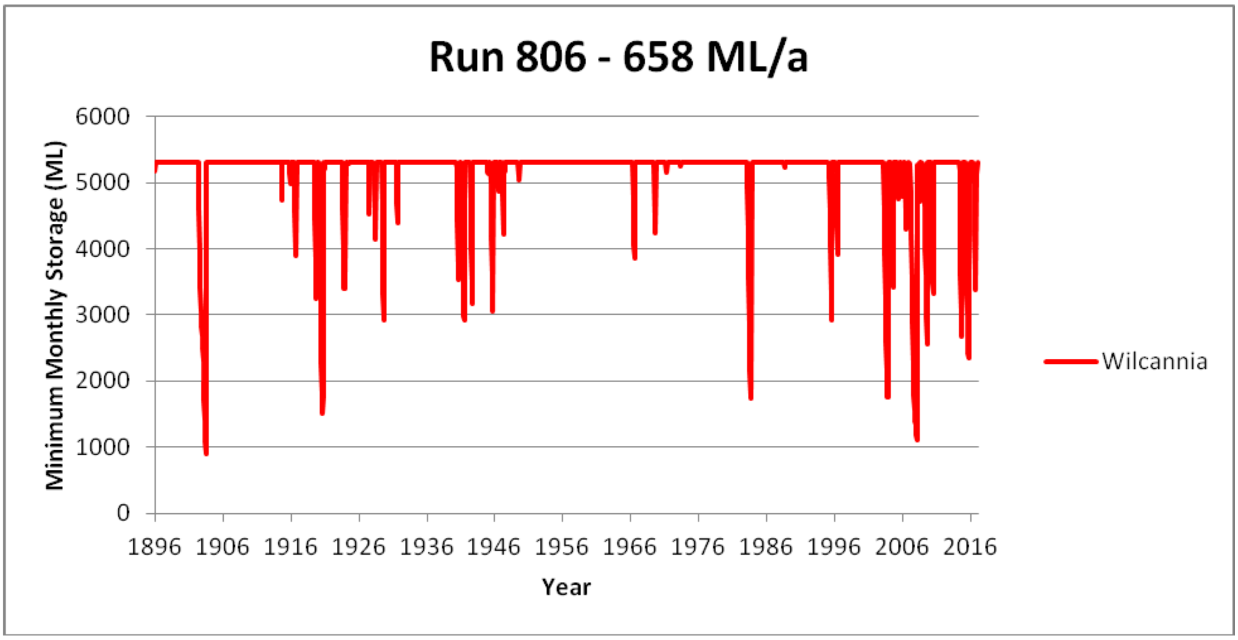
IQQM Merged Flow Series with selected historic flows set as zero with extended critical drought.
Revised new weir storage – 1m fixed crest raising (FSL 66.65).

Figure 21 Storage Behaviour - Critical Run: Median GCM 1 °C Climate Warming Evaporation and Historic Flows with Critical Drought Extended 55 days (15%)



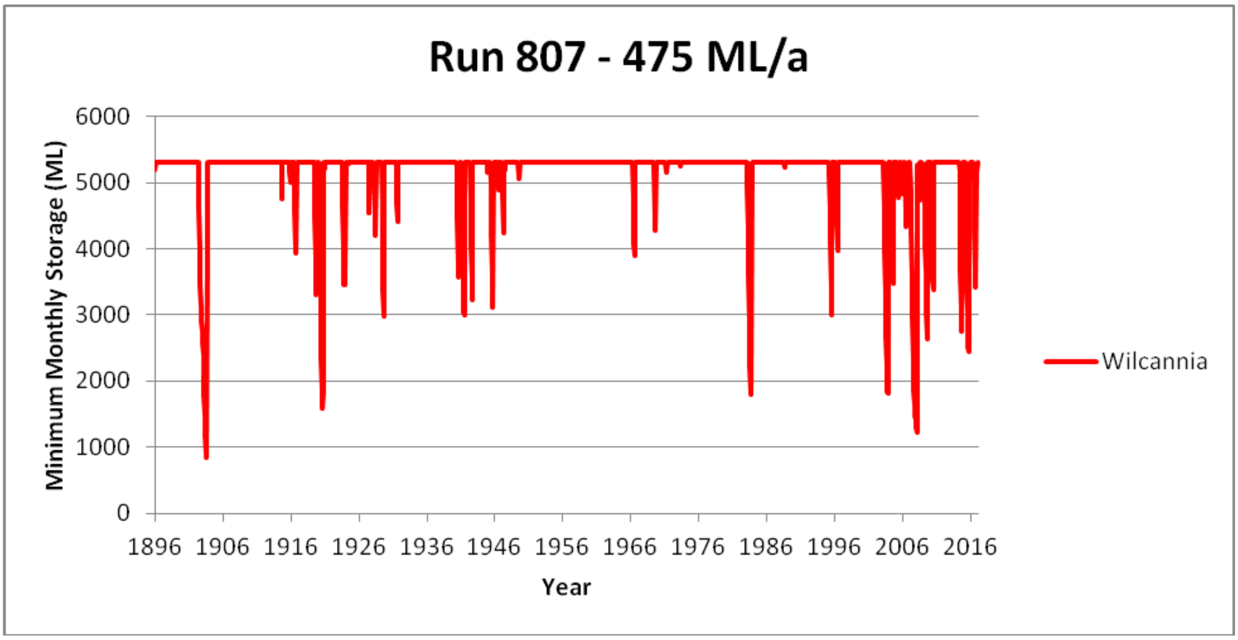
Purple and Green lines almost coincidental.
Blue and Red lines almost coincidental.

Figure 22 Critical Drought Storage Behaviour Comparison



IQQM Merged Flow Series with selected historic flows set as zero with extended critical drought.
Revised new weir storage – 1m fixed crest raising (FSL 66.65).

Figure 23 Storage Behaviour - Historic Climate with Critical Drought Extended 18 days (5%)



IQQM Merged Flow Series with selected historic flows set as zero with extended critical drought.
Revised new weir storage – 1m fixed crest raising (FSL 66.65).

Figure 24 Storage Behaviour - Historic Climate with Critical Drought Extended 37 days (10%)

Appendices

APPENDIX A
Tables 4.6 & 4.7 Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows with Extended Critical Drought

Run 602 conditions (with extended critical drought) – 1m Raising

Wilcannia, Run 602CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_

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	Run	Storage Capacity	Secure Yield	% Restricted at	Restricted % of duration	Restricted % of years	Critical Drought Start	Critical Drought End
HISTORICAL	1	5540.702178	1243	65	1.97	7.83	31/12/1901	24/02/1903
LOWEST	2	5540.702178	1166	65	2.02	8.70	31/12/1901	24/02/1903
	3	5540.702178	1178	65	2.01	8.70	31/12/1901	24/02/1903
	4	5540.702178	1215	65	1.96	7.83	31/12/1901	24/02/1903
	5	5540.702178	1174	65	2.01	9.57	31/12/1901	24/02/1903
	6	5540.702178	1193	65	1.97	7.83	31/12/1901	24/02/1903
	7	5540.702178	1185	65	2.00	9.57	31/12/1901	24/02/1903
	8	5540.702178	1220	65	1.99	8.70	31/12/1901	24/02/1903
	9	5540.702178	1213	65	1.96	7.83	31/12/1901	24/02/1903
	10	5540.702178	1187	65	2.01	8.70	31/12/1901	24/02/1903
	11	5540.702178	1183	65	2.02	8.70	31/12/1901	24/02/1903
	12	5540.702178	1239	65	1.97	7.83	31/12/1901	24/02/1903
	13	5540.702178	1214	65	1.99	8.70	31/12/1901	24/02/1903
MEDIAN	14	5540.702178	1193	65	2.00	8.70	31/12/1901	24/02/1903
	15	5540.702178	1181	65	2.00	8.70	31/12/1901	24/02/1903
	16	5540.702178	1218	65	1.99	8.70	31/12/1901	24/02/1903
10/15/25	2	5540.702178	1643	70	2.79	14.78	31/12/1901	24/02/1903

Run 603 conditions (with extended critical drought) – 0.5m Raising

Wilcannia, Run 603CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_

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					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	4420.550005	641	65	2.09	9.57	31/12/1901	24/02/1903
	2	4420.550005	492	65	2.08	9.57	31/12/1901	24/02/1903
	3	4420.550005	501	65	2.07	9.57	31/12/1901	24/02/1903
	4	4420.550005	647	65	2.11	9.57	31/12/1901	24/02/1903
LOWEST	5	4420.550005	488	60	1.65	6.09	31/12/1901	24/02/1903
	6	4420.550005	577	65	2.08	9.57	31/12/1901	24/02/1903
	7	4420.550005	502	60	1.65	6.09	31/12/1901	24/02/1903
	8	4420.550005	592	65	2.08	9.57	31/12/1901	24/02/1903
	9	4420.550005	631	65	2.09	9.57	31/12/1901	24/02/1903
	10	4420.550005	528	65	2.08	9.57	31/12/1901	24/02/1903
	11	4420.550005	518	65	2.09	9.57	31/12/1901	24/02/1903
	12	4420.550005	642	65	2.10	9.57	31/12/1901	24/02/1903
	13	4420.550005	549	65	2.06	9.57	31/12/1901	24/02/1903
MEDIAN	14	4420.550005	532	65	2.07	9.57	31/12/1901	24/02/1903
	15	4420.550005	525	65	2.08	9.57	31/12/1901	24/02/1903
	16	4420.550005	593	65	2.08	9.57	31/12/1901	24/02/1903
10/15/25	5	4420.550005	989	70	2.95	14.78	31/12/1901	24/02/1903

Run 604 conditions (with extended critical drought) – 0m Raising

Wilcannia, Run 604CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_

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					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	3368.365554	203	60	1.76	6.09	31/12/1901	24/02/1903
LOWEST	2	3368.365554	187	60	1.82	6.09	30/12/1901	24/02/1903
	3	3368.365554	189	60	1.81	6.09	31/12/1901	24/02/1903
	4	3368.365554	198	60	1.78	6.09	31/12/1901	24/02/1903
	5	3368.365554	189	60	1.79	6.09	31/12/1901	24/02/1903
	6	3368.365554	194	60	1.78	6.09	31/12/1901	24/02/1903
	7	3368.365554	191	60	1.79	6.09	31/12/1901	24/02/1903
	8	3368.365554	198	60	1.77	6.09	31/12/1901	24/02/1903
	9	3368.365554	197	60	1.78	6.09	31/12/1901	24/02/1903
	10	3368.365554	191	60	1.80	6.09	31/12/1901	24/02/1903
	11	3368.365554	190	60	1.81	6.09	31/12/1901	24/02/1903
	12	3368.365554	202	60	1.76	6.09	31/12/1901	24/02/1903
	13	3368.365554	197	60	1.78	6.09	31/12/1901	24/02/1903
MEDIAN	14	3368.365554	193	60	1.80	6.09	31/12/1901	24/02/1903
	15	3368.365554	190	60	1.80	6.09	31/12/1901	24/02/1903
	16	3368.365554	197	60	1.78	6.09	31/12/1901	24/02/1903
10/15/25	2	3368.365554	259	65	2.39	12.17	30/12/1901	24/02/1903

APPENDIX B
Tables 4.10 & 4.11 Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows with Extended Critical Drought

Run 700 conditions (with extended critical drought) – 1m Raising - Constrained Transfer

Wilcannia, Run 700CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_

Time: 05/06/2019 12:20:13 PM

	Run	Storage Capacity	Secure Yield	% Restricted at	Restricted % of duration	% of years	Critical Drought Start	End
HISTORICAL	1	5540.702178	636	70	2.06	8.70	31/12/1901	24/02/1903
	2	5540.702178	545	70	2.11	9.57	31/12/1901	24/02/1903
	3	5540.702178	555	70	2.09	9.57	31/12/1901	24/02/1903
	4	5540.702178	636	70	2.07	9.57	31/12/1901	24/02/1903
LOWEST	5	5540.702178	520	70	2.06	9.57	31/12/1901	24/02/1903
	6	5540.702178	624	70	2.09	9.57	31/12/1901	24/02/1903
	7	5540.702178	563	70	2.08	9.57	31/12/1901	24/02/1903
	8	5540.702178	636	70	2.09	9.57	31/12/1901	24/02/1903
	9	5540.702178	636	70	2.07	9.57	31/12/1901	24/02/1903
	10	5540.702178	583	70	2.11	9.57	31/12/1901	24/02/1903
	11	5540.702178	572	70	2.11	9.57	31/12/1901	24/02/1903
	12	5540.702178	636	70	2.07	8.70	31/12/1901	24/02/1903
	13	5540.702178	622	70	2.09	9.57	31/12/1901	24/02/1903
MEDIAN	14	5540.702178	587	70	2.09	9.57	31/12/1901	24/02/1903
	15	5540.702178	579	70	2.10	9.57	31/12/1901	24/02/1903
	16	5540.702178	636	70	2.09	9.57	31/12/1901	24/02/1903
10/15/25	5	5540.702178	636	75	2.70	13.91	31/12/1901	24/02/1903

Run 703 conditions (with extended critical drought) – 0.5m Raising

Wilcannia, Run 703CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_

Time: 06/06/2019 11:39:03 AM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	2	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	3	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	4	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	5	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	6	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	7	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
MEDIAN	8	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	9	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	10	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	11	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	12	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	13	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	14	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
LOWEST	15	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
	16	4420.550005	0	0	0.00	0.00	31/12/1901	24/02/1903
10/15/25	15	4420.550005	75	75	2.79	14.78	31/12/1901	24/02/1903

Run 702 conditions (with extended critical drought) – 1m Raising - Unconstrained Transfer

Wilcannia, Run 702CC		F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_						
Time: 06/06/2019 10:45:49 AM					**Restricted**		**Critical Drought**	
	Run	**Storage Capacity**	**Secure Yield**	**% Restricted at**	**% of duration**	**% of years**	**Start**	**End**
HISTORICAL	1	5540.702178	677	70	2.09	9.57	31/12/1901	24/02/1903
	2	5540.702178	545	70	2.11	9.57	31/12/1901	24/02/1903
	3	5540.702178	555	70	2.09	9.57	31/12/1901	24/02/1903
	4	5540.702178	645	70	2.08	9.57	31/12/1901	24/02/1903
LOWEST	5	5540.702178	520	70	2.06	9.57	31/12/1901	24/02/1903
	6	5540.702178	624	70	2.09	9.57	31/12/1901	24/02/1903
	7	5540.702178	563	70	2.08	9.57	31/12/1901	24/02/1903
	8	5540.702178	649	70	2.10	9.57	31/12/1901	24/02/1903
	9	5540.702178	644	70	2.08	9.57	31/12/1901	24/02/1903
	10	5540.702178	583	70	2.11	9.57	31/12/1901	24/02/1903
	11	5540.702178	572	70	2.11	9.57	31/12/1901	24/02/1903
	12	5540.702178	669	70	2.09	9.57	31/12/1901	24/02/1903
	13	5540.702178	622	70	2.09	9.57	31/12/1901	24/02/1903
MEDIAN	14	5540.702178	587	70	2.09	9.57	31/12/1901	24/02/1903
	15	5540.702178	579	70	2.10	9.57	31/12/1901	24/02/1903
	16	5540.702178	644	70	2.10	9.57	31/12/1901	24/02/1903
10/15/25	5	5540.702178	924	75	2.95	14.78	31/12/1901	24/02/1903

APPENDIX C
Table 4.14 Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows with Extended Critical Drought

Run 802 conditions (with extended critical drought extended 55 days)

Wilcannia, Run 802CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_

Time: 22/10/2020 5:36:49 PM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	5301	363	60	2.18	9.57	31/12/1901	24/02/1903
LOWEST	2	5301	192	55	1.85	6.09	31/12/1901	24/02/1903
	3	5301	205	55	1.84	6.09	31/12/1901	24/02/1903
	4	5301	263	60	2.15	9.57	31/12/1901	24/02/1903
	5	5301	203	55	1.83	6.09	31/12/1901	24/02/1903
	6	5301	229	55	1.82	6.09	31/12/1901	24/02/1903
	7	5301	218	55	1.83	6.09	31/12/1901	24/02/1903
	8	5301	290	60	2.17	9.57	31/12/1901	24/02/1903
	9	5301	264	60	2.15	9.57	27/12/1901	24/02/1903
	10	5301	215	55	1.83	6.09	27/12/1901	24/02/1903
	11	5301	209	55	1.84	6.09	31/12/1901	24/02/1903
	12	5301	365	60	2.19	9.57	31/12/1901	24/02/1903
	13	5301	250	55	1.81	6.09	31/12/1901	24/02/1903
MEDIAN	14	5301	225	55	1.83	6.09	31/12/1901	24/02/1903
	15	5301	208	55	1.83	6.09	31/12/1901	24/02/1903
	16	5301	291	60	2.17	9.57	31/12/1901	24/02/1903
10/15/25	2	5301	497	65	2.79	14.78	31/12/1901	24/02/1903

APPENDIX D
Table 4.15 Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows

Run 802 conditions (with historic flows)

Wilcannia, Run 802CC2 F:\Results\Wilcannia\Data\ClimateChange\WILC_STOR_

Time: 10/11/2020 4:44:18 PM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	5301	844	55	1.88	8.70	31/12/1901	31/12/1902
LOWEST	2	5301	758	55	1.94	9.57	31/12/1901	31/12/1902
	3	5301	765	55	1.92	8.70	31/12/1901	31/12/1902
	4	5301	816	55	1.87	9.57	31/12/1901	31/12/1902
	5	5301	762	55	1.91	9.57	31/12/1901	31/12/1902
	6	5301	790	55	1.89	9.57	27/12/1901	31/12/1902
	7	5301	772	55	1.91	9.57	31/12/1901	31/12/1902
	8	5301	816	55	1.89	8.70	31/12/1901	31/12/1902
	9	5301	815	55	1.87	9.57	31/12/1901	31/12/1902
	10	5301	780	55	1.92	9.57	31/12/1901	31/12/1902
	11	5301	771	55	1.93	9.57	31/12/1901	31/12/1902
	12	5301	840	55	1.88	8.70	31/12/1901	31/12/1902
	13	5301	809	55	1.89	8.70	31/12/1901	31/12/1902
MEDIAN	14	5301	785	55	1.91	8.70	31/12/1901	31/12/1902
	15	5301	768	55	1.91	8.70	31/12/1901	31/12/1902
	16	5301	808	55	1.89	8.70	31/12/1901	31/12/1902
10/15/25	2	5301	1087	60	2.47	12.17	31/12/1901	31/12/1902

Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows with Extended Critical Drought

Run 802 conditions (with extended critical drought extended 55 days)

Wilcannia, Run 802CC F:\Results\Wilcannia\Data\ClimateChangeExtended\WILC_STOR_
Time: 22/10/2020 5:36:49 PM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	5301	363	60	2.18	9.57	31/12/1901	24/02/1903
LOWEST	2	5301	192	55	1.85	6.09	31/12/1901	24/02/1903
	3	5301	205	55	1.84	6.09	31/12/1901	24/02/1903
	4	5301	263	60	2.15	9.57	31/12/1901	24/02/1903
	5	5301	203	55	1.83	6.09	31/12/1901	24/02/1903
	6	5301	229	55	1.82	6.09	31/12/1901	24/02/1903
	7	5301	218	55	1.83	6.09	31/12/1901	24/02/1903
	8	5301	290	60	2.17	9.57	31/12/1901	24/02/1903
	9	5301	264	60	2.15	9.57	27/12/1901	24/02/1903
	10	5301	215	55	1.83	6.09	27/12/1901	24/02/1903
	11	5301	209	55	1.84	6.09	31/12/1901	24/02/1903
	12	5301	365	60	2.19	9.57	31/12/1901	24/02/1903
	13	5301	250	55	1.81	6.09	31/12/1901	24/02/1903
MEDIAN	14	5301	225	55	1.83	6.09	31/12/1901	24/02/1903
	15	5301	208	55	1.83	6.09	31/12/1901	24/02/1903
	16	5301	291	60	2.17	9.57	31/12/1901	24/02/1903
10/15/25	2	5301	497	65	2.79	14.78	31/12/1901	24/02/1903

APPENDIX E:
Table 4.17 Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows with Critical Drought Extended 18 days

Run 806 conditions (with critical drought extended 18 days)

Wilcannia, Run 806CC F:\Results\Wilcannia\Data\ClimateChange18Days\WILC_STOR_

Time: 19/11/2020 3:32:29 PM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	5301	619	55	1.80	7.83	31/12/1901	18/01/1903
LOWEST	2	5301	530	55	1.86	8.70	31/12/1901	18/01/1903
	3	5301	540	55	1.84	8.70	31/12/1901	18/01/1903
	4	5301	590	55	1.80	6.96	31/12/1901	18/01/1903
	5	5301	538	55	1.83	8.70	31/12/1901	18/01/1903
	6	5301	566	55	1.82	7.83	31/12/1901	18/01/1903
	7	5301	551	55	1.83	8.70	31/12/1901	18/01/1903
	8	5301	591	55	1.81	7.83	31/12/1901	18/01/1903
	9	5301	589	55	1.80	6.96	31/12/1901	18/01/1903
	10	5301	553	55	1.84	8.70	31/12/1901	18/01/1903
	11	5301	546	55	1.85	8.70	31/12/1901	18/01/1903
	12	5301	613	55	1.80	7.83	31/12/1901	18/01/1903
	13	5301	584	55	1.80	7.83	31/12/1901	18/01/1903
MEDIAN	14	5301	561	55	1.83	7.83	31/12/1901	18/01/1903
	15	5301	543	55	1.83	7.83	31/12/1901	18/01/1903
	16	5301	585	55	1.81	7.83	27/12/1901	18/01/1903
10/15/25	2	5301	841	65	2.84	14.78	31/12/1901	18/01/1903

Model Results for 15 GCMs
Evaporation and Rainfall Storage Surface Area and corresponding Historic Flows with Critical Drought Extended 37 days

Run 807 conditions (with critical drought extended 37 days)

Wilcannia, Run 807CC F:\Results\Wilcannia\Data\ClimateChange37Days\WILC_STOR_
Time: 19/11/2020 4:56:49 PM

					Restricted		Critical Drought	
	Run	Storage Capacity	Secure Yield	% Restricted at	% of duration	% of years	Start	End
HISTORICAL	1	5301	429	55	1.78	6.09	27/12/1901	06/02/1903
LOWEST	2	5301	340	55	1.84	6.96	31/12/1901	06/02/1903
	3	5301	351	55	1.82	6.09	27/12/1901	06/02/1903
	4	5301	400	55	1.79	6.96	27/12/1901	06/02/1903
	5	5301	348	55	1.81	6.96	31/12/1901	06/02/1903
	6	5301	375	55	1.81	6.96	31/12/1901	06/02/1903
	7	5301	362	55	1.81	7.83	31/12/1901	06/02/1903
	8	5301	401	55	1.79	6.09	31/12/1901	06/02/1903
	9	5301	399	55	1.79	6.96	31/12/1901	06/02/1903
	10	5301	362	55	1.82	6.96	31/12/1901	06/02/1903
	11	5301	356	55	1.83	6.96	31/12/1901	06/02/1903
	12	5301	424	55	1.79	6.09	31/12/1901	06/02/1903
	13	5301	395	55	1.79	6.09	31/12/1901	06/02/1903
MEDIAN	14	5301	371	55	1.81	6.96	27/12/1901	06/02/1903
	15	5301	354	55	1.82	6.96	31/12/1901	06/02/1903
	16	5301	397	55	1.80	6.09	31/12/1901	06/02/1903
10/15/25	2	5301	698	65	2.84	14.78	31/12/1901	06/02/1903

Appendix B. Storage behaviour modelling report

working together to ensure water supply security

NUWS

NSW GOVERNMENT | Public Works Advisory

WILCANNIA WEIR REPLACEMENT

Dual Operating Mode Storage Modelling Report

Prepared for and with contribution by
NSW Public Works Advisory
on behalf of Water Infrastructure NSW

Report No. 20030 - Final 2.0
July 2022
NSW Urban Water Services Pty Ltd

Summary

It was proposed that a new *dual mode* weir would be constructed about 4.92 km downstream of the existing *fixed crest* Wilcannia weir at a location referred to as Refined Site A2. The main purpose of the new weir is to improve the town water supply drought security for Wilcannia. The previously completed secure yield study (Ref 1) identified that the new weir would require a 1m raised crest level compared to the existing weir to meet the future target (2050) annual unrestricted dry year demand of 362 ML/a on a secure yield basis. The yield study also recommended *further studies* be undertaken and this is addressed by the work presented in the current report herein.

The *dual operating mode* functionality proposed for the *new weir* is aimed at minimising the upstream and downstream environmental impacts associated with a 1m raised weir crest level.

The current report examines the performance of the proposed *dual mode* weir and presents the proposed operating rules for the weir that have been developed, tested, and refined as part of the system storage behaviour modelling that has been undertaken.

In simple terms it has been proposed that the *new weir* would have the ability to raise and lower the full supply crest level by 1m between RL 65.71 mAHD and RL 66.71 mAHD. During normal flowing river conditions the weir crest level would be set at RL 65.71 (matched to existing weir). This would be raised by 1m to RL 66.71 at times of anticipated impending drought conditions based on monitoring of upstream flows passing Bourke town weir.

Essentially, the flows past Bourke weir would be used as *trigger flows* to indicate when to implement a change in operating mode for the proposed new Wilcannia weir. Revised trigger flows have been determined with the main aim of ensuring adequate trailing flows are available within the Darling (Baarka) River system between Bourke and Wilcannia that produce Wilcannia weir pool inflows that are sufficient to fully fill the drought storage.

The proposed 1m raised dual mode weir has two distinct operating modes that are linked by operational transition phases. The dual operating modes and related operational river conditions are generally as follows:

- Normal mode: Normal flowing river conditions with the weir full supply level set at RL 65.71 (matched to the existing weir) including an operational high-flow castellated ridge ramp fishway for upstream fish passage;
- Drought Security mode: No flow river conditions with the weir full supply level set at RL 66.71 (1m raised compared to existing) to provide a secure town water supply for Wilcannia with the fishway isolated and non-operational.

The computer based storage behaviour modelling undertaken enabled the development, testing and refinement of the proposed operating rules for the new weir, which covered both *normal* mode and *drought security* mode along with additional rules for the *operational transitional phases*. The modelling also accounted for the individual weir pool portions and their interconnectivity connectivity for each respective Wilcannia weir assessed. Figure A-1 in Appendix A provides the longitudinal schematic profile of the *proposed new weir pool* storage inclusive of that for the *existing weir pool storage*.

The key outputs from the current model study included:

- Refined Bourke trigger flows;
- Developed operating rules;

- Statistical performance results for each assessed operating scenario (refer in Table 4-1 in Chapter 4 for scenarios and both Table B-1 and Table B-2 in Appendix B for results summary);
- Modelled daily times series of flows just downstream of the weir for each respect scenario combined with supporting operating condition data, such as, for example:
  - Current operating mode
  - Active rules
  - Pool levels and volume
  - Weir crest level
  - Pool 2 pumping rate, if applicable.

Key statistical results included:

- frequency and duration of implementation of the weir operating mode changes,
- duration of mode transition phases, and
- reliability of complete storage filling.

The proposed rules were progressively implemented in the model so that their individual merits could be assessed. The developed operating rules for the proposed *dual mode* weir are identified as follows:

- Normal Mode
  - Dynamic Storage rule

    Normal flowing river simulation of weir pool level versus flow discharge relationship.

  - Flow Resumption rule - Reset-lowering phase

    Delay in return of the weir crest to normal mode requirements pending the recommencement of inflows into the weir pool.

  - Progressive Lowering rule - Reset-lowering phase

    Aimed at limiting the maximum weir pool lowering rate to 0.1m/day.

- Drought Mode
  - Progressive Closure rule - Filling phase

    Progressive incremental crest raising to allow the weir pool to be filled by trailing river inflows while avoiding sudden downstream flow shut-off.

  - Inflow Translucency rule - Post initial-filling phase

    Provision for release of net storage inflows into combined Pool 1 and New Town over the top 1.17m range of the new weir storage.

The model study outputs informed the part of the assessments undertaken for the EIS.

Contents

Tables

Figures

1. Introduction

1.1 Background

It was proposed that a new *dual mode* weir would be constructed about 4.92 km downstream of the existing *fixed crest* Wilcannia weir at a location referred to as Refined Site A2. The main purpose of the new weir is to improve the town water supply drought security for Wilcannia. The previously completed secure yield study (Ref 1) identified that the new weir would require a 1m raised crest level compared to the existing weir to meet the future target (2050) annual unrestricted dry year demand of 362 ML/a on a secure yield basis. The *dual operating mode* functionality proposed for the *new weir* is aimed at minimising the upstream and downstream environmental impacts associated with a 1m raised weir crest level.

In simple terms it has been proposed that the *new weir* would have the ability to raise and lower the full supply crest level by 1m between RL 65.71 mAHD and RL 66.71 mAHD. During normal flowing river conditions the weir crest level would be set at RL 65.71 (matched to existing weir). This would be raised by 1m to RL 66.71 at times of anticipated impending drought conditions based on monitoring of upstream flows passing Bourke town weir.

The computer based storage behaviour modelling undertaken for this report enabled the development, testing and refinement of the proposed operating rules for the new weir, which covered both *normal* mode and *drought security* mode along with additional rules for the *operational transitional phases*. The modelling also accounted for the individual weir pool portions and their interconnectivity connectivity for each respective Wilcannia weir assessed.

1.2 Scope of Work

Public Works Advisory (PWA) were engaged to develop functionality requirements and a preliminary concept design for the proposed new Wilcannia weir. The work included the undertaking of a town water supply secure yield study that confirmed the future (2050) annual unrestricted dry year demand could be met by a proposed 1m raised weir crest compared to the existing weir.

This work was extended to include system behaviour modelling for the proposed 1m raised Wilcannia weir with a *dual mode* of operation implemented based on a set of preliminary operating rules. The further work accounted for the following recommendations extending from the yield study:

- Updated WaterNSW SOURCE model flows for the Barwon-Darling catchment with selected DPIE-Water provided tributary inflows.
- Incorporate additional bathymetric survey (2021) that enabled better definition of the dead storages within Pool 3 and the End pool (Pool 4).
- Account for a minor 0.06m higher revised full supply level of RL 65.71 and 1m raised level of RL 66.71.
- Development of more detailed operating rules aimed at minimising environmental impacts associated with the proposed new 1m raised *dual mode* weir at Revised Site A2 (current 2022 site).

NSW Urban Water Services Pty Ltd (NUWS) were engaged by PWA to model the *dual mode* operating rules developed by PWA in consultation with WINSW and Jacobs (EIS) using an updated system behaviour model compared to that used by NUWS for the previous Wilcannia town water supply yield study (Ref 1).

The modelling output was to inform the assessment by others of both upstream impacts and downstream flow impacts of the proposed new weir compared to the existing weir.

The key required outputs from the model study were:

- Refined Bourke trigger flows;
- Developed operating rules;
- Statistical performance results for each assessed operating scenario (refer Table 4-1);
- Modelled daily times series of flows just downstream of the weir for each respect scenario combined with supporting operating condition data.

1.3 Objectives

This report contains a summary of the proposed dual mode operating rules and the results of the system storage behaviour modelling with implementation of the rules to provide an assessment of the expected adequacy of the rules to govern operation of the dual mode weir with the aim of minimising upstream and downstream environmental impacts. This included key operational performance results for aspects such as:

- frequency and duration of implementation of the weir operating mode changes
- duration of mode transition phases
- reliability of complete storage filling.

The outcomes from the modelling presented in this report was to provide input to assist with environmental impact assessment by others of the proposed new weir.

1.4 Methodology

Operating rules for the proposed 1m raised *dual mode* Wilcannia weir were proposed iteratively and tested in the model and refined until a set of rules were developed that met the project objectives.

The model was based on the storage system behaviour model that was used for the recent Wilcannia Weir Yield study (Ref 1) and subsequent refined to meet the requirements of the current study. The model is essentially a daily water balance model and was modified to incorporate all the proposed *dual mode* operating rules. The hydrometeorological data required to be input to the model were inflows (*provided by WaterNSW*) and rainfall and evaporation (*obtained from the SILO Data Drill*).

Figure 1-1 shows the methodology for the application of trigger flows and Figure 1-2 shows the proposed operational modes and transitions phase for the proposed weir inclusive of the rules applicable to each mode/phase.

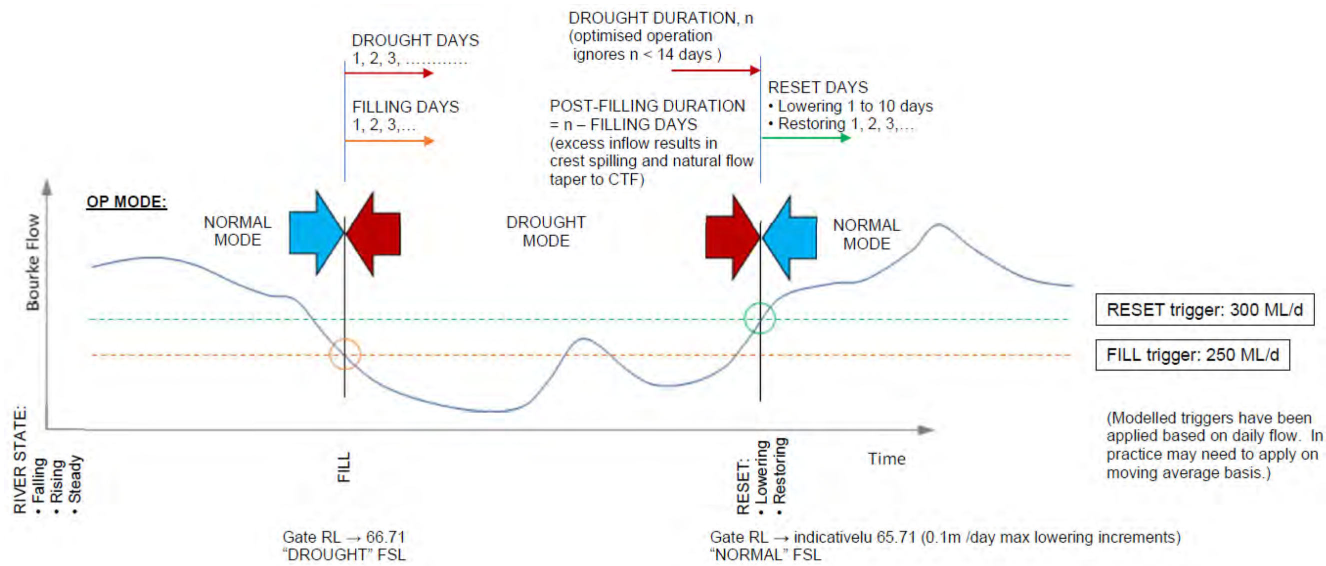

Figure 1-1 Triggers for Filling and Reset transition phases

Modes:	'NORMAL' Normal flowing river conditions FSL 65.71 | 4755 ML (existing + 548 ML)	'DROUGHT' Town water supply drought security FSL 66.71 | 7832 ML (existing + 3,625 ML)
Triggers:	RISING river flows past Bourke > 300 ML/day	FALLING river flows past Bourke ≤ 250 ML/day
Phases:	(1) NORMAL flowing river conditions (**default**)	(2) INITIAL FILLING (transition)
	(4) RESET - LOWERING (typical transition), or - RESTORING (infrequent transition)	(3) POST-FILLING drought conditions (**default**)
Operating Rules:	(1) Dynamic Storage (provisional)	(2) Progressive Closure (transitional filling)
	(4) Flow Resumption (transitional lowering)*	(3) Inflow Translucency (unregltd or anticipated EW)

Figure 1-2 Proposed operation of proposed new 1m raised *dual mode* weir

1.5 Qualifications

The work contained in this report is considered valid within the context of the study purposes, but caution should be exercised if aspects of this report, including data and estimates, are abstracted out of context or are to be used for some other purpose.

Hydrology is not an exact science and necessarily involves some uncertainty and the results should be regarded as estimates within both the limitations of the study and available data for the purposes of providing guidance within an overall project development process.

The modelling outcomes are dependent on the assumed streamflows and operating constraints. For this study the streamflows were provided by others and the operating constraints are as specified. NSW Urban Water Services Pty Ltd and Public Works Advisory does not warrant or accept any liability in relation to the quality or accuracy of the modelled outcomes which are reliant on provided information and no responsibility is accepted by either NSW Urban Water

Services Pty Ltd or Public Works Advisory for the accuracy, currency, reliability, or correctness of any information in this publication provided by the client or third parties.

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2. Hydrometeorological Data

2.1 Introduction

In general, estimates of daily rainfalls, streamflows and, daily evaporation and evapotranspiration for as long a historical period as possible is desirable.

The daily streamflows used as input to the system behaviour modelling for the proposed dual mode Wilcannia weir are detailed in Section 2.3 and cover the period from 1/1/1900 to 20/8/2019, which is about 119.6 years.

In addition to daily streamflows, accompanying daily evaporation and rainfall are required for input to the system behaviour model for determining the net loss from or gain to weir pool storage water surface areas.

Daily evaporation and rainfall upstream of Wilcannia is catered for by the input streamflows.

For the Wilcannia Weir Replacement project, simulated historical daily flow time series data was provided by WaterNSW from the Barwon-Darling catchment SOURCE model inclusive of selected DPIE-Water provided tributary inflows as adapted to suit the purposes of the current project.

2.2 Meteorological Data

The daily rainfall and daily evaporation data were obtained from the SILO Data Drill for the grid points that represent the weir storage water area. The SILO Data Drill is a service provided by the Science Delivery Division of Queensland Department of Science, Information Technology, Innovation and the Arts (DSITIA). The Data Drill accesses grids of data at 0.05° intervals derived from interpolation of point Bureau of Meteorology station records. Interpolations are calculated by Splinning and Kriging techniques. Further details of the processes are given in Ref 2.

The daily evaporation and rainfall data obtained from the SILO Data Drill was used to represent losses from the storages based on the grid points provided in Table 2-1. Morton's shallow lake evaporation data was used.

Table 2-1 SILO grid points – Wilcannia Weir

Grid Point	Latitude	Longitude
1	-31.55°	143.40°

Figure 2-1 and Figure 2-2 provide the time duration exceedance curves for the daily rainfall and daily evaporation used for the modelled period, 1900 to 2019.

The figures show that for about 85% of the days there was no rainfall. The daily evaporation varied from about 0.4mm to about 10.4mm and for about 50% of the days the daily evaporation was greater than 4.3 mm.

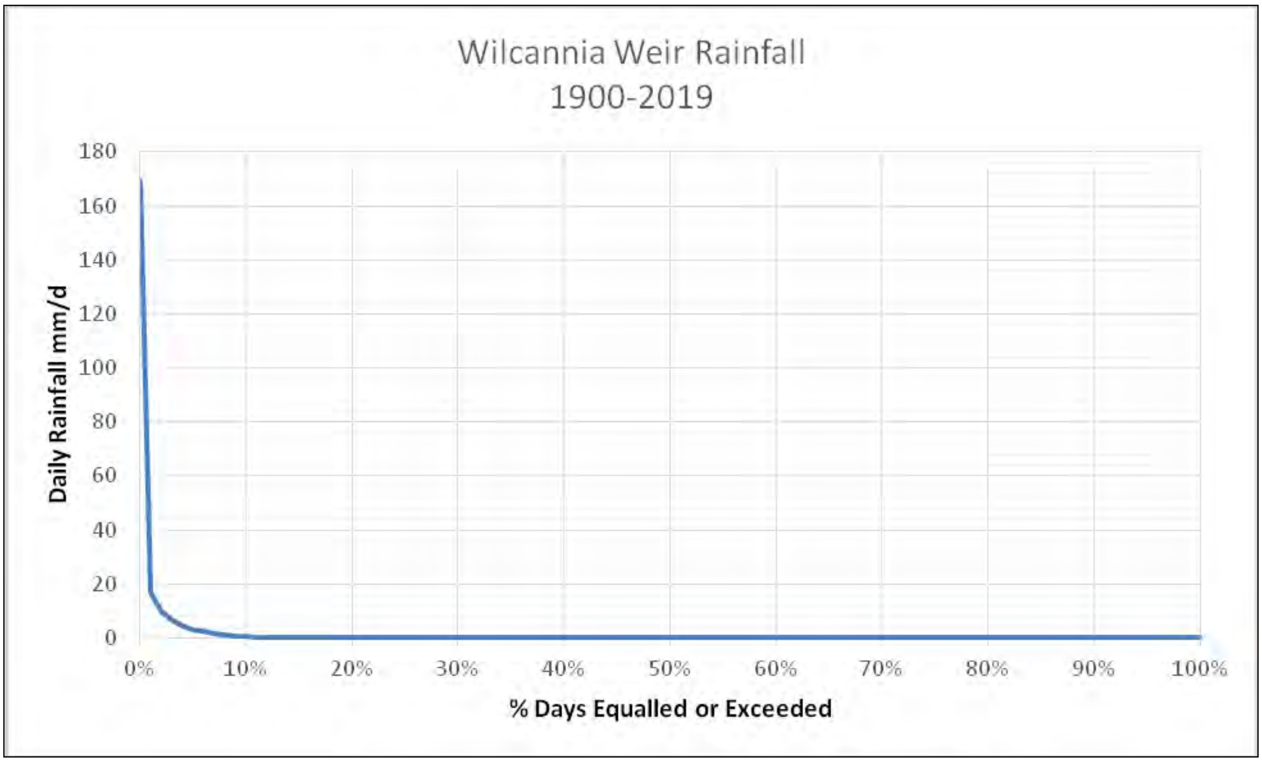


Figure 2-1 Daily Rainfall Exceedance Curve

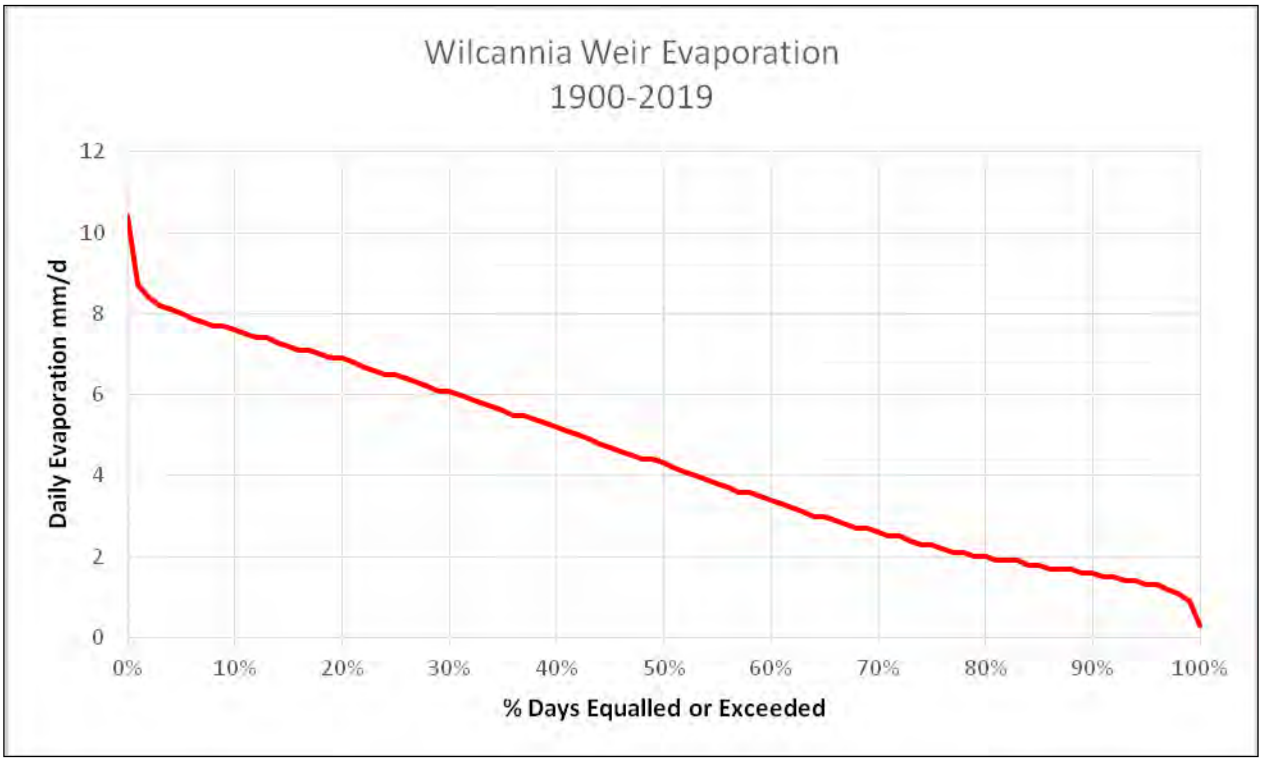


Figure 2-2 Daily Evaporation Exceedance Curve

2.3 Source Flow Data

The key input for modelling the behaviour of the proposed new *dual mode* Wilcannia weir was two (2) simulated historic flow datasets comprising 'actual permitted take' (APT) scenarios from the WaterNSW SOURCE model of the Barwon-Darling catchment inclusive of selected DPIE-Water provided tributary inflows (considered to be more up to date than those replaced in the WaterNSW SOURCE mode).

Each of the two (2) SOURCE based datasets provided by WaterNSW was comprised of the following two (2) daily flow time series for the Darling (Baarka) River:

i. Bourke Trigger Flows: Simulated historical flows time series past Bourke (town) weir adopted as the location of the 'Darling River at Myandetta' gauge (No. 425038), which is located about 31km downstream of the Bourke weir and upstream of Weir 19A.

   These flows were required to implement the trigger for raising and lowering the weir crest full supply level for the proposed dual mode Wilcannia weir.

ii. Wilcannia Inflows: Simulated historical inflows time series at the upstream end of the Wilcannia weir pool (i.e. into the End Pool (Pool 4)).

   These inflows were the same for assessment of either the existing weir or proposed dual mode Wilcannia weir.

The daily flow time series data covered the period from 1/1/1900 to 20/8/2019, which is about 119.6 years. This period included the critical drought identified in the yield study (Ref 1) from 31/12/1901 to 31/12/1902 (12 months).

The SOURCE model adapted by WaterNSW for the Wilcannia Weir Replacement project in consultation with WINSW, Jacobs (EIS) and PWA incorporated the following:

- Base model calibrated against stream gauges with all climatic inputs including evaporation and total loss allowances (no discreet weir pool seepage loss);
- 'Simulated Flows' model accounting for current operating rules and July 2020 Water Sharing Plans superimposed on to the calibrated base model;
- 'Low-Flow Adjusted Simulated Flows' model developed by setting flows at Tilpa that were less than 100 ML/d to zero (ref. Darling River at Tilpa gauge No. 425900);
- No 'environmental water' provisions (planned or managed) within either river flow time series.

Accordingly, the two (2) supplied input datasets are identified as follows:

1 Simulated Flows;

2 Low-Flow Adjusted Simulated Flows.

Consequently, the *Bourke Trigger Flows,* and *Wilcannia Inflows* were all modelled on a consistent basis other than the abovementioned *low-flow adjustment* of *Wilcannia inflows* within the *Low-Flow Adjusted Simulated Flows* dataset. The need for consistency was identified in the previous yield study (Ref 1) study to be an important factor in considering the reliability of results.

The *Low-Flow Adjusted Wilcannia Inflows* time series was aimed at providing an allowance for uncertainty in the SOURCE modelling of low-flows into the Wilcannia weir pool and to provide a means for related sensitivity assessment.

Details of the SOURCE model software are provided by Ref 3.

Figure 2-3 provides the flow duration curves for the input daily flow time series within each dataset. For clarity, the *Bourke Trigger Flows* time series is the same within each dataset while the *Wilcannia Inflows* time series differs between the *Simulated Flows* and the *Low-Flow Adjusted Simulated Flows* datasets.

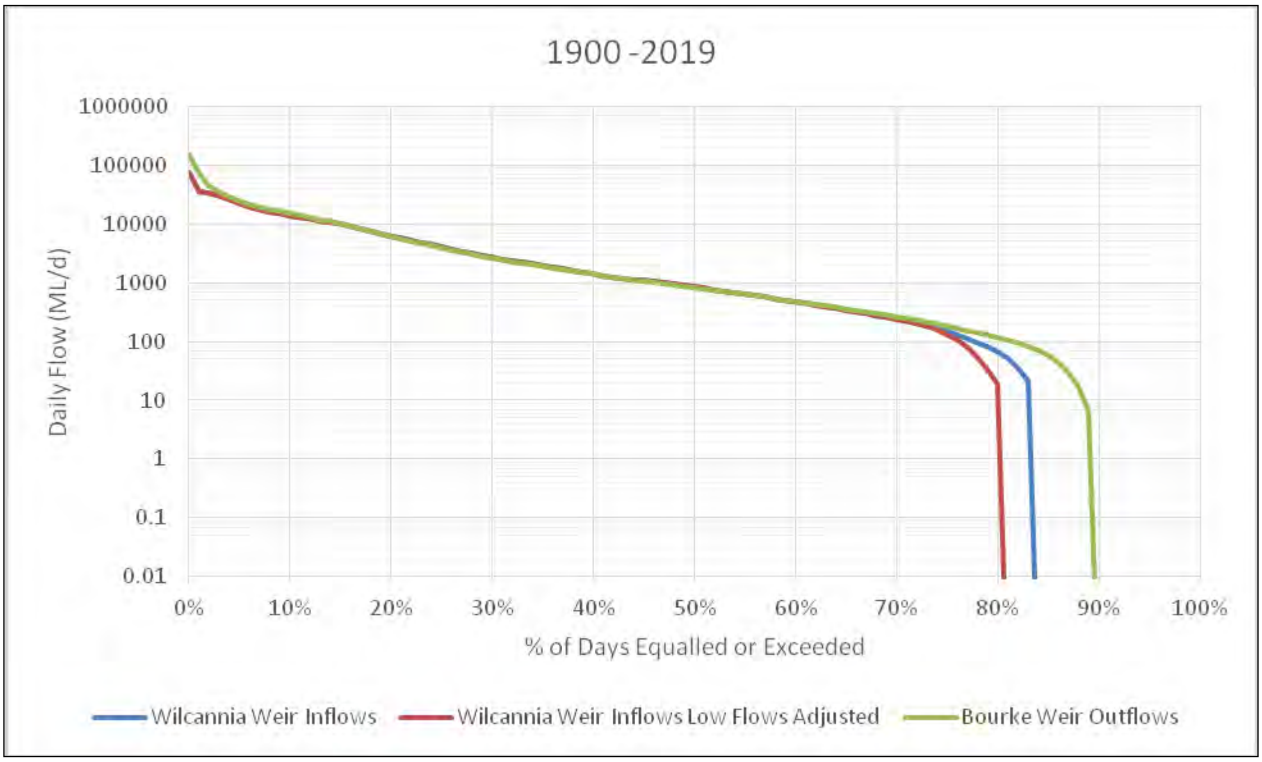


Figure 2-3 Flows Duration Curves for Input Flow Time Series

The Myandetta gauge is located indicatively around 620km upstream of Wilcannia while the Tilpa gauge is located indicatively around 275km upstream of Wilcannia.

3. System Behaviour Modelling

3.1 Introduction

Modelling of the behaviour of the Wilcannia weir storage was required as part of developing and testing operating rules for the proposed 1m raised *dual mode* weir for the purpose of minimising upstream and downstream environmental impacts while delivering the primary function of the proposed weir to secure the future water supply for the town of Wilcannia.

This was done using a computer storage and system behaviour model using an iterative process to satisfy all the requirements implied by the rules and available water while meeting water supply demands.

Essentially the model is a computer program that balances continuity equations on a daily basis between all the water sources and demands. The model simulates the behaviour of the system by accounting for and balancing the available water. The hydrological cycle is modelled external to the model and the required hydrometeorological data is provided as input to the system behaviour model. In essence the system model is driven by operating conditions such as the need to meet a particular demand while satisfying operating constraints such as available water from streamflows and accounting for losses.

In addition to the hydrometeorological data that must be input into the computer simulation model, other data such as identified in the respective sections below has also been input to produce a complete model along with assumptions based on NUWS experience and as informed by the information provided by PWA.

Figure 3-1 provides a schematic of the system behaviour model.

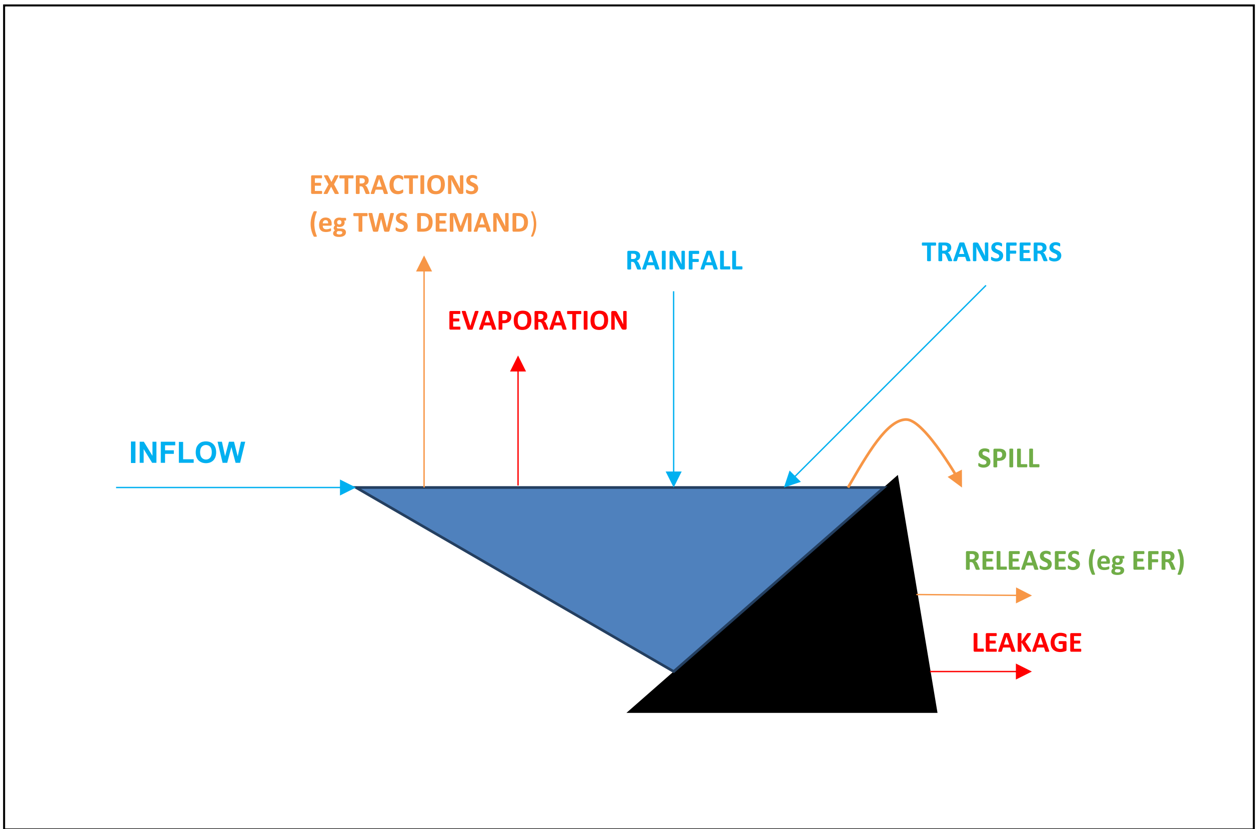


Figure 3-1 Storage Behaviour Model Schematic

For this study, it was assumed there was no leakage from the weir. Also there were no transfers to the weir from other water sources but there were transfers from nominated upstream weir pools to lower weir pools as specified in the town water supply operating rules.

3.2 Headworks System

The Wilcannia water supply headworks system generally consists of:

- Wilcannia weir storage on the Darling River from which water is pumped to supply. The bore water supply was not required to be included in the modelling as the bores have been considered to represent backup supply provisions.

While the *existing* and *proposed* headworks systems are generally similar as per the above, the following key differences are noted:

- <u>Existing Weir</u>: Fixed crest weir with a FSL of RL 65.71 mAHD.
- <u>Proposed Weir</u>: Variable crest weir with *dual operating mod*e that allows for a *normal mode* FSL of RL 65.71 mAHD (matched to existing weir) to be raised by 1m to achieve a *drought security mode* FSL of RL 66.71.

The dual operating mode for the *proposed weir* is facilitated by centrally located weir outlet overshot gates and a high flow castellated-ridge ramp type fishway located adjacent the northern (right-hand side) riverbank, which has overshot isolation gates located upstream of the fishway exit baffle at the upstream end of the fishway. The *proposed weir* also has a fixed crest section adjacent the southern (left-hand side) riverbank with a main crest level of RL 66.71 (matched to the drought FSL).

The discharge characteristics of both the *existing weir* and the *proposed weir and fishway structure* are inherently different due their respective arrangements and the proposed *dual mode* operating rules for the *proposed weir* outlet and fishway gates.

Consequently, the same discharge passing each weir will produce different respective upstream river levels, particularly for the range of flows above zero up to moderate river flows that result in complete weir submergence and drown-out of the *proposed weir*, which is estimated to be at around 11,000 ML/d to 12,000 ML/d (based on the preliminary concept design). For comparison, the existing weir is expected to drown-out between 5000 ML/d and 7000 ML/d.

The system behaviour modelling presented in this report made allowances for the abovementioned structures and related differences in discharge characteristics. These aspects are covered in more detail in Section 3.8.

3.3 Demand Pattern

The annual demand that was required to be met including the impact of any demand restrictions was broken down into a monthly pattern to reflect seasonality based on Wilcannia's past consumption records.

Table 3-1 provides the monthly demand pattern used in the storage behaviour modelling, which is consistent with that used for potable demand in yield study (Ref 1).

It is NUWS experience that generally secure yield and storage behaviour is not that sensitive to the monthly demand pattern if seasonality is shown by the differentials and if the storage can meet several months demand. Accordingly, the potable demand pattern has been used for all Wilcannia town water supply extractions in the modelling for the purposes of simplicity.

Table 3-1 Monthly Demand Pattern

Pattern	Monthly Demand % of Total Annual Demand											
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Wilcannia Potable	6.4	6.4	7.18	9.20	10.61	11.38	12.62	8.76	9.20	6.87	5.77	5.63

Source: PWA.

3.4 Demand Restrictions

Town water supply demand management provisions have been implemented for the system behaviour modelling for both the *existing weir* based on current restriction provisions confirmed with Central Darling Shire Council (CDSC) and for the *proposed new weir* based on developed preliminary restrictions adapted from the existing provisions.

For the *existing weir* modelling, the respective Restriction Level to be implemented is based on river flow conditions (crest spilling or not) and the percentage remaining weir storage volume. The available storage capacity rating for the *existing weir* has been used to determine the corresponding weir pool storage level at which restrictions are to be implemented (consistent with current practice).

For the *proposed weir*, the weir pool storage levels that apply to each respective Restriction Level have been maintained the same as those for the *existing weir*. However, since the storage volume capacity for the *proposed weir* is greater than for the *existing weir* then the respective Restriction Levels are effectively set at lower percentage remaining storage volumes. Consequently, this generally increases the time duration between when the *proposed weir* crest ceases to spill, and the implementation of a given Restriction Level when compared to the *existing weir* under similar conditions.

The preliminary restriction provisions for the *proposed weir* that have been applied in the modelling are anticipated to be conservative from an impact assessment perspective given that demands would be maintained at higher levels for longer, which may result in assessment of lower weir pool storage levels and lesser flows downstream. The delayed implementation of demand restrictions could also be considered to provide enhanced benefits for water consumers.

Due to the apparent inherent conservatism of the developed preliminary restrictions, there may be some opportunity to improve drought storage levels and downstream flows in practice. Notwithstanding this, the approach is considered to provide some degree of flexibility in later refinement of demand management provisions for the *proposed weir*.

The targeted percentage demand reductions for each Restriction Level have been determined in consultation with CDSC and are based on the Orana Water Utilities Alliance (OWRU) regional system of water restrictions guidelines (Ref 4). CDSC is a member of OWRU along with ten (10) other member Councils, including for example Walgett, Brewarrina, Bourke, and Cobar.

Table 3-2 provides the Restriction Levels, corresponding weir pool storage water levels and volumes, and target annual average demand reductions that have been applied in the system modelling.

For example, Level 1 restrictions are applied for the *existing weir* once the crest ceases to spill at FSL 65.71 with the storage at 100% full. In comparison for the *proposed weir*, Level 1 restriction are not applied until the 1m raised drought storage falls from FSL 66.71 to RL 65.71 at which point the storage would be 46% full, while noting that the remaining volume would still match that for the *existing weir* at 100% full.

Table 3-2 Restriction levels and target demand reductions

Restriction Level	Weir pool Level (mAHD)	Existing Weir Accessible Storage Capacity	Proposed Weir Accessible Storage Capacity	Target Annual Average Consumption (L/person/d)	Target Demand Reduction (%)
Unrestricted (proposed)	66.71 (drought FSL)	---	100% (CTF)	280 (assumed)	0%
Unrestricted (existing)	> 65.71	Crest spilling	---	“	“
1 - Low	65.71 (normal FSL)	100% (CTF)	46%	260	7%
2 - Moderate	65.40	75%	35%	240	14%
3 - High	64.90	50%	23%	220	21%
4 - Very High	64.57	35%	16%	200	29%
5 - Extreme	64.33	25%	12%	160	43%
6 - Critical (bore supply)	63.65 (dead storage)	0%	0%	120	57%

Notes:
FSL denotes full supply level: The storage level that corresponds to 100% full storage volume capacity.
CTF denotes cease-to-flow level: The storage level at which flow over the weir crest just ceases to spill.
For the existing weir, FSL is 65.71mAHD.
For the proposed ‘dual mode’ weir, the FSL varies between ‘normal’ mode FSL 65.71 mAHD and ‘drought’ mode FSL 66.71 mAHD (1m raised FSL).
Storage levels and capacity details account for 2021 bathymetric survey data.

Section 3.5 provides details of the weir pool storages, volume capacity ratings and respective storage surface areas for both the *existing weir* and *proposed weir*.

3.5 Weirpool Storages

3.5.1 Overview

The weir pool storage size varies between the *existing weir* and *proposed weir* due to the following:

- addition of the proposed new portion of weir pool between the *existing weir* and the *proposed weir* to be located at Revised Site A2 about 4.92km downstream of the existing weir;
- proposed 1m raised weir FSL compared to the existing weir.

Details of the *proposed weir* and key differences compared to the *existing weir* are discussed above in Section 3.2.

Figure A-1 in Appendix A provides a longitudinal schematic profile of the proposed new weir pool including the location of riverbed bars that divide the weir pool into separate portions as the weir pool is drawn down and the interconnectivity of the weir pool portions becomes impacted.

3.5.2 Weir Pool Storage Portions and Interconnectivity

In the modelling, the weir pool storage volume and surface area data for both the *existing weir* and *proposed new weir* has been divided into storage portions that account for the potential effects of the identified riverbed bars (1, 2 and 3). The separate weir pool portions that are defined by the dividing bars are outlined as follows:

- End Pool (Pool 4): Pool upstream of Bar 3 RL 65.59 - length ~9.87 km at existing FSL 65.65, which becomes longer with any weir raising;
- Pool 3: Pool between Bar 3 and Bar 2 RL 65.52 - length~19.08 km;
- Pool 2: Pool between Bar 2 and Bar 1 RL 65.27 - length ~24.69 km;
- Pool 1: Pool between Bar 1 and existing weir (FSL 65.65) - length ~5.43 km;
- New additional (town) pool: Pool between existing and proposed weirs (raised FSL varies) - length ~5.25 km.

The storage volumes within Pool 4 and Pool 3 below the cease-to-flow levels of the respective downstream bars (Bar 3 and Bar 2) has been treated as isolated dead storage.

The dead storage level for Pool 2, Pool 1 and the New Town Pool has is RL 63.65 as determined by PWA based on information provided by CDSC.

The proposed decommissioning of the existing weir would effectively combine Pool 1 and the New Town Pool above the dead storage level.

The New Town Pool is only applicable to the proposed new weir since it is downstream of the existing weir.

For the current system behaviour modelling, the Wilcannia weir pool inflows are applied at the upstream end of Pool 4. At times of low weir pool levels upstream pools are required to first fill up to the level of the respective downstream bar before any flow volume can spill into the next downstream pool - noting that the model kept track of this.

Evaporation losses and any rainfall gains are applied to the respective water surface areas of each individual weir pool portion. Water is extracted from combined Pool 1 and New Town Pool, which in effect draws water from the upstream pools until the disconnects occur when water is below the respective riverbed bar crest levels. However, for Pool 2 it was assumed water could be transferred by pumping into Pool 1 (*and the model kept track of this*) when both the conditions were met of the Pool 2 storage level being below the downstream Bar 1 cease-to-flow level, and the Pool 1 storage level falling to RL 64.5 mAHD.

3.5.3 Available Data and Bathymetric Survey Cross-Section Locations

The estimation of respective weir pool storage volumes and surface area been based on:

- an available digital terrain model (DTM) acquired in 2014 of the Darling River (Baaka) at Wilcannia for the portion above the respective water levels captured in the DTM, and
- available river cross-sectional survey undertaken in 2020 and 2021 upstream of the proposed new weir for the portion below the respective water levels captured in the DTM.

The DTM was provided as a 1m resolution grid with the following expected accuracies:

- vertical accuracy: +/- 0.15m;
- horizontal accuracy: +/- 0.3m.

The cross-sectional survey data was provided by WaterNSW as follows:

- 2020 survey: New Town Pool, Pool 1, and Pool 2 with typical cross-section spacing of around 1 km
- 2021 survey: Pool 3 and End Pool (Pool 4) with typical cross-section spacing of around 2 to 2.5 km.

Figure 3-2 shows the indicative locations of the bathymetric survey cross-section within each individual weir pool component and the resulting Darling (Baarka) River bed profile.

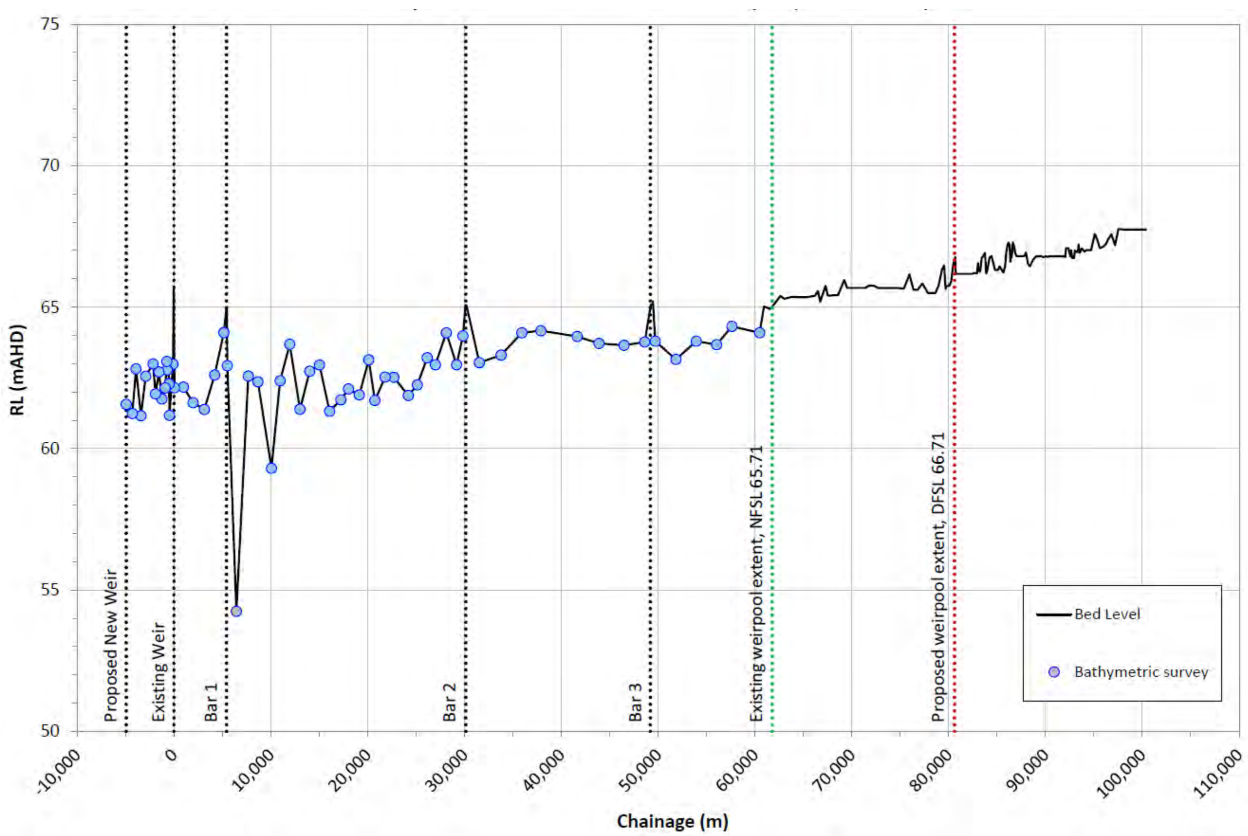


Figure 3-2 Plot of bathymetric survey cross-sections (2020 and 2021)

3.5.4 Modelled Storage Characteristics (Ratings)

The five (5) tables contained within this section provide the storage characteristics for each individual weir pool component and these were incorporated into the storage behaviour modelling.

Table 3-3 End Pool (Pool 4) Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km²	Pool Level RL (mAHD)
5,554.15	1.712919	69.65
4,720.21	1.622984	69.15
3,932.37	1.528183	68.65
3,191.59	1.435479	68.15
2,498.72	1.334859	67.65
1,858.72	1.222027	67.15
1,281.80	1.081011	66.65
786.6992	0.851291	66.15
451.6398	0.648508	65.71
416.4618	0.500016	65.65
387.5365	0.463549	65.59
355.9582	0.440575	65.52
268.7185	0.271245	65.27
245.2162	0.253509	65.18
235.2996	0.244805	65.14
202.561	0.242857	65.02
174.5558	0.233183	64.91
114.4663	0.207969	64.65
86.82327	0.167621	64.50
39.07792	0.096964	64.15
26.52839	0.075476	64.00
7.458318	0.023726	63.65
3.703184	0.017525	63.50
2.011495	0.012634	63.39
1.043993	0.008784	63.30
0.384918	0.005697	63.22
0	0	63.15
0	0	63
0	0	62.95
0	0	62.85
0	0	62.76

Source: PWA.

Table 3-4 Pool 3 Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km²	Pool Level RL (mAHD)
4142.45	0.978712	69.65
3662.38	0.941748	69.15
3200.94	0.903924	68.65

Storage Volume ML	Water Surface Area km^2	Pool Level RL (mAHD)
2758.67	0.865197	68.15
2336.13	0.824757	67.65
1934.48	0.78136	67.15
1555.54	0.733887	66.65
1201.72	0.680605	66.15
914.21	0.625216	65.71
876.97	0.616593	65.65
840.28	0.60735	65.59
798.19	0.596059	65.52
654.93	0.550147	65.27
606.49	0.528862	65.18
583.02	0.525869	65.14
514.02	0.516888	65.02
452.51	0.508656	64.91
316.59	0.489198	64.65
245.82	0.443293	64.50
118.85	0.276177	64.15
81.12	0.198303	64.00
34.51	0.075341	63.65
24.31	0.063901	63.50
17.31	0.057553	63.39
12.16	0.051057	63.30
7.11	0.044647	63.22
3.59	0.036392	63.15
0	0	63
0	0	62.95
0	0	62.85
0	0	62.76

Source: PWA.

Table 3-5 Pool 2 Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km^2	Pool Level RL (mAHD)
6826.36	1.343368	69.65
6167.99	1.291721	69.15
5534.28	1.243256	68.65
4924.70	1.195202	68.15
4339.08	1.147103	67.65
3777.82	1.09753	67.15
3241.71	1.046495	66.65
2731.28	0.996046	66.15

Storage Volume ML	Water Surface Area km²	Pool Level RL (mAHD)
2303.77	0.947323	65.71
2247.19	0.94003	65.65
2191.06	0.932561	65.59
2126.15	0.923664	65.52
1899.83	0.88935	65.27
1820.69	0.874402	65.18
1786.00	0.866699	65.14
1684.31	0.827104	65.02
1591.25	0.817841	64.91
1378.74	0.795948	64.65
1261.17	0.77136	64.50
1003.45	0.688218	64.15
902.37	0.638323	64.00
699.39	0.510199	63.65
623.72	0.461598	63.50
573.99	0.428109	63.39
535.67	0.401462	63.30
503.65	0.37678	63.22
476.92	0.357252	63.15
423.89	0.318505	63.00
407.43	0.304862	62.95
374.73	0.279611	62.85
348.30	0.256757	62.76

Source: PWA.

Table 3-6 Pool 1 Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km²	Pool Level RL (mAHD)
1746.23	0.403561	69.65
1553.00	0.370444	69.15
1375.09	0.341954	68.65
1210.10	0.318386	68.15
1056.11	0.297827	67.65
911.65	0.280738	67.15
775.28	0.265184	66.65
645.91	0.2526	66.15
537.50	0.240013	65.71
523.16	0.238047	65.65
508.95	0.236002	65.59
492.51	0.233532	65.52
435.31	0.22412	65.27

Storage Volume ML	Water Surface Area km^2	Pool Level RL (mAHD)
415.33	0.220549	65.18
406.55	0.218858	65.14
380.68	0.213143	65.02
357.69	0.205364	64.91
308.77	0.181287	64.65
282.11	0.175018	64.50
223.45	0.155986	64.15
199.85	0.148997	64.00
148.73	0.135459	63.65
128.71	0.127177	63.50
114.88	0.121012	63.39
104.36	0.11617	63.30
95.11	0.111869	63.22
87.34	0.108026	63.15
72.06	0.099025	63.00
67.15	0.095902	62.95
57.72	0.089075	62.85
50.13	0.081801	62.76

Source: PWA.

Table 3-7 New Town Pool Storage Volume - Surface Area

Storage Volume ML	Water Surface Area km^2	Pool Level RL (mAHD)
5,554.15	1.712919	69.65
4,720.21	1.622984	69.15
3,932.37	1.528183	68.65
3,191.59	1.435479	68.15
2,498.72	1.334859	67.65
1,858.72	1.222027	67.15
1,281.80	1.081011	66.65
786.6992	0.851291	66.15
451.6398	0.648508	65.71
416.4618	0.500016	65.65
387.5365	0.463549	65.59
355.9582	0.440575	65.52
268.7185	0.271245	65.27
245.2162	0.253509	65.18
235.2996	0.244805	65.14
202.561	0.242857	65.02
174.5558	0.233183	64.91
114.4663	0.207969	64.65

Storage Volume ML	Water Surface Area km^2	Pool Level RL (mAHD)
86.82327	0.167621	64.50
39.07792	0.096964	64.15
26.52839	0.075476	64.00
7.458318	0.023726	63.65
3.703184	0.017525	63.50
2.011495	0.012634	63.39
1.043993	0.008784	63.30
0.384918	0.005697	63.22
0	0	63.15
0	0	63
0	0	62.95
0	0	62.85
0	0	62.76

Source: PWA.

3.6 Environmental Flows

There were generally no requirements to make releases for any of the system behaviour modelling scenarios considered other than those contained within the *dual mode* operating rules, which are presented in Section 3.8.

Note that weir pool storage inflow translucency during *drought mode* operation is facilitated by the *dual mode* operating rules.

It is noted the adopted secure yield (Ref 1) was in effect controlled by a period of about 12 months of zero inflows thus any requirements for translucency of weir inflows would have little influence on the secure yield.

It is understood that there is no requirement to provide environmental flows from a town water supply licence perspective. The purpose of the weir is for town water supply purposes without any provision for river re-regulation.

3.7 Town Water Supply Operating Rules

Table 3-7 provides the main operating rules modelled in terms of meeting town water supply demand.

Table 3-8 Operating Rules – Town Water Supply Demand

System	Operating Rules
Wilcannia	Water pumped from river weir pool storage to supply. If Pool 1 became disconnected from Pool 2 then it was modelled that any isolated accessible storage water in Pool 2 would commence to be transferred by pumping from Pool 2 to Pool 1 once the Pool 1 storage water level dropped to RL 64.50 (FSL-1.21). Water that could be pumped was based on water accessibility and daily inflow with pumping based on the modelled daily time step.

3.8 Dual Mode Operating Rules

Existing Weir

- Dynamic Storage rules (applied on a consistent flow basis to the proposed new weir).

Proposed New Weir

- Low flow rules: NORMAL mode with flow < 60.4 ML/d
- Dynamic Storage rules: NORMAL mode with flow ≥ 60.4 ML/d
- Progressive Closure rules: DROUGHT mode INITIAL-FILLING phase
  - No Progressive Closure (immediate shut-off);
  - Trial 1 (slower shut-off);
  - Trial 2 (faster shut-off).
- Translucency rules: DROUGHT mode POST-FILLING phase (RL 66.71 (DFSL) > HWL > 65.54 (DFSL-1.17m))
- Flow resumption rules: NORMAL mode RESET-LOWERING phase (0.1m/d max lowering delay until inflow > 60.4 ML/d).

For the Progressive Closure rules, only the results for Trial 2 (faster shut-off) have been reported here since it has previously been proposed that these more aggressive shut-off rules for the DROUGHT mode INITIAL-FILLING phase should be carried forward for the purposes of the EIS. It is noted that the slower or longer it takes to fill the weir pool while flow is also being allowed to discharge downstream increases the risk that the weir pool drought storage will not be fully filled.

The report entitled, "Hydrology, Geomorphology, Groundwater, Surface Water and Flooding Impact Assessment" (Ref 5) provides discussion and details of the following headwater ratings used in the storage behaviour modelling:

- Dynamic Storage rule for the existing weir and proposed weir (see Figure 3-3);
- Inflow Translucency rule for the proposed weir (Figure 3-4).

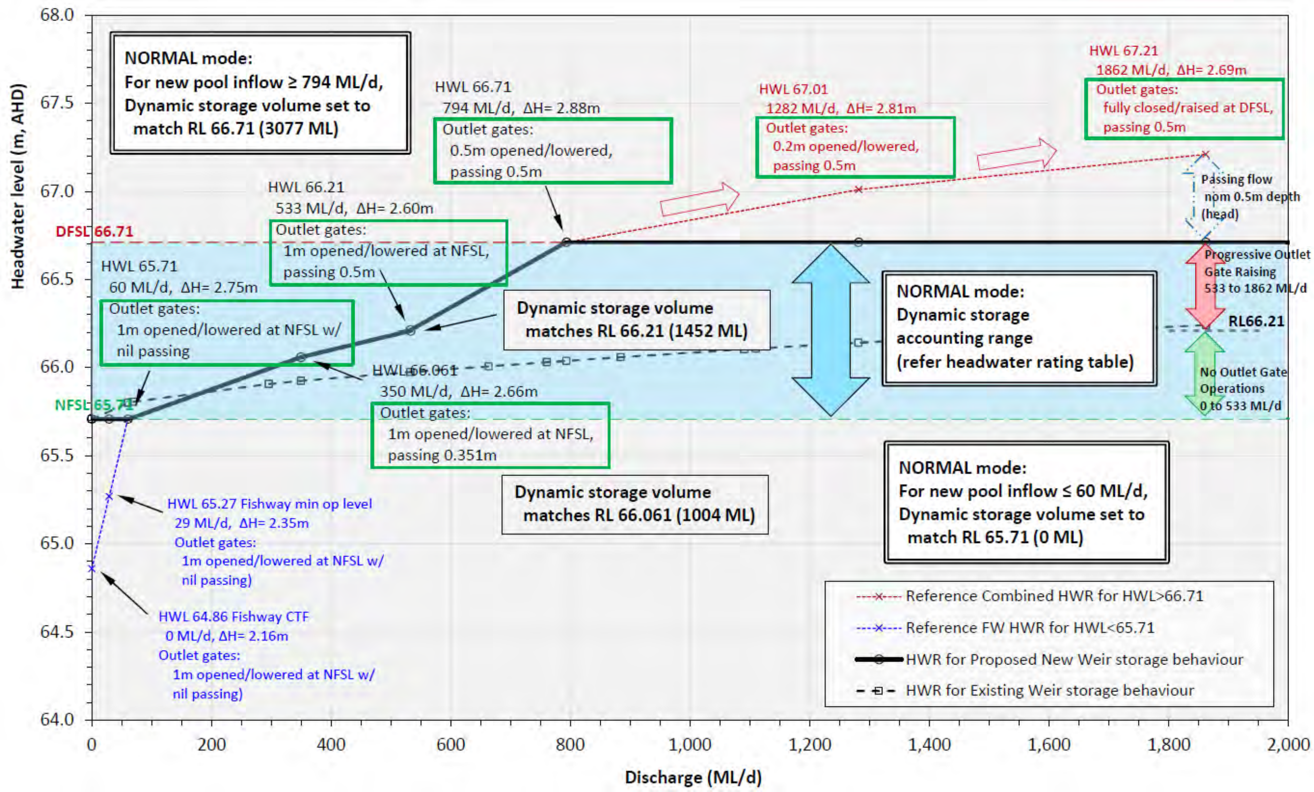


Figure 3-3 Headwater rating curve for dynamic storage modelling

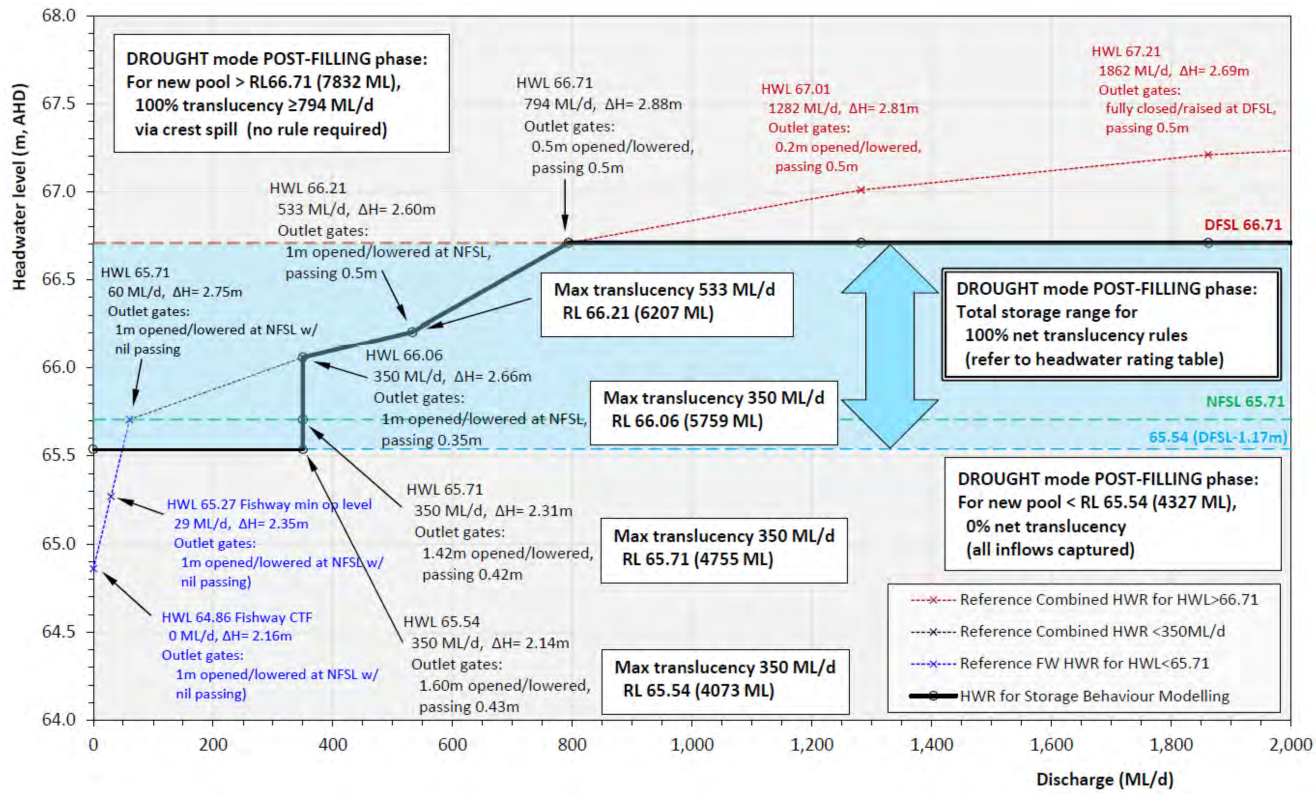


Figure 3-4 Proposed weir rating curve for Translucency Rule

4. Modelling Results

4.1 Introduction

The six (6) scenarios have been modelled as summarised in Table 4-1.

Table 4-1 Scenarios Modelled

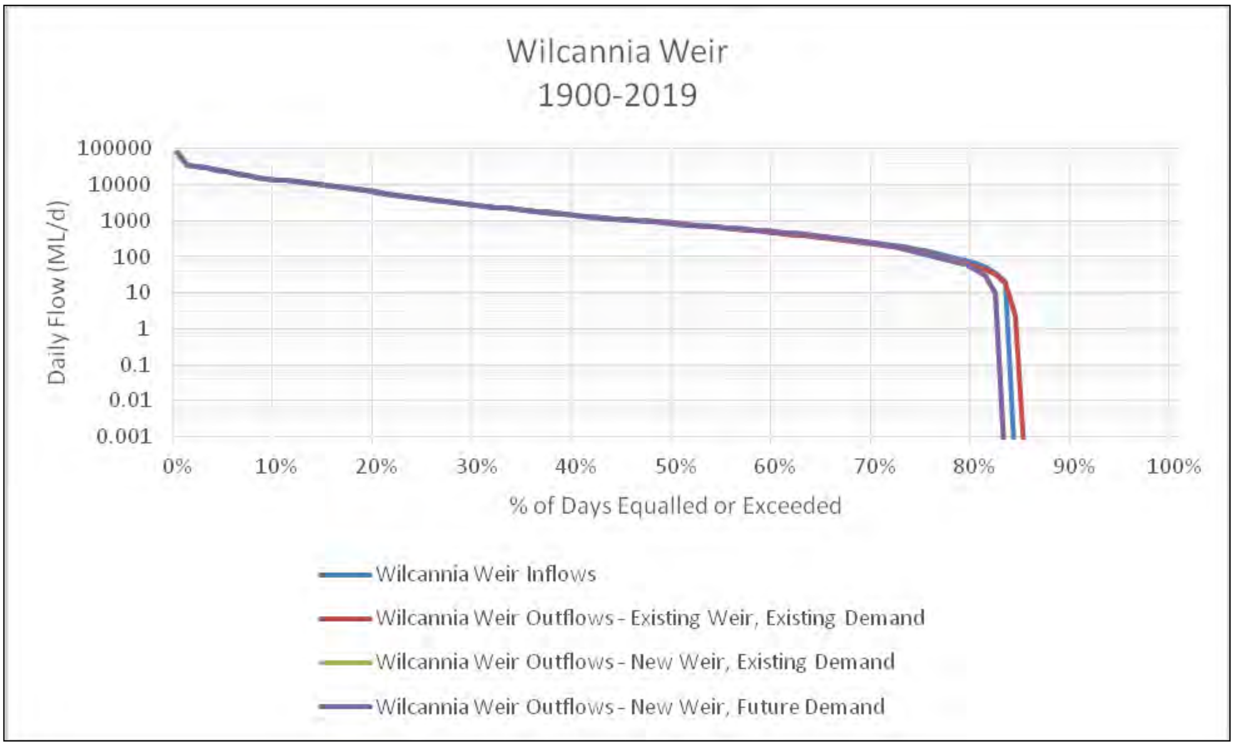
Run Nos.	Existing Weir	Proposed 1m Raised 'Dual Mode' Weir (trigger flows 250/300 ML/d past Bourke)	
River Flow Sequence	Existing Demands	Existing Demands	Future Demands
Simulated Flows	879-1	888r-1	887r-2
Low-Flow Adjusted Simulated Flows (sensitivity)	882	889r-1	890r-1

Existing Demand was 322 ML/a.
Future Demand (2050) was 362 ML/a .
Simulated Flows were provided by WaterNSW from their SOURCE modelling of the Barwon-Darling catchment for historic climate (1900-2019) based on July 2020 Water Sharing Plans.
Low-Flow Adjusted Flows were WaterNSW simulated flows with low flows adjusted.
The trigger to raise the weir was when Bourke weir outflow was 250 ML/d.
The trigger to start lowering the weir was when Bourke weir outflow was 300 ML/d.

The main output from the modelling was the flows just downstream of the weir. Figure 4-1 and Figure 4-2 compare on a flow duration curve basis the flows just downstream of the weir (i.e. outflows) with the inflows for the two cases of inflows (i.e. simulated and low flow adjusted) for the six scenarios for the modelled period 1900-2019.

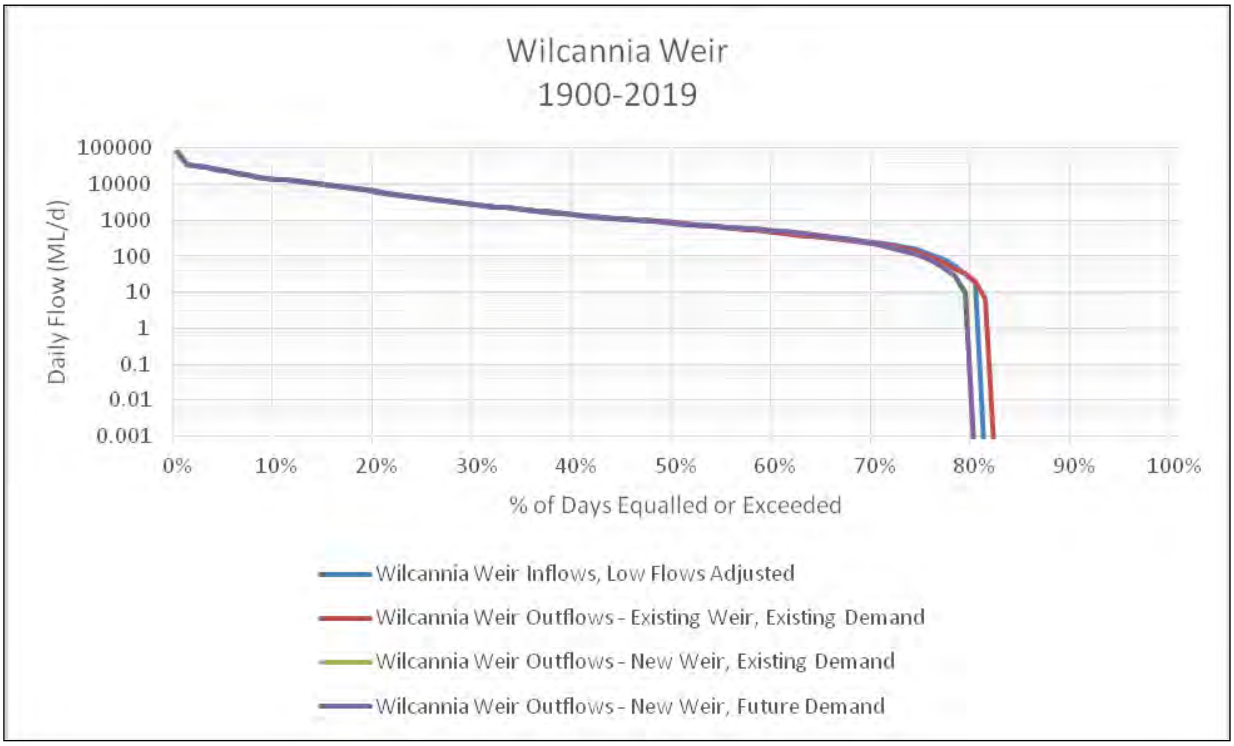
The apparent improvement in the outflow duration curve compared to the inflows on some days is a consequence of either:

- High rainfall on days where the storage is full/near full.
- Dynamic storage rule, water stored on a previous day ends up being released on a later day.
- Resumption rule, water is being released while the storage level is being lowered.



The Wilcannia Weir Outflows – New Weir, Existing Demand trace (Green) is hidden by the future demand trace (Purple)

Figure 4-1 Modelled Flow Duration Curve Comparison (Simulated Flow Case)



The Wilcannia Weir Outflows – New Weir, Existing Demand trace (Green) is hidden by the future demand trace (Purple)

Figure 4-2 Modelled Flow Duration Curve Comparison (Adjusted Low Flow Case)

4.2 Results

In terms of reconciling the modelling outcomes it is noted the evaporation loss from the weir pools was significantly greater than the water supply extraction as shown in Table 4-2.

Table 4-2 Evaporation Loss Comparison

<table>
<tr><th>River Flow Sequence</th><th>Weir</th><th>Average Daily Demand ML/d</th><th>Average Daily Evaporation Loss ML/d</th><th>Run No</th></tr>
<tr><td>Simulated Flows</td><td>Existing</td><td>0.882</td><td>9.562</td><td>879</td></tr>
<tr><td>Low Flow Adjusted Flows (Sensitivity)</td><td>Existing</td><td>0.882</td><td>12.135</td><td>882</td></tr>
<tr><td rowspan="2">Simulated Flows</td><td rowspan="4">Proposed New Weir All Operating Rules Triggers 250/300</td><td>0.882</td><td>12.132</td><td>888r</td></tr>
<tr><td>0.992</td><td>9.524</td><td>887r</td></tr>
<tr><td rowspan="2">Low Flow Adjusted Flows (Sensitivity)</td><td>0.882</td><td>12.138</td><td>889r</td></tr>
<tr><td>0.992</td><td>12.135</td><td>890r</td></tr>
</table>

Table B-1 and Table B-2 in Appendix B presents the final results summaries for the modelled scenarios and model runs.

These are the results that informed the EIS along with the output time series

5. Recommendations

The results presented in this report should be used keeping in mind the assumptions on which the estimates are based.

6. References

1. NSW Urban Water Services (2022), "Wilcannia Weir Replacement - Yield Study Report", Report No. 20014 Final 2.0, July 2022.
2. Jeffrey, S.J., Carter, J.O., Moudie, K.M., and Beswick, A.R. (2001), "Using Spatial Interpolation to construct a Comprehensive archive of Australian Climatic data", Environmental Modelling and Software, Vol 16/4 pp309-330,2001.
3. eWater: https://ewater.org.au/products/ewater-source.
4. Orana Water Utilities Alliance (2019), "Regional system of water restrictions - Guidelines for OWUA Councils", June 2019.
5. Jacobs (2022), "Wilcannia Weir Replacement - Hydrology, Geomorphology, Groundwater, Surface Water and Flooding Impact Assessment", Document No. IS350400-EIS-NW-REP-0001, July 2022.

Appendix A Longitudinal Weir Pool Profile

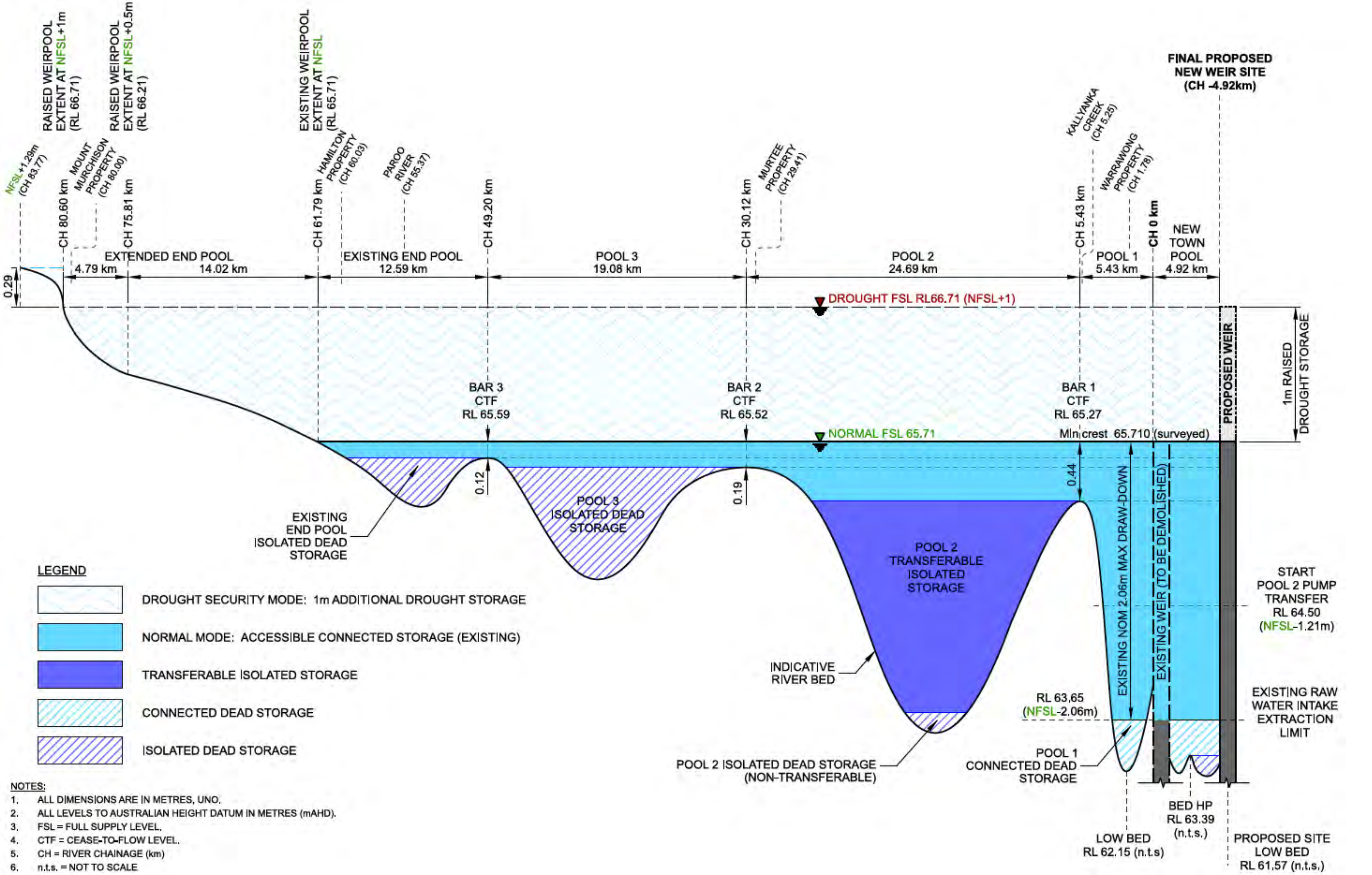


Figure A-1 Longitudinal schematic profile of the proposed new weir pool

Appendix B Results Summary

Table B-1 Final Results Summary - Simulated Flows

<table>
<tr><th>River Flow Time Series</th><th>Existing Weir</th><th colspan="2">Proposed 1m Raised New Weir
(Operating mode change
triggers 250/300 ML/d past Bourke)</th></tr>
<tr><th></th><th>Existing Demands</th><th>Existing Demands</th><th>Future Demands</th></tr>
<tr><td rowspan="2">Simulated Flows</td><td rowspan="2"><u>Run 879-1</u>
▪ NORMAL 100 %
▪ Mode cycles total 'nil'
▪ 50 %'ile in/out flow 856/841 ML/d
▪ 50 %'ile Pool 1 RL 65.86
(limited to dynamic max RL 66.24 at 1861.6 ML/d - matches NW flow at RL 67.21)

▪ Pool 2 min RL 64.04 (dead+0.39m)
▪ Pool 1 min RL 63.85 (dead+0.2m)
▪ Pump 2→1 max 1.04 ML/d
(13 instances (5 since Year 2000), total 622 days, avg 48 days)</td><td colspan="2"><u>Common for Runs 888r-1 & 887r-2</u>
▪ NORMAL/DROUGHT 70/30 %
71/29 % *
▪ Mode cycles total 265/195 *
▪ Mode cycles per year 2.22/1.63 *
▪ 50 %'ile in/out flow 856/820 ML/d
▪ 50 %'ile Pool 1 RL 66.69
(limited to dynamic max RL 66.71 (DFSL) at 793.6 ML/d w/ HWR up to RL 67.21 (DFSL+0.5) at 1861.6 ML/d)

DROUGHT mode durations:
▪ Max 367 | 367 days *
▪ 95 %'ile 157 | 174 days *
▪ 75 %'ile 62 | 80 days *
▪ 50 %'ile 31 | 48 days *
▪ 25 %'ile 14 | 28 days *
▪ Min 2 | 15 days *</td></tr>
<tr><td><u>Run 888r-1</u>
▪ Pool 2 min RL 65.08 (dead+1.43m)
▪ Pool 1 min RL 64.93 (dead+1.28m)
▪ Pump 2→1 max 0.0 ML/d
(nil instances)

<u>Effective operational -
events and durations</u>

FILLING RELIABILITY:
▪ fully filled 96.9 % (189/195)
▪ ¾ filled 97.9 % (191/195)
▪ ½ filled 99.5 % (194/195)
▪ ¼ filled 100 % (195/195)

FILLING (195 events):
▪ 100/95 %'ile 106/15 days
▪ 75 %'ile 8 days
▪ 50 %'ile 5 days

RESET-LOWERING (186 events):
▪ 100/95 %'ile 26/17 days
▪ 75 %'ile 13 days
▪ 50 %'ile 9 days

RESET-RESTORING (9 events):
▪ 100/95 %'ile 33/28 days
▪ 75 %'ile 21 days
▪ 50 %'ile 15 days</td><td><u>Run 887r-2</u>
▪ Pool 2 min RL 65.07 (dead+1.42m)
▪ Pool 1 min RL 64.90 (dead+1.25m)
▪ Pump 2→1 max 0.0 ML/d
(nil instances)

<u>Effective operational -
events and durations</u>

FILLING RELIABILITY:
▪ fully filled 96.9 % (189/195)
▪ ¾ filled 97.9 % (191/195)
▪ ½ filled 99.5 % (194/195)
▪ ¼ filled 99.5 % (194/195)

FILLING (195 events):
▪ 100/95 %'ile 106/15 days
▪ 75 %'ile 8 days
▪ 50 %'ile 5 days

RESET-LOWERING (186 events):
▪ 100/95 %'ile 26/17 days
▪ 75 %'ile 13 days
▪ 50 %'ile 9 days

RESET-RESTORING (9 events):
▪ 100/95 %'ile 33/28 days
▪ 75 %'ile 21 days
▪ 50 %'ile 15 days</td></tr>
</table>

<u>Table Notes:</u>

* denotes for 'mode cycles' and 'drought mode durations': *All triggers enacted* / *Effective triggers only enacted* (triggers for short-duration DROUGHT mode periods of ≤ 14 days ignored).

For the proposed *dual mode* weir, Pool 1 represents the water level in both Pool 1 and the New Pool combined since they are directly connected given proposed effective removal of the existing weir structure.

The start of pumped transfer from Pool 2 to Pool 1 to meet both TWS and weirpool stock and domestic demand (as appropriate) has been set at a Pool 1 trigger level of RL 64.50. Reference restriction levels:

- Level 4 Very high - RL 64.63 (accessible remaining 16% (new weir) | 35% existing weir))
- Level 5 Extreme - RL 64.40 (accessible remaining 12% (new weir) | 25% (existing weir)).

Table B-2 Final Results Summary - Low-Flow Adjusted Simulated Flows

River Flow Time Series	Existing Weir	Proposed 1m Raised New Weir (Operating mode change triggers 250/300 ML/d past Bourke)	
	Existing Demands	**Existing Demands**	**Future Demands**
Low-Flow Adjusted Simulated Flows (sensitivity)	**Run 882** ▪ NORMAL 100 % ▪ Mode cycles total 'nil' ▪ 50 %'ile in/out flow 856/840 ML/d ▪ 50 %'ile Pool 1 RL 65.86 (limited to dynamic max RL 66.24 at 1861.6 ML/d - matches NW flow at RL 67.21) ▪ Pool 2 min RL 64.03 (dead+0.38m) ▪ Pool 1 min RL 63.84 (dead+0.19m) ▪ Pump 2→1 max 1.13 ML/d (14 instances (5 since Year 2000), total 780 days, avg 56 days)	**Common for Runs 889r-1 & 890r-1** ▪ NORMAL/DROUGHT 70/30 % 71/29 % * ▪ Mode cycles total 265/195 * ▪ Mode cycles per year 2.22/1.63 * ▪ 50 %'ile in/out flow 856/822 ML/d ▪ 50 %'ile Pool 1 RL 66.69 (limited to dynamic max RL 66.71 (DFSL) at 793.6 ML/d w/ HWR up to RL 67.21 (DFSL+0.5) at 1861.6 ML/d) DROUGHT mode durations: ▪ Max 367 | 367 days * ▪ 95 %'ile 157 | 174 days * ▪ 75 %'ile 62 | 80 days * ▪ 50 %'ile 31 | 48 days * ▪ 25 %'ile 14 | 28 days * ▪ Min 2 | 15 days *	
		Run 889r-1 ▪ Pool 2 min RL 65.08 (dead+1.43m) ▪ Pool 1 min RL 64.93 (dead+1.28m) ▪ Pump 2→1 max 0.0 ML/d (nil instances) Effective operational events and durations FILLING RELIABILITY: ▪ fully filled 96.4 % (188/195) ▪ ¾ filled 97.9 % (191/195) ▪ ½ filled 99.0 % (193/195) ▪ ¼ filled 99.5 % (194/195) FILLING (195 events): ▪ 100/95 %'ile 106/15 days ▪ 75 %'ile 8 days ▪ 50 %'ile 4 days RESET-LOWERING (185 events): ▪ 100/95 %'ile 26/18 days ▪ 75 %'ile 13 days ▪ 50 %'ile 11 days RESET-RESTORING (10 events): ▪ 100/95 %'ile 33/28 days ▪ 75 %'ile 20 days ▪ 50 %'ile 15 days	**Run 890r-1** ▪ Pool 2 min RL 65.07 (dead+1.42m) ▪ Pool 1 min RL 64.90 (dead+1.25m) ▪ Pump 2→1 max 0.0 ML/d (nil instances) Effective operational - events and durations FILLING RELIABILITY: ▪ fully filled 95.9 % (187/195) ▪ ¾ filled 97.9 % (191/195) ▪ ½ filled 99.0 % (193/195) ▪ ¼ filled 99.0 % (193/195) FILLING (195 events): ▪ 100/95 %'ile 106/22 days ▪ 75 %'ile 8 days ▪ 50 %'ile 4 days RESET-LOWERING (185 events): ▪ 100/95 %'ile 26/18 days ▪ 75 %'ile 13 days ▪ 50 %'ile 11 days RESET-RESTORING (10 events): ▪ 100/95 %'ile 33/28 days ▪ 75 %'ile 20 days ▪ 50 %'ile 15 days

Table Notes:

Table B-2 notes are the same as for Table B-1 above.

Appendix C. Hydrodynamic modelling report

Appendix D. Groundwater risk assessment

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Stage 2 Report

Wilcannia Weir Upgrade - Groundwater Risk Assessment

for Water NSW
July 2021

J1764.2R-rev0

CMJA

C. M. Jewell & Associates Pty Ltd

Stage 2 Report –Wilcannia Weir Upgrade - Groundwater Risk Assessment

July 2021

J1764.2R-rev0

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CHRIS JEWELL

Principal

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APPENDICES

1.0 INTRODUCTION

1.1 Background

Wilcannia is a small town in western NSW with a population of about 550 people. It is located in the Central Darling Shire and is 261 kilometres (km) west of Cobar and 196 km east of Broken Hill on the Barrier Highway. Figure 1 shows the general setting of the town and surrounding area.

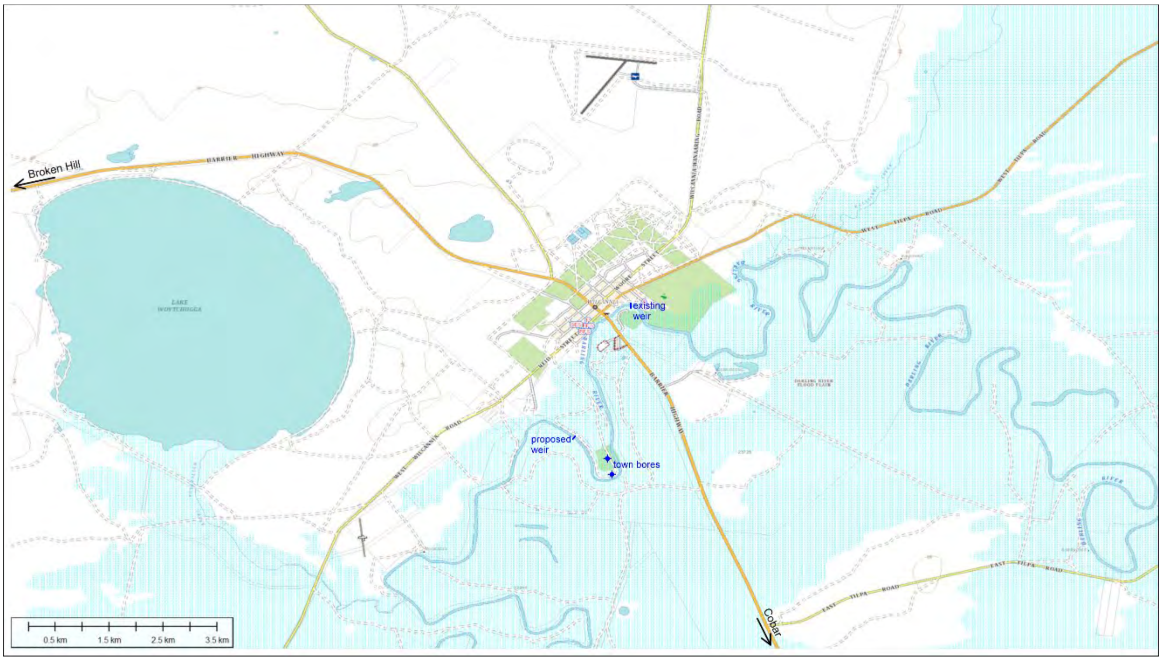


Figure 1: General Setting of Wilcannia

On Figure 1 the incised channel of the Darling River flowing from north-east to south-west and the extensive flood-plain on both banks can be clearly seen. The Barrier Highway crosses the river via a bridge south-east of the town. There is a weir on the Darling River approximately 370 metres (m) upstream from the Barrier Highway. The weir was originally constructed in 1942 and is the primary source of water supply for the town. The supply from the weir is augmented by an emergency groundwater supply from boreholes located south of the town that provide a limited amount of water for basic community needs.

The existing 3.5-m high weir has a fixed crest length of about 47 m and comprises a main line of steel sheet piling driven into the foundations, upstream and downstream rockfill and sub-surface remnant timber crib work. The weir is in poor condition, which has resulted in the inability to hold the weirpool at the design full supply (FSL) level during no-flow periods. A structural assessment carried out in 2019 found that the weir was at the end of its effective design life and needed to be replaced. There is a significant amount of erosion of the river channel and degradation of the weir structure, which has reduced the capacity of the weir to store water and poses significant risk to the long-term security of the town water supply.

Water NSW has proposed that the existing weir be decommissioned and removed, and a new weir and associated fishway be constructed. The proposed new weir will be constructed at a site located approximately 4.92 km downstream of the existing weir. The full supply crest level of the existing weir is at about Relative Level (RL) 65.71 metres above Australian Height Datum (mAHD) and that of the proposed new weir is at RL 66.71 mAHD, which represents a 1-m weir raising compared to the existing weir.

The new weir will retain a longer weirpool, which will include the river channel that extends around the two existing emergency water supply bores and a recently-drilled supplementary bore, which are located on a point bar on the north-western - true right - bank of the river and will thus have the weirpool on three sides. A water quality risk assessment carried out in 2012 to assess hazards related to the construction a new weir noted that there is an existing risk of high salinity water in the weirpool due to drought and prolonged periods of no or low flow in the Darling River.

There could thus be a risk of adverse impact on the quality of the emergency groundwater supply when required and used during a drought period.

In order to assess and, if necessary, mitigate this risk, a hydrogeological investigation was required to assess the risk of contamination of Wilcannia's emergency ground water supply due to poor river water quality during an extended drought period, following the relocation of the weir downstream. The results of the investigation will be used to inform the detailed design of the weir and assess the need to actively manage supply risk due to salinity in the weirpool.

Water NSW has engaged C. M. Jewell & Associates Pty Ltd (CMJA) to carry out the assessment of hydrogeological conditions in the area and quantify the water quality risk.

1.2 Assessment Objectives

The objective of this assessment is to assess the risk to the quality of water within the groundwater system utilised by the town that may be associated with the proposed weir replacement. In essence, this involves an assessment of the degree of hydraulic connection between the river and the town water supply bores and the likely rate of solute transport along any flow paths connecting the river with the bores.

1.3 Scope of Work

The scope of work completed involved:

- review of the available geological, hydrological and hydrogeological data;
- a site visit including inspection of all exiting bores, measurement of groundwater levels where possible and walking the river channel along the full length of the proposed weir pool;
- preliminary data analysis;
- preparation of a preliminary report;
- a follow-up site visit to carry out an electromagnetic (EM) survey of the river channel to identify areas where the leakance of the river-bed may be high;
- a pumping test on the newly-completed third town water supply bore (TWS3) to measure the hydraulic conductivity of the aquifer and assess the behaviour of the river as a recharge boundary;
- analysis of the geophysical and pumping test data;
- development of a numerical model of groundwater flow; and
- preparation of this final report.

It had originally been hoped to complete the geophysical survey before the arrival of flow in the Darling in February 2020. Unfortunately, the necessary equipment was not available until the first week in February; the work then had to be aborted due to heavy rainfall preventing site access, and the arrival of flood water in the river on 6 February.

1.4 Report Format

Section 2 of this report describes the geological and hydrogeological setting of Wilcannia and summarises the available data.

Section 3 sets out visual and geophysical observations made during the two site visits and Section 4 provides a review and analysis of that data.
Section 5 describes the pumping test undertaken on that site, and the analysis of the data acquired during that test

Section 6 develops and presents a conceptual hydrogeological model and Section 7 uses this model to develop a numerical model and assess the risks of adverse surface-water impacts on groundwater under conditions where the proposed weir pool contains poor-quality water and the town emergency water supply bores are in use.

Section 7 sets out the conclusions and recommendations of this assessment.

Appendix A provides relevant DPIE Water work summary reports for local groundwater bores; bore hydrographs are provided in Appendix B.

Appendix C contains the pumping test analysis reports, and Appendix D provides details of the numerical model.

This report is designed and formatted for on-screen viewing using an Acrobat reader. The figures are high-resolution and best viewed under zoom. If a printed copy is desired, then figures should be printed separately in landscape format. Note that all maps have north to the top.

1.5 Limitations and Intellectual Property Matters

This report has been prepared by CMJA for the use of the client identified in Section 1.1, for the specific purpose described in that section. The project objectives and scope of work outlined in Sections 1.2 and 1.3 were developed for that purpose, taking into consideration any client requirements set out in the proposal referenced in Section 1.1.

The work has been carried out, and this report prepared, utilising the standards of skill and care normally expected of professional scientists practising in the fields of hydrogeology and contaminated land management in Australia. The level of confidence of the conclusions reached is governed, as in all such work, by the scope of the investigation carried out and by the availability and quality of existing data. Where limitations or uncertainties in conclusions are known, they are identified in this report. However, no liability can be accepted for failure to identify conditions or issues which arise in the future and which could not reasonably have been assessed or predicted using the adopted scope of investigation and the data derived from that investigation.

Where data collected by others have been used to support the conclusions of this report, those data have been subjected to reasonable scrutiny but have essentially, and necessarily, been used in good faith. Liability cannot be accepted for errors in data collected by others.

This report, the original data contained in the report, and its findings and conclusions remain the intellectual property of CMJA. A licence to use the report for the specific purpose identified in Section 1.1 is granted to the persons identified in that section on the condition of receipt of full payment for the services involved in the preparation of the report.

This report should not be used by other persons or for other purposes than those identified in Section 1.1 and should not be reproduced except in full and with the permission of CMJA.

2.0 GEOLOGICAL AND HYDROGEOLOGICAL SETTING OF WILCANNIA

2.1 Description of the Site and Neighbouring Land

The site of the proposed replacement weir lies within the channel of the Darling River, as shown on Figure 2.

Figure 2: Location of Existing and Proposed Weirs

2.2 Surrounding Area

Beyond the site, apart from the urban area of Wilcannia, the surrounding land is predominantly rural, under pastoral use.

2.3 Topography

Wilcannia is located on the Darling River. The elevation of the town is about 81 mAHD and the crest of the existing weir at 65.71 mAHD. North of Wilcannia the land surface rises to about 92 mAHD but apart from the incised river channel the floodplain generally is very flat, typically between 74 and 77 mAHD with a very shallow gradient to the south-west. A detailed representation of the form of the land surface is available from the NSW 1m LiDAR. This is shown in Figure 25, later in this report. This information, and much of the other geospatial information referenced in this section, was compiled into a project GIS database.

2.4 Hydrometeorology

The mean annual rainfall at Wilcannia is 265 millimetres (mm). The 10-percentile is 136 mm and the 90-percentile 414 mm. Rainfall is infrequent, but events are reasonably evenly distributed through the year, with the late winter and early spring (July to September being driest. Monthly evaporation exceeds rainfall throughout the year, with the largest deficit occurring in summer.

2.5 Surface Hydrology

The Darling River at Wilcannia has an upstream catchment area of 569,000 and a mean daily flow of 6,314 megalitres (ML) over the period 1913-2016 (NSW DPIE 2019). The hydraulic gradient in this reach of river is very low, averaging 0.01 metre per kilometre (m/km).

The mean annual flow at Wilcannia is 2,305 gigalitres (GL), but the inter-annual variability is extreme, as shown on Figure 3.

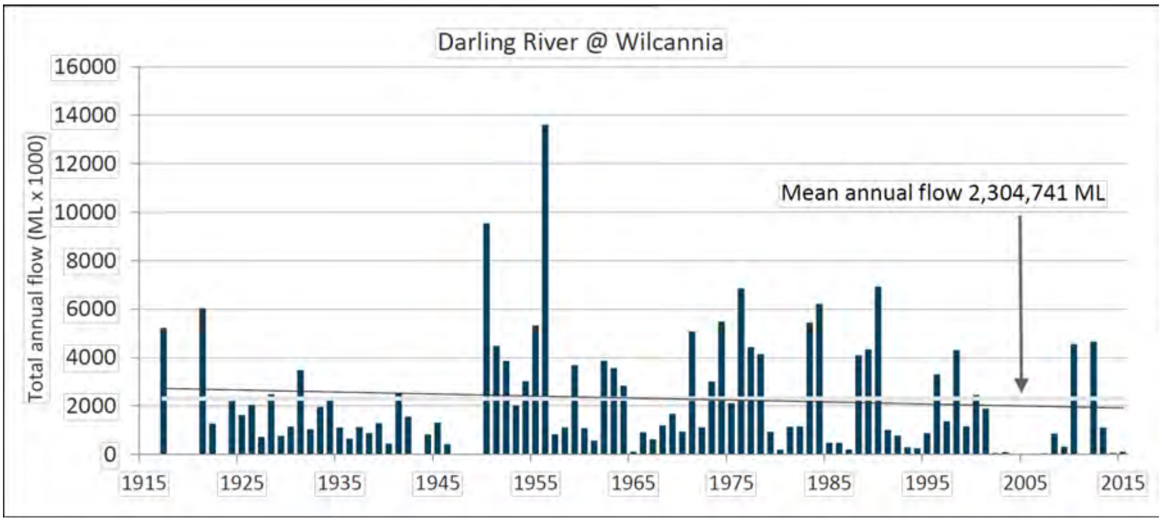


Figure 3: Inter-annual Flow Variability at Wilcannia (DPIE 2019a)

This is reflected in the daily flow variability and the large inter-quintile range, as shown on Figure 4. The median daily flow is significantly lower than the mean daily flow.

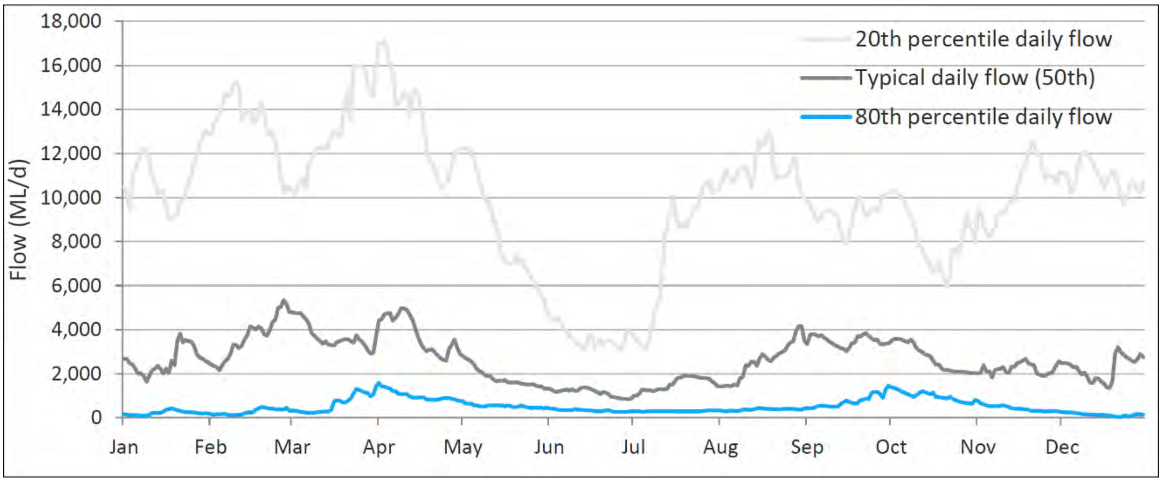


Figure 4: Median, First and Fourth Quintile Daily Flows at Wilcannia (DPIE 2019a)

Figure 5 shows a low-flow frequency analysis. It can be seen from the flow-duration curves that the river would be expected to cease to flow for more than a month approximately once in four years, and for more than three months once in about 20 years. However, these curves are based on historical statistics and do not allow for the effects of a drying climate and abstraction for irrigation upstream.

From the perspective of this assessment, these statistics give an indication of the frequency and duration of events in which poor quality water could be available for groundwater recharge.

A number of rating curves have been used over the period of record and these diverge significantly at low flows. However, for the purpose of this report it has been assessed from examination of the stage-discharge graph that a flow of 100 megalitres per day (ML/d) is approximately equivalent to a river stage of 64 mAHD and a flow of 1,000 ML/d to a stage of 64.5 mAHD. Recurrence intervals for these events for one and three month durations are 3.3 years and 10 years, and 3 years and 7 years respectively.

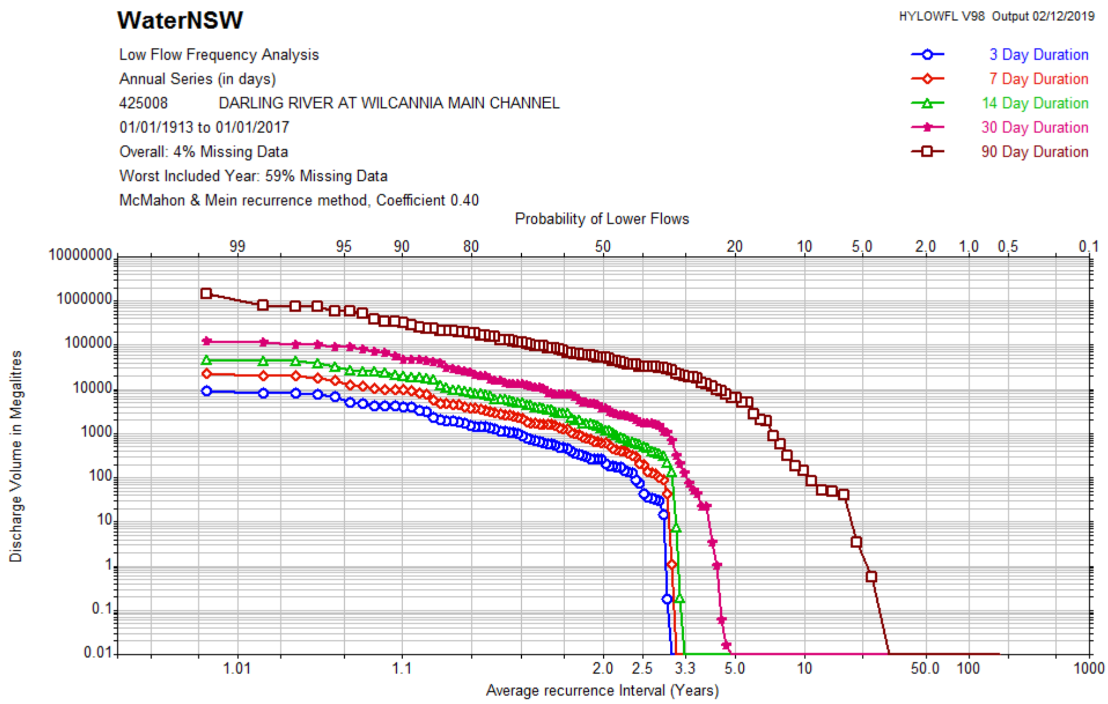


Figure 5: Low-Flow Frequency Analysis – Darling at Wilcannia

2.6 Geology

The alluvial plains and channels south-east of Wilcannia, both upstream and downstream, are underlain by a sequence of interbedded channel and overbank deposits laid down by the meandering Darling River. These deposits, generally known as the Upper Darling Alluvium (DPIE 2019) are of Quaternary age and up to 100 m thick. Beneath the Quaternary sediments are sandstones and quartzites of the Devonian-age Mulga Downs Group.

The current river channel is incised into the Quaternary Sediments, with a depth of typically 10 to 11 m below the top of the banks. Between Bourke and Wilcannia, and for some distance downstream from Wilcannia, the channel is marked by numerous tight bends and meanders, such the length of the channel is over twice the straight-line distance between these locations. However, overall, the river and the Upper Darling Alluvium follow an almost straight course to the south-west along the Darling River Lineament – a dominant feature that is obvious on satellite imagery at any scale. The lineament is a Late-Proterozoic age structure – a zone of faults and fractures – marking the Tasman Line. The structure was reactivated several times during the Phanerozoic, to at least as late as the Miocene (O'Sullivan et al 1998) and is the primary geological control on the course of the Darling River.

The shallower alluvial deposits beneath the banks of the river are predominantly silts, clayey silts and silty clays. Clayey silts and silty clays with some fine sands are present at shallow depth beneath the channels.

The southern part of the point bar within Union Bend, where the town emergency water supply bores are located, is underlain by an alluvial sequence predominantly composed of fine-textured deposits ranging from sandy silts to silty clays. Within this sequence are buried sandbars, typically fine-grained but sometimes medium and coarse grained. These sandbars are probably quite narrow and discontinuous but can sometimes be sufficiently continuous and extensive to form good aquifers.

Water bores in the area around Wilcannia are shown on Figure 6 and those for which useful information is available are listed in Table 1; work summary reports for these bores are attached in Appendix A. The deeper bores (GW40891, GW040892, GW040893, GW040897, GW804531) typically encountered the top of a thick clay horizon at between about 20 and 30 m depth, extending to about 45 m depth, with interbedded sands and clays below that depth to bore termination at about 67 m. However, GW040872, located close to the east Menindee Road turnoff from the barrier highway south of Wilcannia penetrated a shallower clay horizon, between 2 and 20 m, then predominantly sands to a depth of 92 m, terminating in sandstone.

GW040897 and GW804531 are the town emergency water supply bores. GW040897 encountered a fine sand unit between 48 and 55 m depth and GW804531 is screened in sand between 48 and 53 m. Most of the unsuccessful test bores, including the bore converted to a monitoring bore, encountered sand at about this depth, but the unit was thinner and the sand finer in those bores.

The set of three monitoring bores (GW040874 pipes 1 to 3) at the end of the bar close to GW804531 encountered such sand units over the intervals 14.5 to 20.5 m, 21 to 23 m, 42 to 48 m, and 51 to 57 m.

The two geotechnical investigation bores drilled at the site of the new weir encountered clayey silts and silty clays to between 3 and 9 m depth, overlying a thick sequence of fine to coarse sands, with silt.

Figure 6: Registered Bores near Wilcannia

(N.B. Coordinates as shown on the Water NSW All Groundwater map: some are incorrect. Monitoring bores shown in red, other bores in blue)

Figure 7 shows an extract from the 1:100,000 scale geological map (Frienda et al 1965) and Figure 8 shows a simplified map that emphasises the recent floodplain sediments (Qacm – shown in yellow). These maps are substantially based of air-photo interpretation and are of limited value from a hydrogeological perspective.

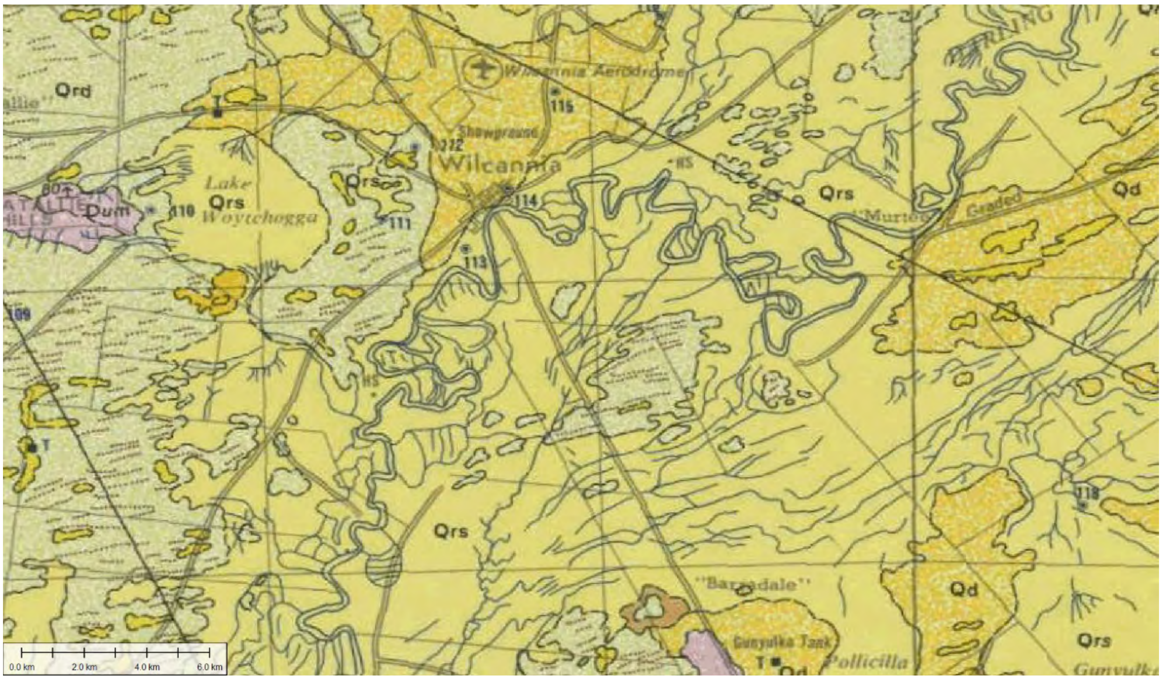


Figure 7: Extract from 1:250,000 Geological Map

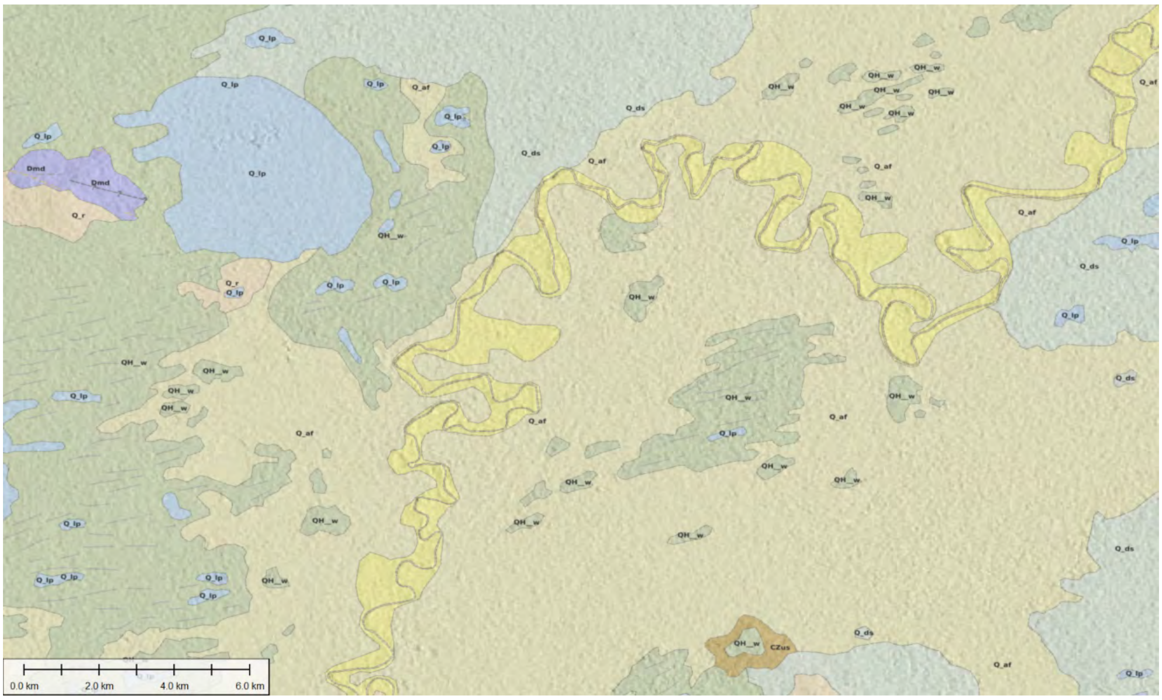


Figure 8: Simplified Geological Map

2.7 Hydrogeology

For practical purposes, the only aquifers of interest to this project are within the Quaternary alluvial sediments; the top of the Devonian sedimentary rocks can be considered to be hydrogeological basement.

As indicated in Section 2.6 above, the alluvial sediments are comprised of interbedded clays, silts and sands, together with materials with a range of intermediate textures including clayey silts, silty sands and clayey sands. The coarser units, predominantly fine to medium-grained sands, function as aquifers.

Depending on the thickness and permeability of the overlying sand and silt aquitards, the sand aquifers may be unconfined to semi-confined.

Water levels measured in monitoring bores located on the flood plain above the channel banks are typically 9 to 11 m below ground level, generally similar to the channel base and low-flow river levels.

Aquifer water levels fluctuate in response to changes in river discharge and stage. The range of fluctuation decreases with distance from the river, and with depth.

Where water levels have been measured in multiple pipes screened in multiple aquifers at different levels (GW040872, GW040873 and GW049874 and GW040892), as is shown on the hydrographs included in Appendix B, the water level is deepest in the deepest aquifer during periods of high to moderate river flow, but the difference disappears or reverses under low flow conditions. This is indicative of recharge being derived from the river under high flows with potential groundwater discharge to the channel under low flow conditions.

In the specific case of GW040892, the monitoring bore north of the town borefield, the range in the shallow (14 to 17 m) screened interval is about 3.2 m, in the 28 to 31 m screened interval, it is 2.2 m and in the deepest (48 to 54 m) screened interval it is 1.3 m.

In GW040874, at the southern end of the borefield, the corresponding ranges are 2.5 m (17-23 m), 1.5 m (42-48 m) and 1.5 m (54-57 m). These ranges exclude the overbank flood event in 2012 when the site was submerged. It should also be noted that groundwater levels in the deepest pipe (Pipe 3) are significantly influenced by pumping in TWS1, which is nearby (45 m north-east).

It is thus apparent that at least a pressure effect, and possibly fluid transfer, is transmitted to the aquifer utilised by the town bores. This implies that the observed clayey horizons may be laterally discontinuous, or else of relatively high permeability.

This is also reflected in the salinity of groundwater in the three aquifers recent (September 2020 measurements in GW040892 indicated an electrical conductivity of 1,169 deci-Siemens per metre (dS/m - equal to micro-Siemens per centimetre) in the shallow aquifer, 539 dS/m in the middle aquifer and 399 dS/m in the deepest aquifer.

Prior to this investigation, there were no data available concerning the hydraulic conductivity or storativity of any of these aquifers, which made prediction of aquifer behaviour difficult. That situation has now been remedied.

The Darling River at this location is provisionally categorised as a predominantly connected, losing stream that may be locally gaining under low flow conditions.

2.8 Local Water Supply and Monitoring Bores

There are two currently operational town water supply bores and one new and unequipped town bore in Wilcannia. These bores are located on a point bar within a river meander (Union Bend) south of Wilcannia, as shown on Figure 9. When the new weir is completed the weir pool will extend around this meander.

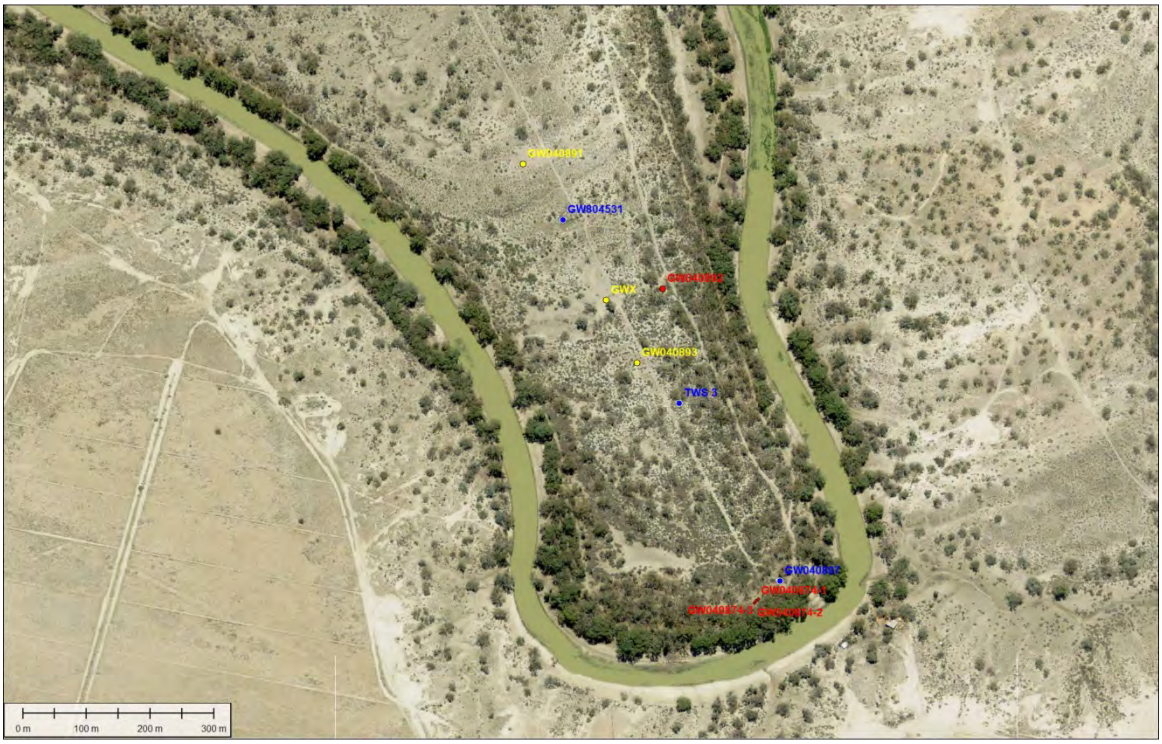


Figure 9: Town Water Supply and Monitoring Bores (Measured Coordinates)

Figure 10: Wilcannia Town Water Supply Bore 1 (TWS 1 - GW040897)

GW040897 (TWS 1) is housed in a partially-buried concrete chamber for flood protection. GW804531 (TWS 2) and TWS 3 are completed in concrete slabs, with pump controls located in housings on elevated platforms. All bores are fitted with submersible pumps.

Table 1 provides a summary of local bore construction and usage details.

Figure 11: Wilcannia Town Water Supply Bore 2 (TWS 2 - GW804531)

At the time of the initial assessment, TWS 2 was not operational. TWS 3 had recently been completed and was awaiting pump installation. TWS 1 had been pumping at an average discharge of 6 litres per second (L/s) for approximately six months. At the time of the pumping test in September, the permanent pump has been installed in TWS 3, but it was not yet in service. TWS 2 was still not operational and TWS 1 was still supplying the town's water needs.

Figure 12: Wilcannia Town Water Supply Bore 3 (TWS 3)

TABLE 1
Summary of Wilcannia Bore Construction and Use

Works No.	Easting (MGA 55)	Northing (MGA 55)	Elevation (mAHD)	Depth (m)	SWL (m)	RWL (mAHD)	PWL (m)	WBZ (m)	Top Screen (m)	Base Screen (m)	Top Screen (mAHD)	Base Screen (mAHD)	Aquifer	Yield (L/s)	Use
GW010163	723828	6504612	78.80	15.20	9.80	69.00									Unknown
GW019002	726136	6506411	80.96	35.10	12.2	68.76			33.5	35.0	47.46	45.96	Sandstone	0.9	Domestic
GW036839	736671	6503290	79.71	132.00	14.7 15.7 15.7	65.01 64.01 64.01			37 58 99	43 64 105	42.71 21.71 -19.29	36.71 15.71 -25.29	Coarse sand		Monitoring
GW039479	727292	6505010	75.43	26.75	9.16	66.27	13.55		22.75	24.75	52.68	50.68	Coarse sand	2.14	Monitoring
GW040872	728885	6498505	78.01	92.00	10.38 10.59 10.62	67.63 67.42 67.39			21 57 88	27 60 92	57.01 21.01 -9.99	51.01 18.01 -13.99	Fine sand	3.84	Monitoring
GW040873	725532	6500145	76.14	106.00	10.38 10.08 11.07	65.76 66.06 65.07			24 34 94	27 40 100	52.14 42.14 -17.86	49.14 36.14 -23.86	Sand Sand gravel	3.10 2.91 3.40	Monitoring
GW040874	725858	6503003	70.93	60.00	9.60 8.10 9.20	61.33 62.83 61.73			17 48 54	23 48 60	53.93 22.93 16.93	47.93 22.93 10.93	Med-coarse sand	0.91 2.85 3.27	Monitoring
GW040891	725911	6503535	72.78	54.00				18.3-20.4	46	26.78	20.78		Fine sand		Monitoring
GW040892	725743	6503497	75.32	67.00	10.35 10.26 10.28	64.97 65.06 65.04			14 28 48	17 31 54	61.32 47.32 27.32	58.32 44.32 21.32	Fine sand	0.84 1.10 1.30	Monitoring
GW040893	725911	6503535	72.78	45.00				18.3-20.4					Fine sand		Monitoring
GW040897 (TWS 1)	725895	6503029	74.2	57.00	9.10	63.68		47.6-55.2	49	55			Fine sand		Public
GW042427	717748	6503905	72.25	9.60	9.48	62.77		5-13					Sand		Monitoring
GW042428	721955	6502552	75.06	14.70	10.79	64.27		11-13					Sand		Monitoring

TABLE 1
Summary of Wilcannia Bore Construction and Use

Works No.	Easting (MGA 55)	Northing (MGA 55)	Elevation (mAHD)	Depth (m)	SWL (m)	RWL (mAHD)	PWL (m)	WBZ (m)	Top Screen (m)	Base Screen (m)	Top Screen (mAHD)	Base Screen (mAHD)	Aquifer	Yield (L/s)	Use
GW042429	724364	6502983	74.52	11.72	10.42	64.10		7.5-12.5					Fine sand		Monitoring
GW042430	727249	6502664	74.39	0.00	9.99	64.40		12-15					Sand		Monitoring
GW042431	728275	6500204	74.54	0.00	9.82	64.72		7-13					Fine sand		Monitoring
GW042432	728936	6498646	74.03	21.10	11.00	63.03		None					None		Monitoring
GW042433	729720	6496887	73.43	13.90	9.80	63.63		13-14.5					Fine sand		Monitoring
GW042434	730491	6494950	72.48	11.40		72.48		13-14.5					Coarse sand		Monitoring
GW803951	729213	6507025	77.04	24.00	10.60	66.44	13.0	13-21	15	21	62.04	56.04	Coarse sand	1.00	Stock
GW804531 (TWS 2)	725806	6503287	73.06	54.00	14.0	59.06		48-53	48	54	25.06	19.06	Sand	10.0	Public
TWS 3	725766	650330	73.2		10.78	62.4								7.5	Public

3.0 SITE OBSERVATIONS

The entire bed of the dry channel of the Darling River from the Barrier Highway to the site of the proposed new weir was walked in February 2020.

This inspection was carried out on 6 and 7 February 2020, near the end of an extended dry period.

Figure 13: Channel on Eastern Side of Union Bend

The objectives of this inspection were to assess the feasibility of an electromagnetic (EM) survey along the channel, to assess the extent of remnant water ponding and the reason for retention, and to observe bank condition and bed lithology with regard to infiltration potential. Observations were mapped onto an aerial photograph taken during a previous cease-flow-event.

The remnant pools were much smaller than shown on the previous dry-period photography and were assessed to be water-table-connected. Floor material observed in the pools and the dry channel bed was predominantly and quite uniformly cream-brown clayey silt and silty clay with some sand. There were occasional patches of grey clay in depressions in the channel floor. No sand deposits were observed. Bank slopes were typically 45° and bank materials were predominantly silt. The pool location was assessed to be due primarily to variations in bed topography (i.e. the pools were located in low points in the channel) rather than to variations in bed lithology.

At the time there was adequate access for an EM survey along almost the entire channel.

Town Borefield Standing Water Level Measurements made on 6 February 2020, at the end of a long dry period with low river level and no flow. Data are shown in Table 2.

TABLE 2
Groundwater Levels – February 2020

Bore	SWL (m bgl)	Surface Elevation (mAHD	RWL (m AHD)
GW040891	10.21	73.2	63.0
GWX	9.24	72.4	63.2
GW040893	10.52	73.2	62.7
TWS3	10.55	73.2	62.7

Note that surface elevations were derived from the NSW 1 m LiDAR mapping.

Figure 14: Site Observations

Corresponding measurements were made on 7 September 2020, with higher river levels, as shown in Table 3.

TABLE 3 Groundwater Levels – September 2020			
Bore	**SWL (m bgl)**	**Surface Elevation (mAHD**	**RWL (m AHD)**
GW040891	10.21	73.2	63.3
GWX	9.24	72.4	63.4
GW040893	10.52	73.2	63.1
TWS3	10.55	73.2	63.2

Groundwater levels were also marginally higher.

4.0 ELECTROMAGNETIC SURVEY

In September 2020 the planned electromagnetic (EM) survey of the river channel was completed. The objective of this survey was to detect any anomalies that might indicate the presence of sand lenses that could prove high-permeability windows permitting high rates of infiltration from the channel to the upper aquifer. In an EM survey, these would show as areas of low apparent ground conductivity.

EM methods are used to map variations in electrical properties. The main physical property involved in these methods is inductive electrical conductivity, which is a measure of how easily electrical current can pass through a material. Conductivity is a complex function of several variables including the conductivity of solid materials, conductivity of pore fluids, porosity, arrangement of pores and degree of saturation (Lane 2002). It is usually measured in units of milli-Siemens per metre (mS/m). Table 4 shows typical conductivities for various saturated geological materials.

TABLE 4
Conductivity (σ) of various materials and water (various sources)

Material	σ [mS/m]
Sand and gravel	0.4–10
Clay	10–1,000
Loam	20–200
Marls	14–300
Sandstone	2–20
Soil	1.25–100
Natural water	10–1,000

The instrument used to carry out the survey was a GSSI Profiler EMP-400, which is a multi-frequency electromagnetic ground conductivity meter, operating in the frequency domain. It has transmitter and receiver loops mounted on a single hand-portable "paddle", operating as vertical dipoles. A time- varying current passing through the transmitter loop is used to create a time varying magnetic field and a voltage is induced in the receiver coils proportional to the time rate of change of the magnetic field induced in the ground.

The depth of penetration of the instrument, generally expressed as "skin depth", being the depth at which the signal is reduced to 1/e (37%) of the original amplitude is not a constant but varies with the conductivity of the ground and the signal frequency. The Wilcannia survey was carried out at three frequencies, 1 kHz, 6kHz and 15 KHz, giving approximate skin depths in the range 10 to 20 m in the 6 kHz band, for the lithologies anticipated.

Figure 15 shows the orientation of the EM traverse around Union Bend and Figure 17 provides a plot of apparent conductivity along the channel. Unfortunately, the floor of the channel was submerged at the time of the survey, and it was necessary to carry out the traverse at the base of the steep bank on the northern side of the channel. Terrain ranged from almost flat to 50^{o}, slopes steeper than that could not be safely traversed, and there a consequently some gaps, with gaps also present where obstructions such as fallen trees had to be negotiated.

Figure 16 shows the river level at the time of the survey; this can be compared with Figure 13, taken when the channel was dry. The level was 1.196 m.

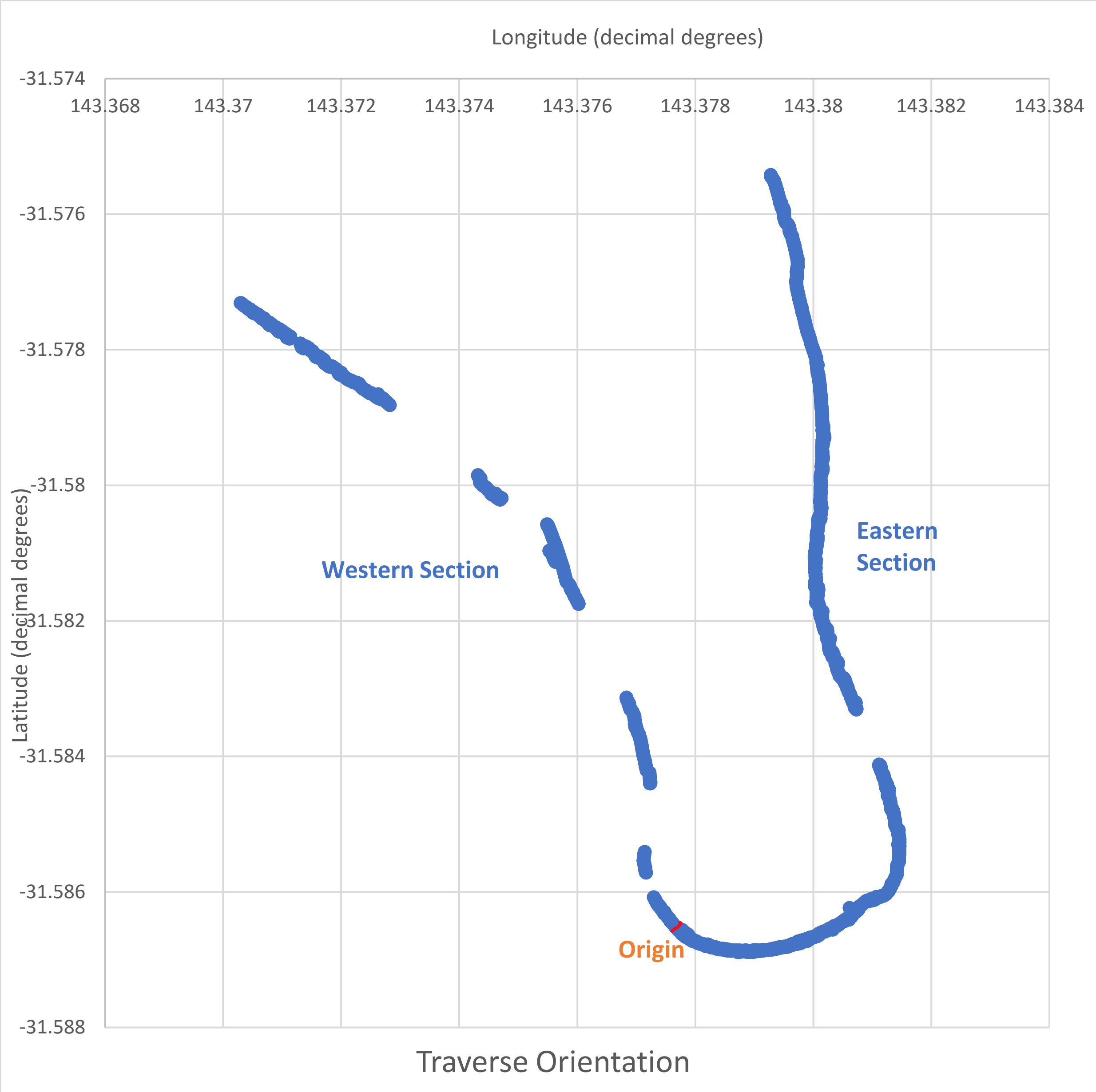
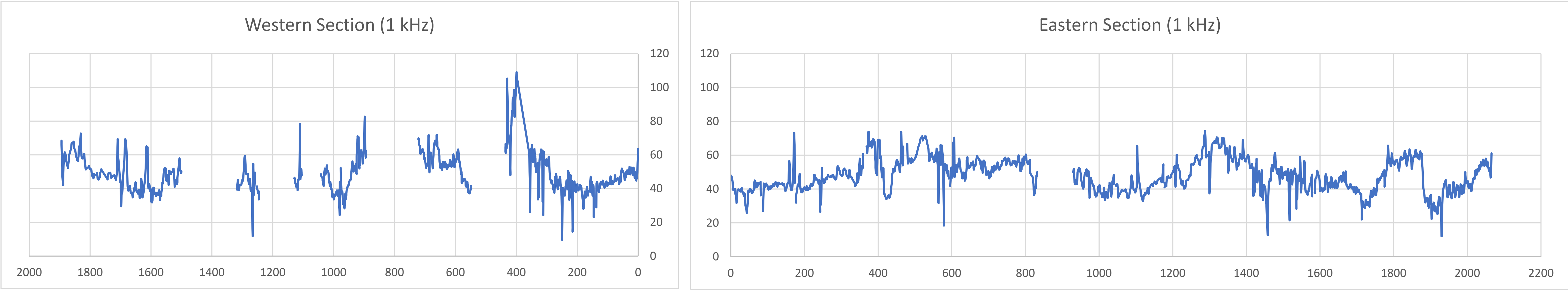


Figure 15: Location of EM Traverse around Union Bend

Figure 16: Water Level at Survey



Note – vertical axis scale Conductivity (mS/m), horizontal axis scale distance from origin (metres).

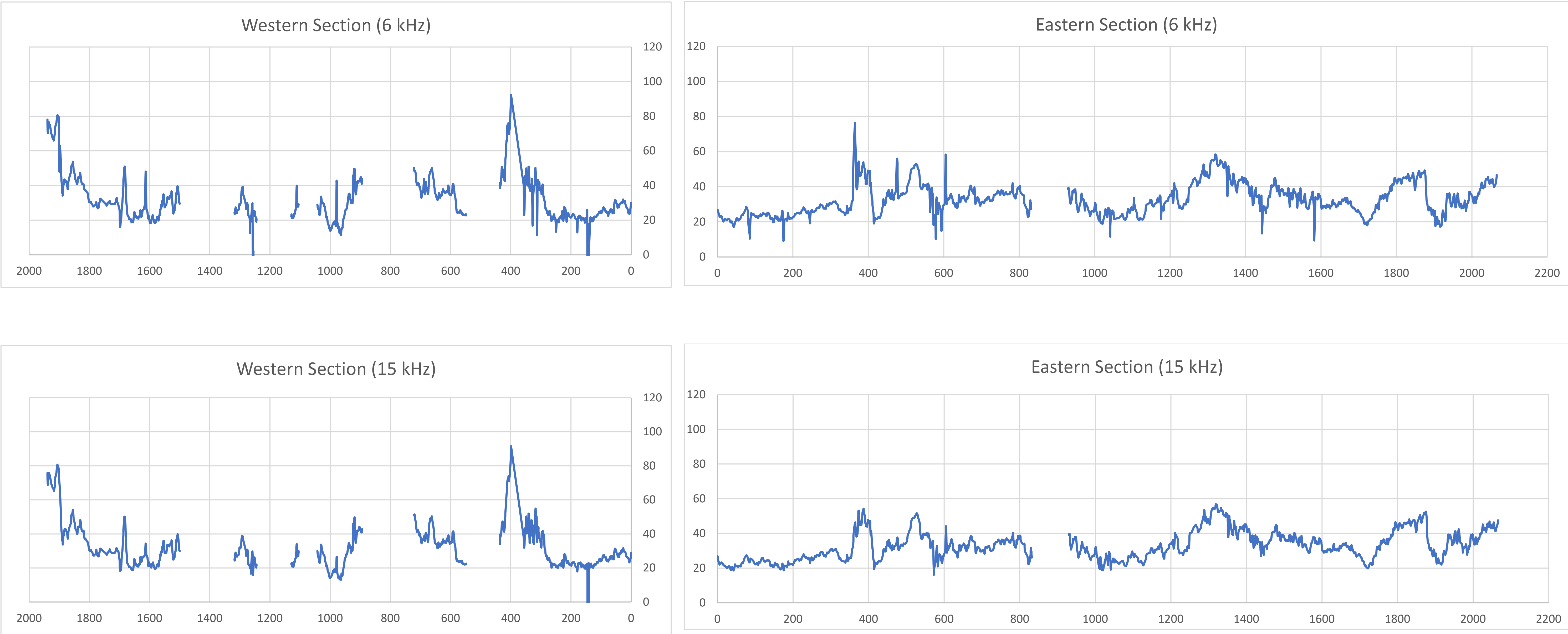


Figure 17: EM Traverse

The traverse indicates the presence of a laterally consistent profile, with conductivity at 15 kHz and 6 kHz generally in the 15-40 mS/m range, and without major low-conductivity anomalies. This conductivity range is consistent with the silt/clayey silt deposits observed on the surface of the banks, and previously on the channel floor. The somewhat higher conductivity (40-70 mS/m) recorded at a lower frequency (1 kHz), is indicative of an increasing clay content with depth, but not really suggestive of a solid clay aquitard.

In summary, the survey indicated a uniform silt to clayey silt profile without significant sand channels or stringers.

5.0 PUMPING TESTS

A 48-hour constant rate pumping test with a measured recovery period was completed on TWS 3 between 7 and 10 September 2020. The pumping rate was measured by digital flowmeter and varied between 6.75 and 7.47 L/s with most of the variations being attributable to movement or kinking of the lay-flat discharge hose by vehicles. Water levels in the pumped well during the pumping and recovery were measured by electric tape, with a digital water level logger also installed and downloaded at the end of the test. Water levels were also manually measured in GW040874 - abbreviated to "74" in tables - (Pipes 1, 2 and 3), GW040892 – "92" - (pipes 1, 2 and 3), GW040891, GW040893 and GWX. The water level loggers in Pipes 1 and 3 in GW040874 were downloaded telemetrically and the data supplied by Water NSW. The locations of these wells are shown on Figure 9.

The drawdown in the pumped well at the end of the test was 4.77 m, indicating a specific capacity of 1.56 L/s/m or 135 m^3/d/m. Drawdown in observation wells screened in the same aquifer ranged from 1.05 (GW040874-3) to 1.31 m (GW040892-3).

A complication to the test was that it was necessary to resume pumping from TWS 1, at a rate of 5.1 L/s, 21 hours into the test. This made the analysis more challenging, but not impossible. The complex drawdown and recovery curves for the pumping well and two observation wells are shown in Figure 18.

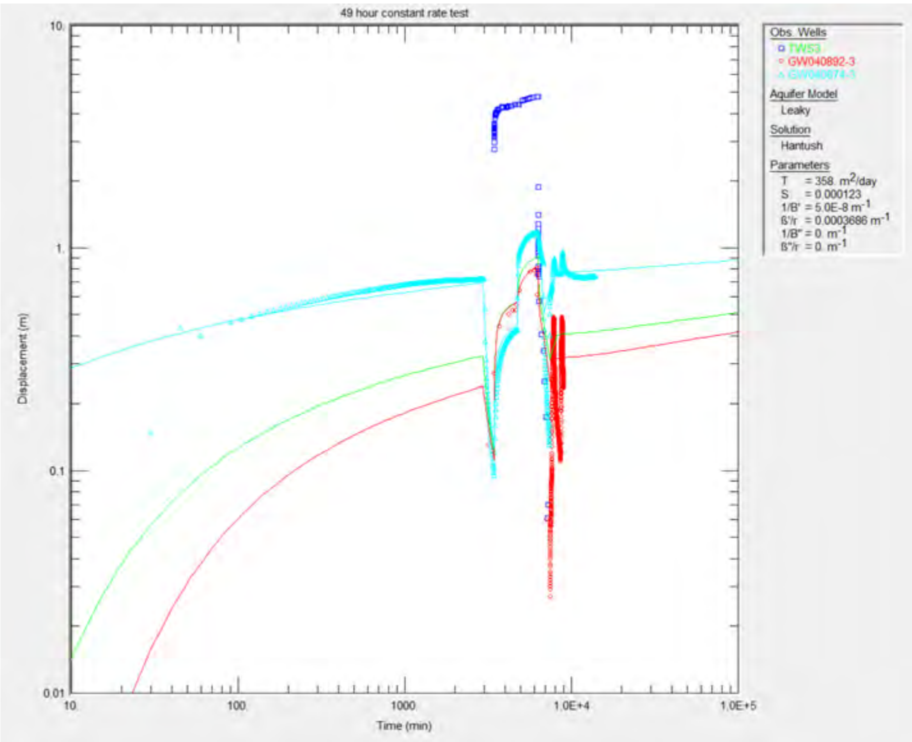


Figure 18: Drawdown and Recovery Curves for Duration of Test and Recovery

Pumping test analysis was carried out using the software AQTESOLV. Results were initially analysed using the approximate method of Cooper-Jacob (confined assumption). The Theis analysis (confined assumption) was then applied but gave poor matches and the alternative methods of Hantush-Jacob and Hantush (leaky) assumption) were used instead. Pumping test analysis results are provided in full in Appendix C and are summarised in Tables 5 and 6.

TABLE 5 Aquifer Characteristics					
Method	**Jacob (PW)**	**Jacob (OW-92)**	**Jacob (OW-74)**	**Hantush-Jacob (OW-74)**	**Hantush (OW-74)**
Thickness b (m)	8.5	8.5	8.5	8.5	8.5
Transmissivity T (m^2/d)	285	495	327	344	334
Hydraulic Conductivity K (m/d)	33.6	58.2	38.5	40.5	39.3
Storativity S	-	3.40E-04	1.80E-04	2.00E-04	1.10E-04
Specific Storage ss (m^{-1})	-	4.00E-05	2.12E-05	2.35E-05	1.29E-05

TABLE 6 Aquitard Properties						
Pumping Well – Obs Well	**TWS3-74**	**TWS1-74**	**TWS1-74**	**TWS1-74**	**Both-74**	**Both-All**
Analysis	Hantush-Jacob	Hantush	Hantush-Jacob	Hantush	Hantush	Hantush
Thickness b (m)	8.5	8.5	8.5	8.5	8.5	8.5
Transmissivity T (m^2/d)	349	312	344	334	335	358
Hydraulic Conductivity K (m/d)	41.1	36.7	40.4	39.3	39.4	42.1
Storativity S	1.10E-04	1.92E-04	2.00E-04	1.10E-04	1.10E-04	1.23E-04
Specific Storage ss (1/m)	1.29E-05	2.26E-05	2.35E-05	1.29E-05	1.29E-05	1.45E-05
Thickness b' (m)	3	3	3	3	3	3
Radius (m)	317	45	45	45	317	317
r/B'	2.08E-01	1.00E-05	3.17E-02	1.00E-05	2.18E-01	-
B' (m)	1.52E+03	4.50E+06	1.42E+03	4.50E+06	1.45E+03	2.00E+07
β'	-	0.01992	-	0.01862	0.1383	0.1168
Aquitard conductivity K' (m/d)	4.50E-04	-	5.12E-04	-	4.77E-04	-
Aquitard storage S'	-	1.22E-04	-	6.10E-03	7.06E-04	1.07E-05
Aquitard Leakance (d^{-1})	1.50E-04	-	1.71E-04	-	1.59E-04	-

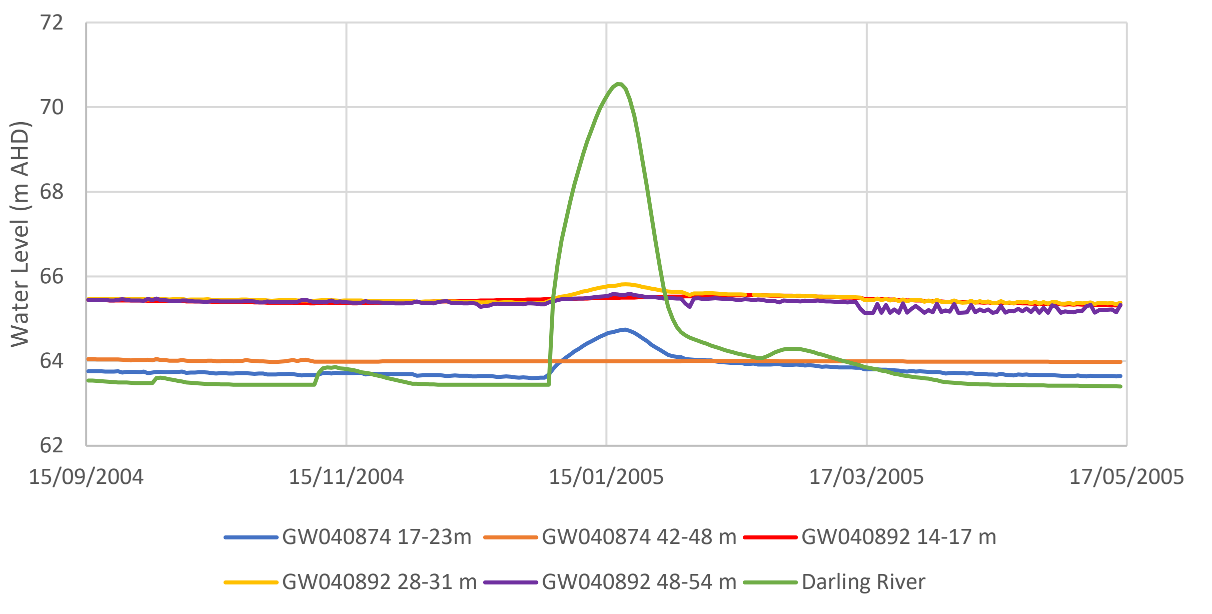
Generally, the different methods gave consistent results. Reasonable values to carry forward are:

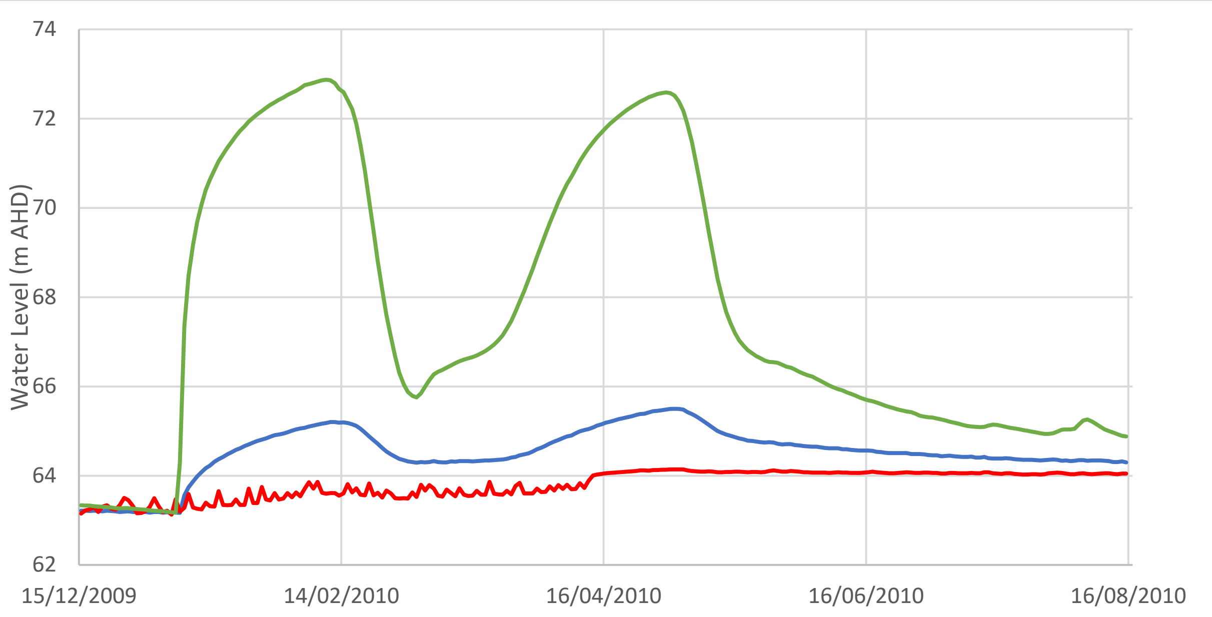
- Transmissivity 340 m^2/d
- Storativity 1.5 x 10^{-4}
- Hydraulic Conductivity 40 m/d
- Specific Storage 2 x 10^{-5} m^{-1}
- Aquitard conductivity 5 x 10^{-4} m/d

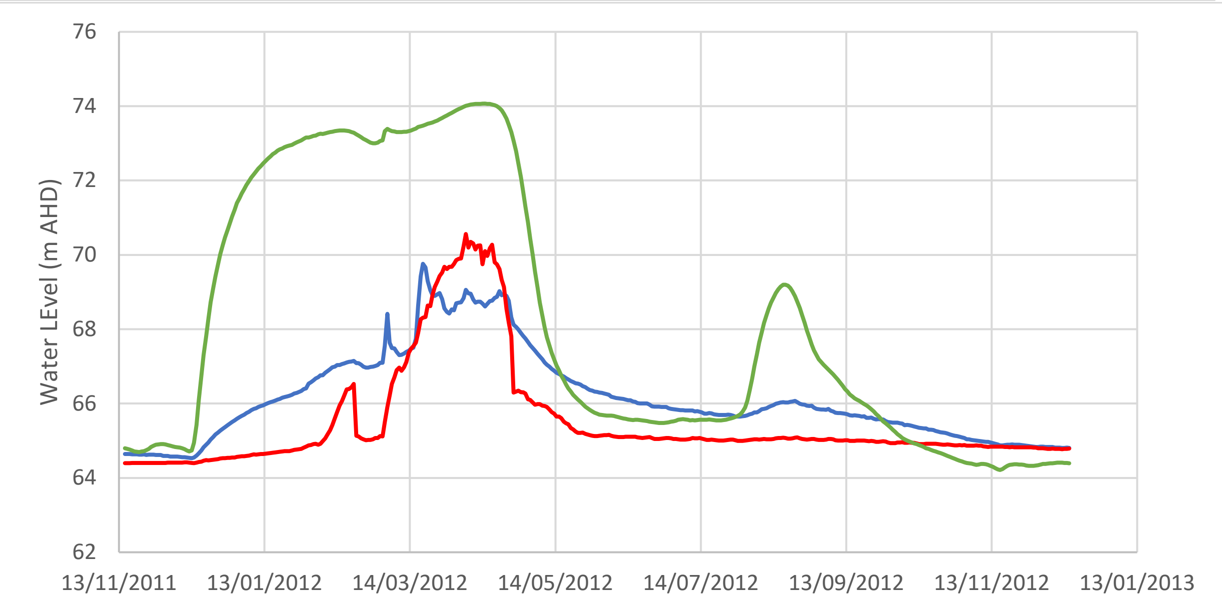
Storativity can only be calculated from observation well data. Calculated values need to be broadly consistent with the poroelastic constraints on the possible range of values of specific storage of 2 x 10^{-7} to 1.3 x 10^{-5} m^{-1} outlined by Anderson et al 2018 and Rau et al 2018. Some latitude in storativity around the values calculated from these specific storage constraints is available due to uncertainty and likely variability in aquifer or aquitard thickness over the area influenced by the pumping test.

6.0 DATA REVIEW AND ANALYSIS

The water levels in monitoring bores GW040874 and GW040892 were logged daily from 2003 to 2013 and river levels at the gauge (425008) located near the road bridge, downstream of the weir, were also recorded hourly over the same period and a daily average calculated. The gauge elevation is 63.445 mAHD. Figure 19 compares the water level response in two bores at three different levels to four flood events in the river that occurred between September 2004 and March 2017.


Water Level (m AHD)
72
70
68
66
64
62
15/09/2004
15/11/2004
15/01/2005
17/03/2005
17/05/2005
GW040874 17-23m
GW040874 42-48 m
GW040892 14-17 m
GW040892 28-31 m
GW040892 48-54 m
Darling River


Water Level (m AHD)
74
72
70
68
66
64
62
15/12/2009
14/02/2010
16/04/2010
16/06/2010
16/08/2010


Water LEvel (m AHD)
76
74
72
70
68
66
64
62
13/11/2011
13/01/2012
14/03/2012
14/05/2012
14/07/2012
13/09/2012
13/11/2012
13/01/2013

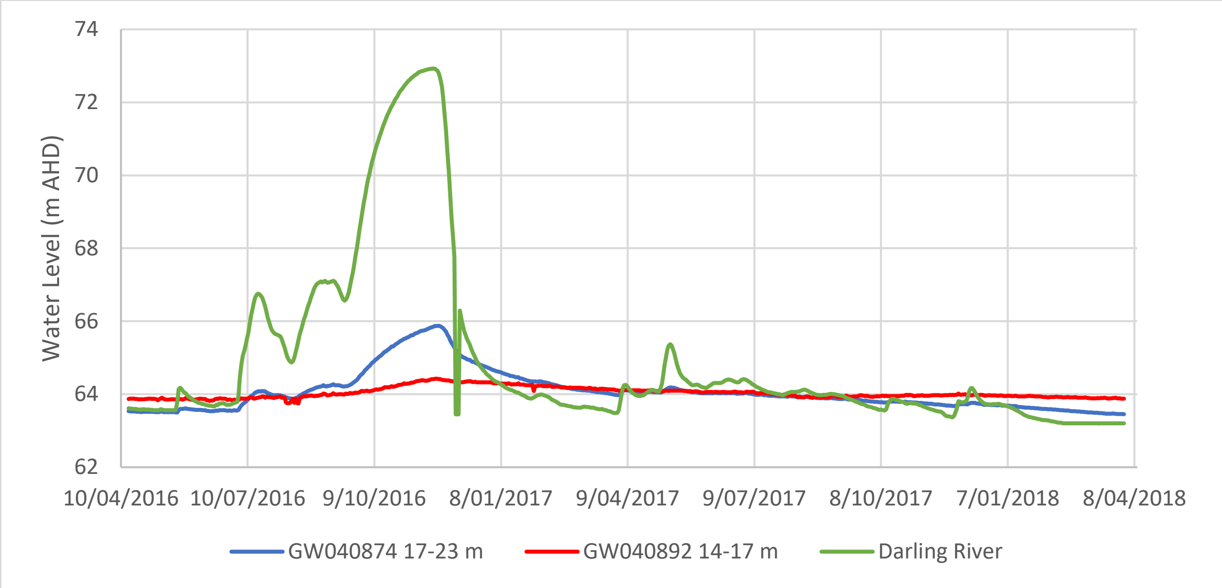


Figure 19: Comparison of Water Level Response in Bores to Floods in Darling River

There is a good correlation between river stage and the groundwater level in the upper aquifer. In all aquifers the initial response to the river stage rise in flood events is almost instantaneous, indicating pressure transmission, but thereafter there is gradual steady rise rather than the rapid rise seen in the river. This is indicative of water inflow to the upper aquifer, rather than pressure transmission alone.

The response becomes progressively subdued in the deeper aquifers; the rise in GW040892 is smaller than that in GW040892, reflecting the greater distance from the river of the latter bore. Initial recession from the peaks in GW040892 also occurs quickly following the fall in river level, but the rate of fall then declines, reflecting slow drainage back to the river. It can be seen that the river level (at the gauge 2.9 km upstream) falls below the groundwater level during the later stages of recession.

The groundwater recovery seen in April 2012 may be partially due to a cessation of pumping from the town borefield.

Figure 20 shows the passage of the March 2020 flood wave, and Figure 21 shows levels for the remainder of the year.

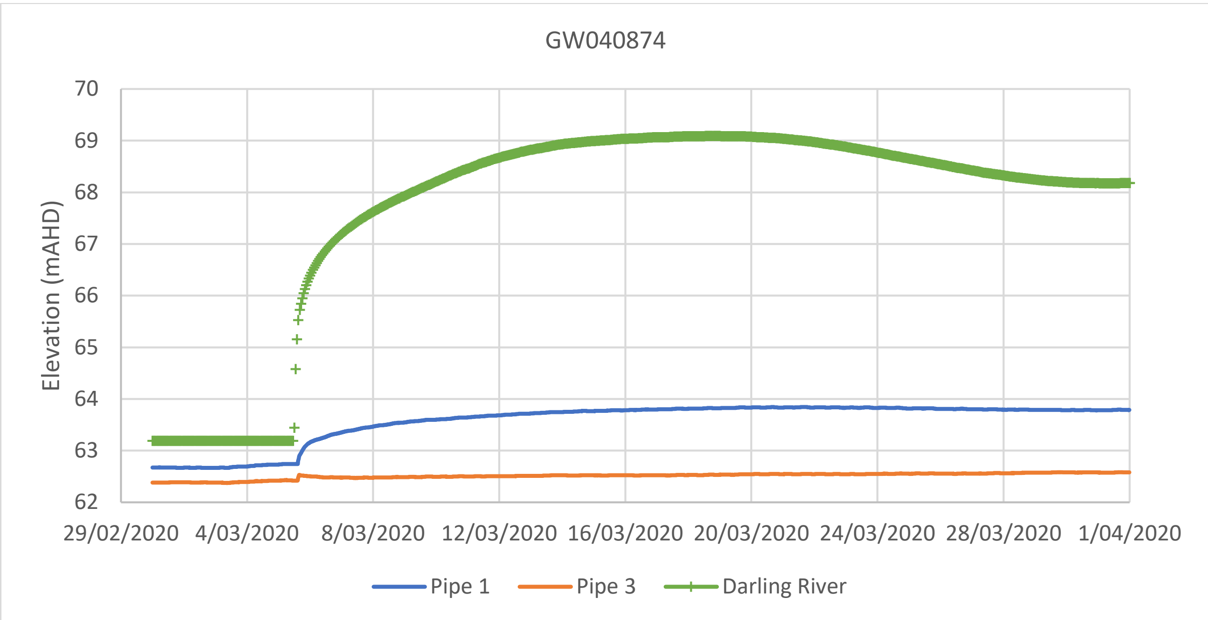


Figure 20: Detailed Plot of March Flood Wave

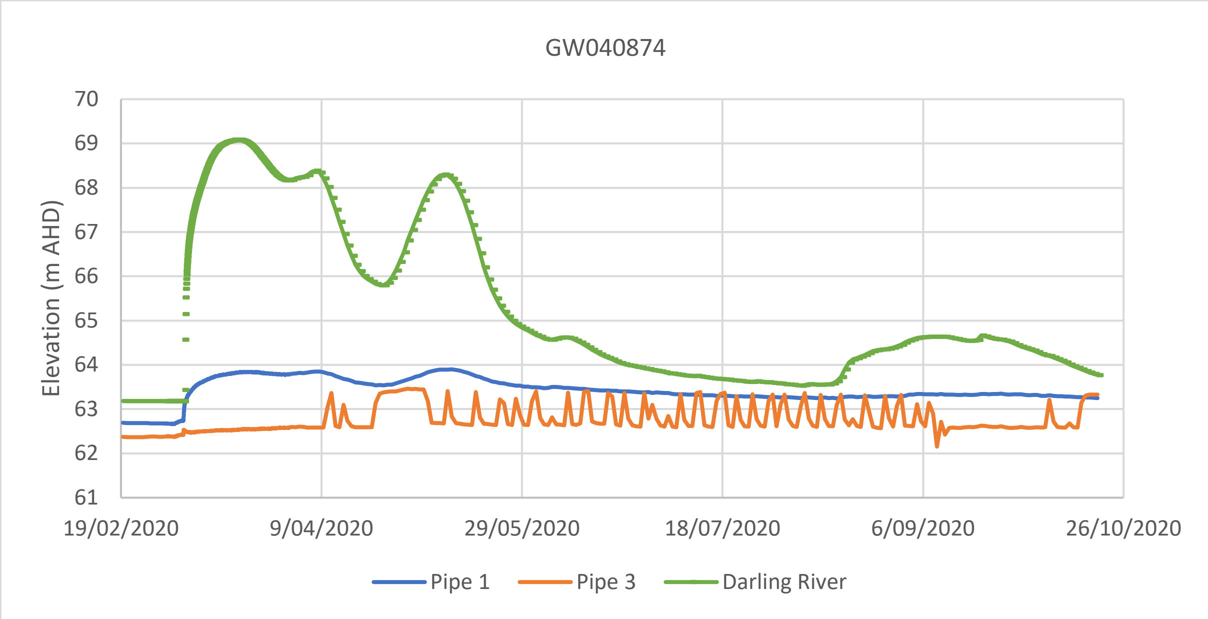


Figure 21: Recession following flood – note effect of pumping from TWS 1

Considering the lithology of the river bed and that of the deposits between the river bed and the upper aquifer, the persistence of the residual pools observed in the channel and the observation that water levels in the upper aquifer are generally similar to, but slightly below river levels, it is considered that the river over this reach would be classified as a connected, losing stream that naturally gains under low-flow conditions, but that backflow from the aquifer is locally curtailed by pumping from the town water supply bores.

The lower aquifer shows only a very subdued response to changes in river level. This gives an indication that the aquifer pumped by the town bores receives recharge by slow leakage from the overlying aquifers and may not experience rapid changes in water quality due to changes in river water quality. However, the level plots indicate that in the recent event, backflow from the aquifer to the river did not occur, as it had in some previous events; this is consistent with the high conductivity measured in the upper aquifer, which may indicate continued seepage of poor quality water from remnant pools. Aquifer water levels are lower than in previous drought events, which may reflect heavier pumping from the town borefield.

The geotechnical bores at the new weir site show a higher proportion of sand, and more coarse sand, than the deposits further east. There may thus be a more direct connection to the lower aquifer in the west.

7.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

7.1 Conceptual Model

The conceptual hydrogeological model has been refined and is as follows.

- The alluvial plains and channels south-east of Wilcannia, both upstream and downstream, are underlain by a sequence of interbedded channel and overbank deposits laid down by the meandering Darling River. These deposits are of Quaternary age and up to 100 m thick. Beneath the Quaternary sediments are sandstones and quartzites of the Devonian-age Mulga Downs Group.
- The current river channel is incised into the Quaternary Sediments, with a depth of typically 10 to 11 m below the top of the banks.
- The shallower deposits beneath the banks are predominantly silts, clayey silts and silty clays. Clayey silts and silty clays with some fine sands are present at shallow depth beneath the channels. Sands and clays may be present at shallow depth beneath the channels, but the observable superficial materials are predominantly silt and clayey silt.
- Deeper bores (GW040874, GW40891, GW040892, GW040893, GW040897, GW804531) typically encountered the top of a thick clay horizon at between about 20 and 30 metres depth, extending to about 45 m depth, with interbedded sands and clays below that depth to bore termination at about 67 m. GW040891, GW040893 and GW804531 are the town emergency water supply bores. However, GW040872, located close to the Menindee Road turnoff from the barrier highway south of Wilcannia penetrated a shallower clay horizon, between 2 and 20 m, then predominantly sands to a depth of 92 m, terminating in sandstone.
- Locally at least, a multi-aquifer system comprised of three sand aquifers separated by clay aquitards is present, as illustrated in Figure 22.

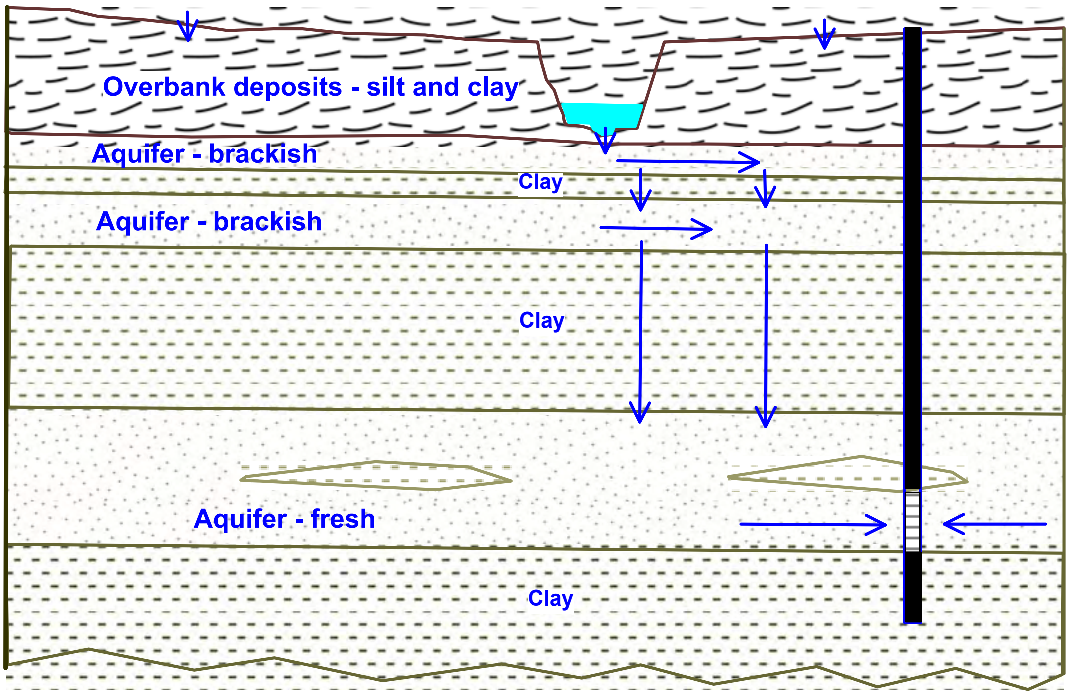


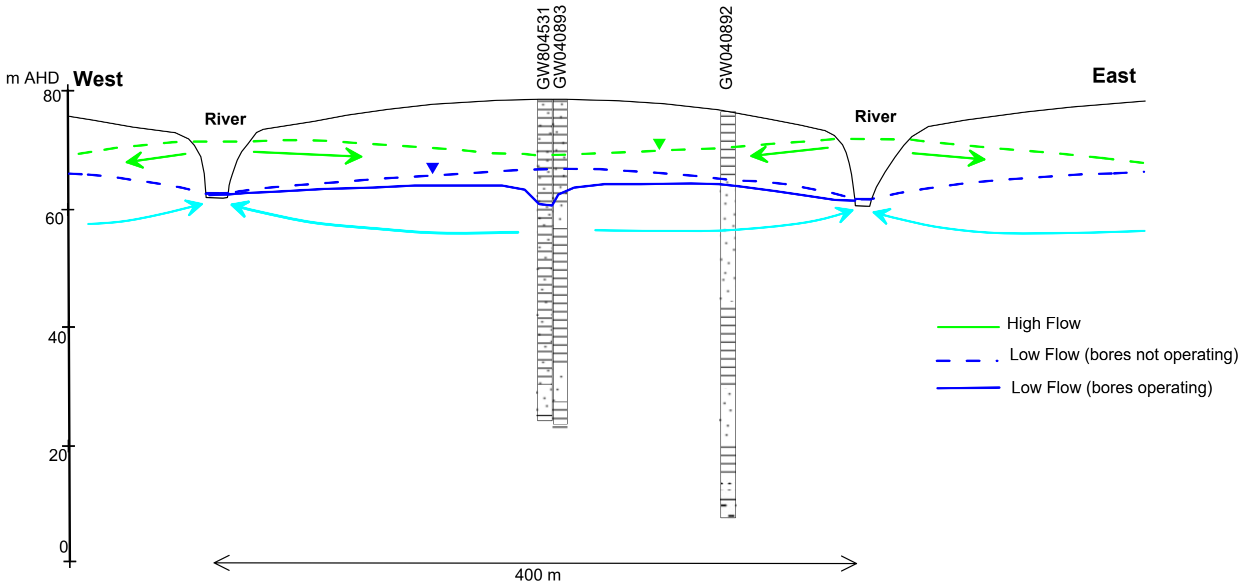
Figure 22: Concept of Multi-Aquifer System at Site

- Historically, water levels measured in the monitoring bores on the Union Bend point have typically been in the range 8 to 9 m below ground level. However, current levels are 10.2 to 10.5 m below ground level generally similar to or slightly below the channel base and below the recent low-flow river levels.
- Where water levels have been measured in multiple pipes screened in multiple aquifers at different levels, the water level is deepest in the deepest aquifer during periods of high to moderate river flow,

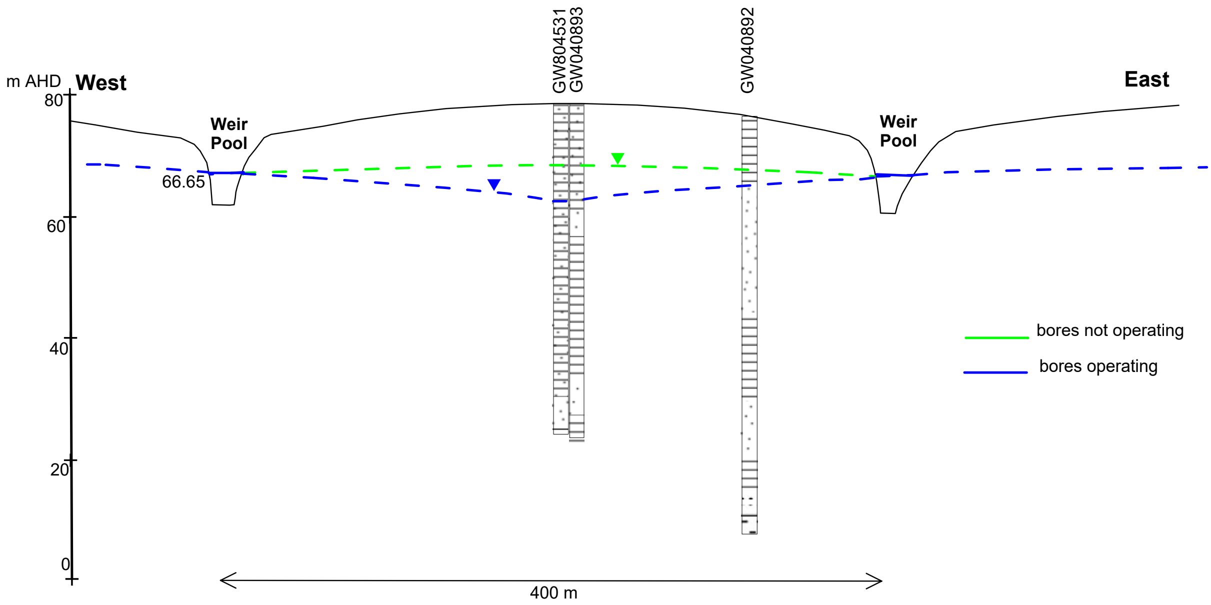
but the difference has sometimes reversed under low flow conditions. This is indicative of recharge being derived from the river under high flows with potential groundwater discharge to the channel under low flow conditions. However, this did not occur in the most recent event.

- Aquifer water levels fluctuate in response to changes in river discharge and stage. The range of fluctuation decreases with distance from the river, and with depth (i.e. the fluctuation range is smaller in the lower aquifers). There is also a very shallow regional gradient (estimated slope 0.00024) gradient from north to south, and a lateral gradient that is inwards (i.e. towards the middle of the ridge) when the river stage is high, and, previously, sometimes outwards under very low river stage conditions.
- In the specific case of GW040892, the monitoring bore at the town borefield, the range in the shallow (14 to 17 m) screen is about 3.2 m, in the 28 to 31m screen it is 2.2 m and in the deepest (48 to 54 m) screen it is 1.3 m.
- It is thus apparent that at least a pressure effect, and possibly fluid transfer, is transmitted from the river to the shallow aquifer, and from the shallow aquifer to the deeper aquifers. This implies that the observed clayey horizons may be laterally discontinuous, or else of relatively high permeability.
- The river channel around Union Bend is quite uniform in morphology and lithology, with some localised terrace and channel-in-channel features. The surface materials in the channel floor and banks are predominantly clayey silts and silty clays with some fine sand.
- The remnant pools in the channel floor are may at times have been water-table windows, but in the recent drought event were perched above the shallow water table.
- The Darling River at this location is provisionally categorised as a predominantly connected, losing stream that may sometimes be locally gaining under low flow conditions.

A sectional CSM has been prepared and is shown on Figure 23. It should be noted that the section is oriented approximately west to east. The regional hydraulic gradient is assumed to be north to south and therefore orthogonal to the section. There will be local hydraulic gradient either towards or away from the Darling River depending on antecedent conditions.



The section above shows the relationship between the major aquifer units, the current river channel pool and the town water supply bores. Under high and medium flow conditions water from the river seeps through the river bed and banks and recharges the shallow aquifer, which provides leakage to deeper aquifers. Under low flow conditions or when the channel contains only residual poos, groundwater flows into the river/pools.



The lower section shows conditions following completion of the new weir. The water level will generally be stable at 66.71 m AHD but may be drawn down under cease-to-flow conditions. Under stable conditions there will be very minor outflow from the aquifer to the weirpool due to minimal rainfall recharge. When the bores are operating there may be outflow from the weir pool towards the bores. If the weir pool is drawn down, then conditions could approach those shown in the top section, but this will occur slowly due to the additional storage in weir pool.

Figure 23: Conceptual Site Model

8.0 SURFACE HYDROLOGY AND PROPOSED WEIR OPERATION

This section has been based on information supplied by Water NSW (Barma 2020, Robinson 2021).

8.1 The Existing Weir

The existing Wilcannia weir is a fixed-crest structure with a crest elevation of 65.71 m AHD and no gated outlet provisions.

During drought periods the weirpool water level typically falls below the weir full supply (crest) level and consequently downstream flows cease past the weir. This occurs when combined town water supply demand extraction and evaporation and infiltration losses are greater than river inflow volumes.

The absence of existing outlet gate provisions means that there is no way to generate downstream flow releases for water sharing purposes and achieve a degree of inflow translucency past the weir at times when the weirpool storage level is below crest level.

Water quality management in the existing weirpool has been a significant issue during drought periods.

The main contributors to these weirpool water quality issues have been identified as:

- Vertical thermal stratification due to inadequate flow mixing within the storage;
- Potential development of blue-green algae blooms during the hottest months of the year (October-March), which is related to thermal stratification;
- Progressive increase in water salinity with reducing weirpool water storage levels resulting from concentration due to the significant evaporation losses;
- Potentially higher salinity river inflows compared to that of the weirpool water storage, which is understood to be an issue under low or zero flow conditions upstream near Louth that potentially results in high salinity ground water inflows to the river that are then passed downstream. These high-salinity flows may occur as slugs of saline water when flow resumes following a period of zero flow.

Other water quality issues include water turbidity, pH, town stormwater inflows, farm run-off and live-stock related contamination.

8.2 Proposed Water Quality Management Strategies

The water quality issues related to salinity and stratification are being addressed in the development of the design for the proposed replacement weir. The inclusion of outlet gate provisions was considered fundamental to facilitating a degree of water quality management for the weirpool raw water storage. The ability to manage water quality issues is subject to the occurrence of favourable river inflows to the weirpool that can be used to promote mixing, dilution and water volume exchange via the controlled release of water from the weirpool water storage. It is noted that no additional storage volume or weir height is proposed to enable significant river re-regulation at Wilcannia or otherwise to allow for the release of storage water without the assured occurrence of a storage inflow event needed to preserve or restore drought security.

Water quality management will by implemented by the following mechanisms:

- mixing of river inflow volumes with stored water within the weirpool including dilution and volume exchange; and
- destratification of the weirpool.

Differences in salinity and temperature between water stored in the weirpool and river inflow volumes have the potential to influence the effectiveness of water quality management operations.

It is proposed that a required minimum average velocity of 0.035m/s be adopted for the achievement of mixing and destratification purposes. The flow needed to achieve this velocity in a particular river cross-section is dependent on the level of the weirpool at the time and the cross-sectional waterway area.

8.3 Proposed Weir Operation

The proposed new weir will have an effective 1 m raised crest relative to the existing weir. At this stage the proposed new weir is envisioned to incorporate a 1m raised fixed crest section, a gated section comprising one or more weir outlet gates and a significant fishway structure integrated into the weir.

The new weir will be capable of being operated in two (2) distinct modes as outlined below.

Normal mode – normal flowing river conditions:

- Weir outlet gate(s) sufficiently raised to match the level of the existing weir crest.
- Fishway fully open and operational.

This operational mode is intended to minimise additional upstream impacts compared to the existing weir for most of the time and avoid permanently locking in the impacts associated with a 1m raised weir.

Lower river flows would primarily pass via the fishway structure. Additional flows may also be passed via partially opened weir outlet gate provisions to optimise headwater stage discharge characteristics and to further minimise upstream impacts associated with increased river flow profiles. Operation would be subject to maintenance of a minimum weirpool level matched to the existing weir crest to ensure the maintenance of existing conditions.

At higher flows, the weir outlet gate(s) may be further opened while flows would also tend to spill over the fixed crest weir section. This configuration would be applicable during flood conditions.

In the event of very low flows, the fishway would be isolated utilising upstream located gated provisions to prevent storage loss and to preserve the minimum weirpool level. This could be expected to be a rare occurrence in Normal operating mode.

No water quality management operational provisions or procedures are proposed in Normal operating mode.

With respect to groundwater-surface water interactions in the vicinity of the town borefield on Union Bend, conditions following construction of the new weir will differ significantly from current and previous condition, because the new weir will be located further downstream and the weir pool will extend around Union Bend, close to the borefield.

Drought Security mode – typical no-flow river conditions:

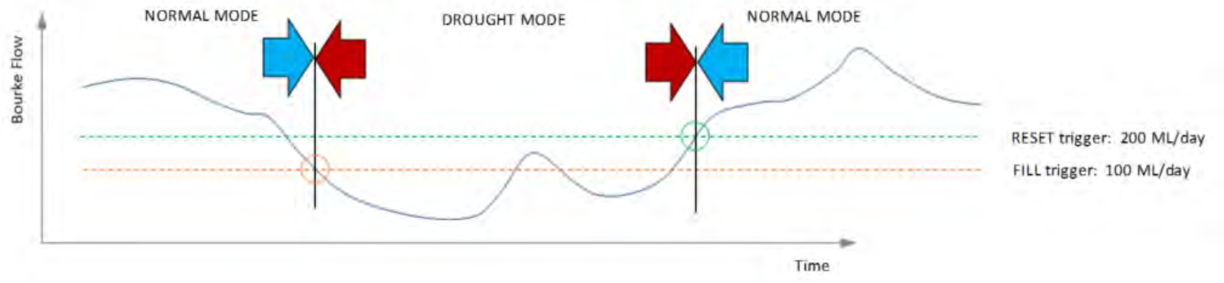
- Weir outlet gate(s) fully raised to match the level of the adjacent 1m raised fixed crest section.
- Fishway fully closed and non-operational.

This operational mode is aimed at allowing the storage to be completely filled for the purpose of providing a secure town water supply source in preparation for the potential onset of drought conditions. The success of this operational mode is dependent on the capture of adequate trailing weirpool inflow volumes to fully fill the storage prior to river flows ceasing or otherwise becoming insufficient. As a consequence of the need to fill the weirpool by up to 1m compared to that in Normal mode, downstream flows could be expected to cease sooner than for the existing weir.

The transition timing between the two weir operating modes has been initially decided to be based on a set of upstream river flow condition triggers near Bourke weir, which are defined as follows:

- River flows fall to less than 100 ML/day: Weirpool filling transition from Normal mode to Drought Security mode;
- River flows rise to greater than 200 ML/day: Weirpool lowering transition or restoring (refilling to normal level) transition from Drought Security mode to Normal mode.

This is illustrated in Figure 24.



BOURKE FLOW (ML/d)	≤ 100 ML/d TRIGGER	≥ 200 ML/d TRIGGER	TRANSITION EVENT
FALLING	DROUGHT	-	FILL
RISING	-	NORMAL	RESET
STEADY	-	-	-

Figure 24: Weirpool Operating Mode Transitions

Water NSW considers that the optimisation of the flow trigger values with operational experience and river flow forecasting has the potential to improve the reliability of weirpool filling and reduce instances of unnecessary short duration operation in Drought Security mode.

In the event that the weirpool is fully filled prior to inflows ceasing then these flows would subsequently be passed by a combination of spilling over the weir fixed crest section and discharge via the weir outlet gate(s) and/or fishway.

The basis for town water supply secure yield assessment conservatively assumed nil storage inflows during the critical drought to meet future Year 2047 annual demand for Wilcannia. This assumption creates the opportunity to provide for a degree of inflow translucency past the weir via downstream gated releases whilst the weir is in Drought Security mode. This is considered to provide a potential environmental benefit compared to the existing weir. The ability to release inflow volumes downstream also provides an opportunity to use these flows to generate velocities within the river reach occupied by the weirpool to create a flow mixing effect and thereby provide a means for weirpool water quality management.

For the proposed new weir, gated releases in response to favourable storage inflows during Drought Security mode may be carried out in two (2) ways, either:

- at a discharge rate similar to the inflow rate; or
- at a varied discharge rate following initial capture of inflows and subsequent discharge at a more beneficial rate needed to meet management objectives.

8.4 Water NSW Modelling

The current WaterNSW model of the Barwon-Darling river system (the Barwon-Darling Source Model) run period is from 1/1/1900 to 20/8/2019. The same run period was used for the Wilcannia surface water model, utilising daily time-steps.

Model inputs were:

Date	Flow Passing Bourke Weir (ML/day)	Gross Storage Inflow (ML/day)	Expected Weirpool Infiltration (ML/day)	Expected Weirpool Evaporation (ML/day)	Expected Domestic & Stock Demands (ML/day)	TWS Demand (ML/day)

The following outputs were generated:

Date	Flow Passing Bourke Weir (ML/day)	Gross Storage Inflow (ML/day)	Weirpool Level (mAHD)	Wilcannia Storage Vol (ML)	Gate Crest Level (mAHD)	D/s Spill Flow (ML/day)

Two sets of inflow data were used:

- ***Simulated Flows*** - simulated flows below the Bourke Weir and into the Wilcannia weirpool storage output from the Source model.

- ***Low Flow Adjusted Simulated Flows*** - given that the river system models are known to over predict low flows, a low flow adjusted simulated sequence was also generated. WaterNSW carried out this adjustment on the basis of a comparison of simulated and observed flows at the Tilpa gauge.

A total of nine scenarios were modelled.

These scenarios were derived by utilising the four input variables with binary alternatives in different combinations to generate nine alternative datasets. The four binary alternatives were:

- Simulated flows **or** Low-flow adjusted simulated flows
- Existing weir **or** Proposed weir
- Existing demand **or** future (2047) demand of 315 ML/yr
- Operating mode transition triggers of 100/200 **or**250/300 **or** 250/300 + S&D

This scenario matrix and final output run numbers are summarised in Table 7.

TABLE 7
Water NSW Modelling Scenarios

River Flow Sequence	Demand	Existing Weir	Proposed Weir (Triggers 100/200)	Proposed Weir (Triggers 250/300)	Proposed Weir (Triggers 250/300 + S&D)
Simulated Flows	Existing	Run 864	Run 865	Run 866	-
	Future	-	Run 860	Run 861	-
Low Flow Adjusted Simulated Flows (sensitivity)	Existing	Run 867	-	Run 868	-
	Future	-	-	Run 862	Run 863

9.0 NUMERICAL GROUNDWATER MODEL

9.1 Background

A key requirement of this hydrogeological study is to assess the volumetric flows between the Darling River and the shallow aquifer, and between the shallow aquifer and the deep aquifer that is used for emergency town water supply. This assessment is required both under current conditions, and when the new weir is completed and operational. In association with the known salinity (as electrical conductivity) in the Darling River under a range of flow conditions, this will allow the effect of the new weir pool construction on groundwater quality to be assessed. Although not included in the original scope of this study, it was decided that the best way to do this was to use a numerical model.

A finite difference model was built using MODFLOW USG-T.

For lateral discretisation, a Voronoi mesh was created using ALGOMESH. This is shown in Figure 26.

The model was set up with seven layers representing:

- Layer 1 - the superficial sediments and overbank deposits
- Layer 2 – the shallow aquifer
- Layer 3 – the upper aquitard
- Layer 4 – the intermediate aquifer
- Layer 5 – the lower aquitard
- Layer 6 – the lower aquifer
- Layer 7 – the basal residual surface / Devonian basement

This layered structure is similar to that shown in conceptual form in Figure 22. Elevation of the top of Layer 1 (representing the ground surface) was applied using a gridded representation of the 1 m LiDAR data, exported from the GIS, as shown on Figure 27. The base of layer 1 and all other layer bases were assigned using the borehole logs for GW040874, GW40891, GW040892, GW040893, GW040897 and GW804531.

Figure 24 shows a cross section of the model from west to east, through TWS 1.

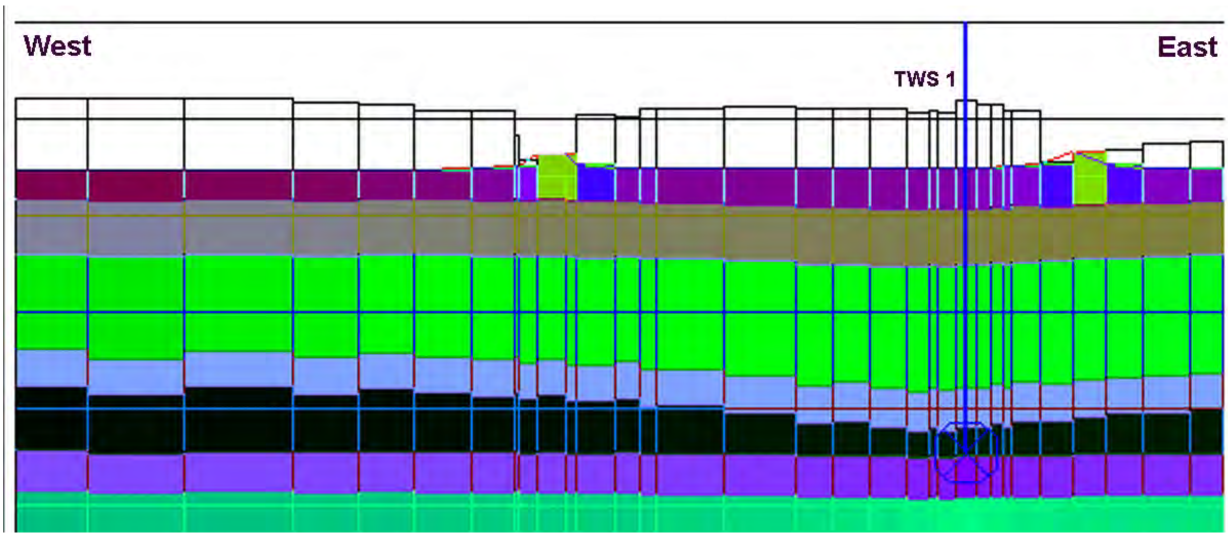


Figure 25: Model Cross-Section

General head (constant gradient) boundaries imposing the regional hydraulic gradient of 0.00024 to the south were applied along the northern and southern boundaries of the model.

The model was set up with a single recharge zone extending across the entire model, with a low steady-state net recharge (recharge-evapotranspiration) of 1% of mean annual rainfall, and a transient recharge of 1% of monthly rainfall. This low recharge was assumed on the basis that the vegetation across most of the model area had developed to use essentially all of the available infiltration, with a few windows where some deep recharge may occur. Consequently, rainfall recharge constitutes a very minor component of the water balance.

Seven hydraulic conductivity zones were established, one for each model layer. Values derived from the pumping test were applied to both the aquifer and aquitard layers; these were adjusted during model calibration. It is recognised that, in reality, lateral hydraulic conductivity within each layer is spatially heterogeneous. However, there are no data to define this variability and in the absence of such data the variability has been assumed to be random, about the assumed mean value.

Point bar deposits such as that at Union Bend are formed as the river channel migrates progressively along the axis of the bend. Traces of numerous prior channels can be clearly seen on the aerial photographs of the area. Over the course of the Quaternal period the river channel has shifted countless times, generally by the common process of erosion on the outside of bends followed by break-though and channel abandonment following flood events. Thus, the local hydrogeological conceptual model is of a stacked series of abandoned channels with a predominant westerly direction and thus anisotropic hydraulic conductivity with the principal axis oriented to the west.

Lateral aquifer hydraulic conductivity and vertical aquitard hydraulic conductivity were calibrated against the available groundwater level records for GW040874 and GW040892. Lateral anisotropy factors of 0.25 to 0.33 were applied during model calibration. Vertical hydraulic conductivity factors were in the range 0.03 to 0.10.

An unconfined specific yield of 0.05 was initially applied to the Layer 1 over-bank deposits, confined storage values assessed from the pumping tests were initially applied to the deeper layers.

The river boundary was calibrated using river-bed elevation and river stage data from the gauge at Wilcannia.

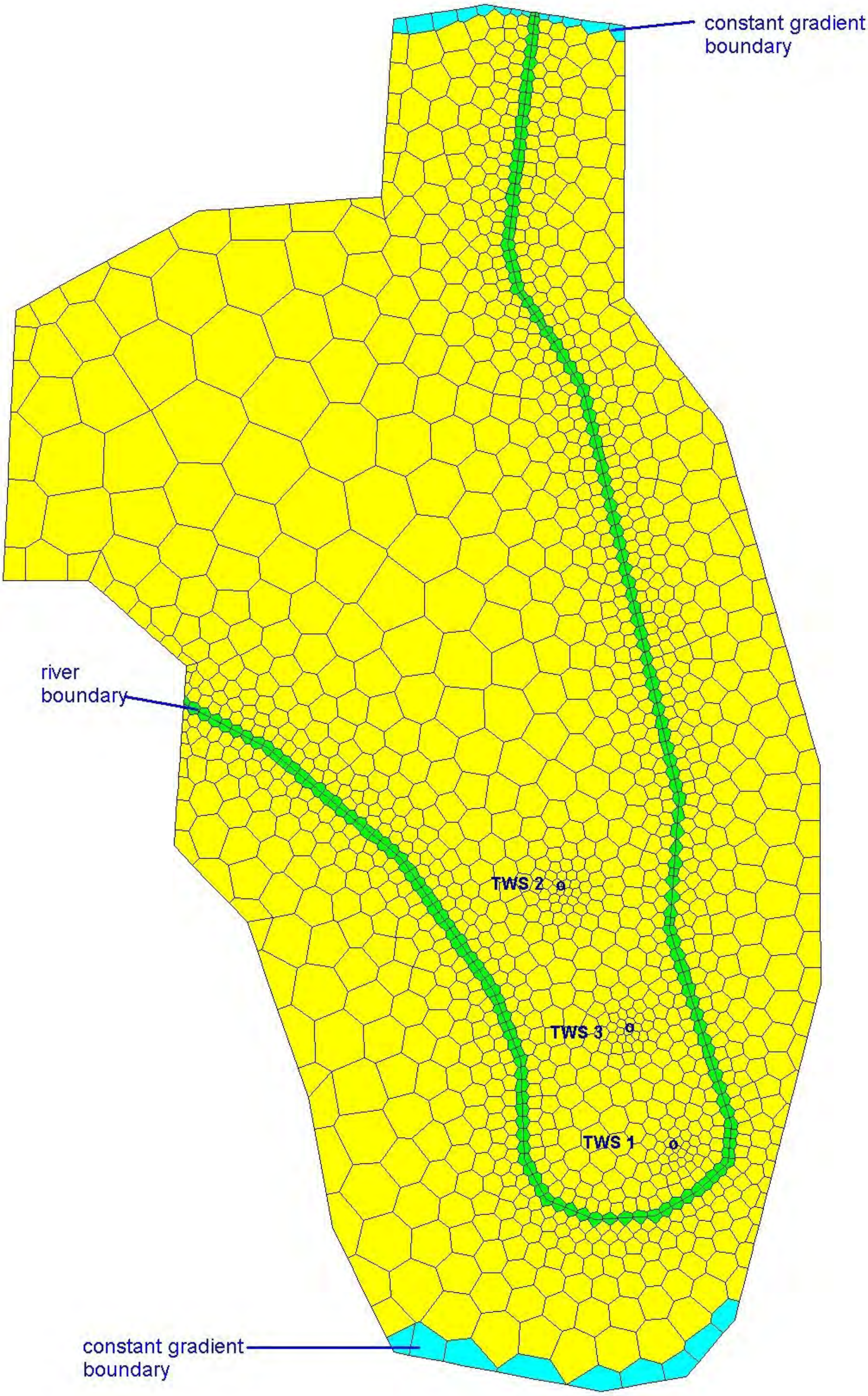


Figure 26: Voronoi mesh created as unstructured grid for MODFLOW USG-T

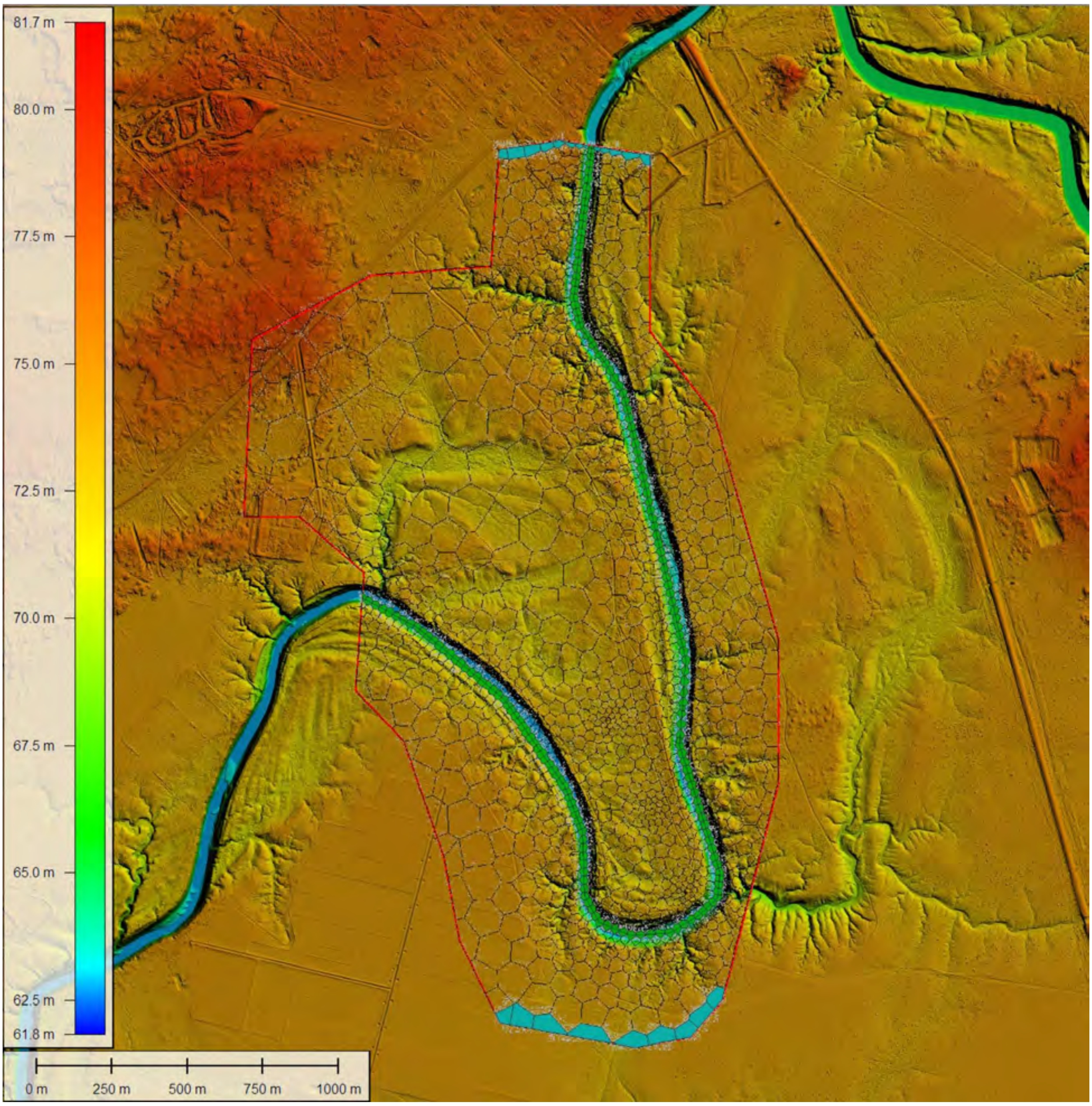


Figure 27: Surface topography representing top of Layer 1

9.2 Calibration

The transient model calibration was carried out using 1-month stress periods for the period from 2013 to 2020 and using variable 0.5 to 10 day stress periods for the period following the 2020 flood wave (March-October 2020).

Parameters as calibrated are given in Table 8. Uniform parameters were applied to each layer as there was insufficient observational data to calibrate laterally variable parameters.

TABLE 8 Calibrated Aquifer Parameters					
Parameter	**Kx**	**Ky**	**Kz**	**Sy**	**Ss**
Units	**m/d**	**m/d**	**m/d**	**-**	**-**
Layer 1	0.05	0.05	0.005	0.01	$1x10^{-4}$
Layer 2	20	5	2	0.05	$3x10^{-5}$
Layer 3	0.01	0.01	0.0015		$1x10^{-4}$
Layer 4	60	20	2		$3x10^{-5}$
Layer 5	0.1	0.1	0.004		$1x10^{-4}$
Layer 6	60	20	2		$3x10^{-5}$
Layer 7	0.001	0.001	0.0005		$1x10^{-4}$

Figure 28 shows calibrated vs measured hydrographs for the Water NSW monitoring bore GW040874.

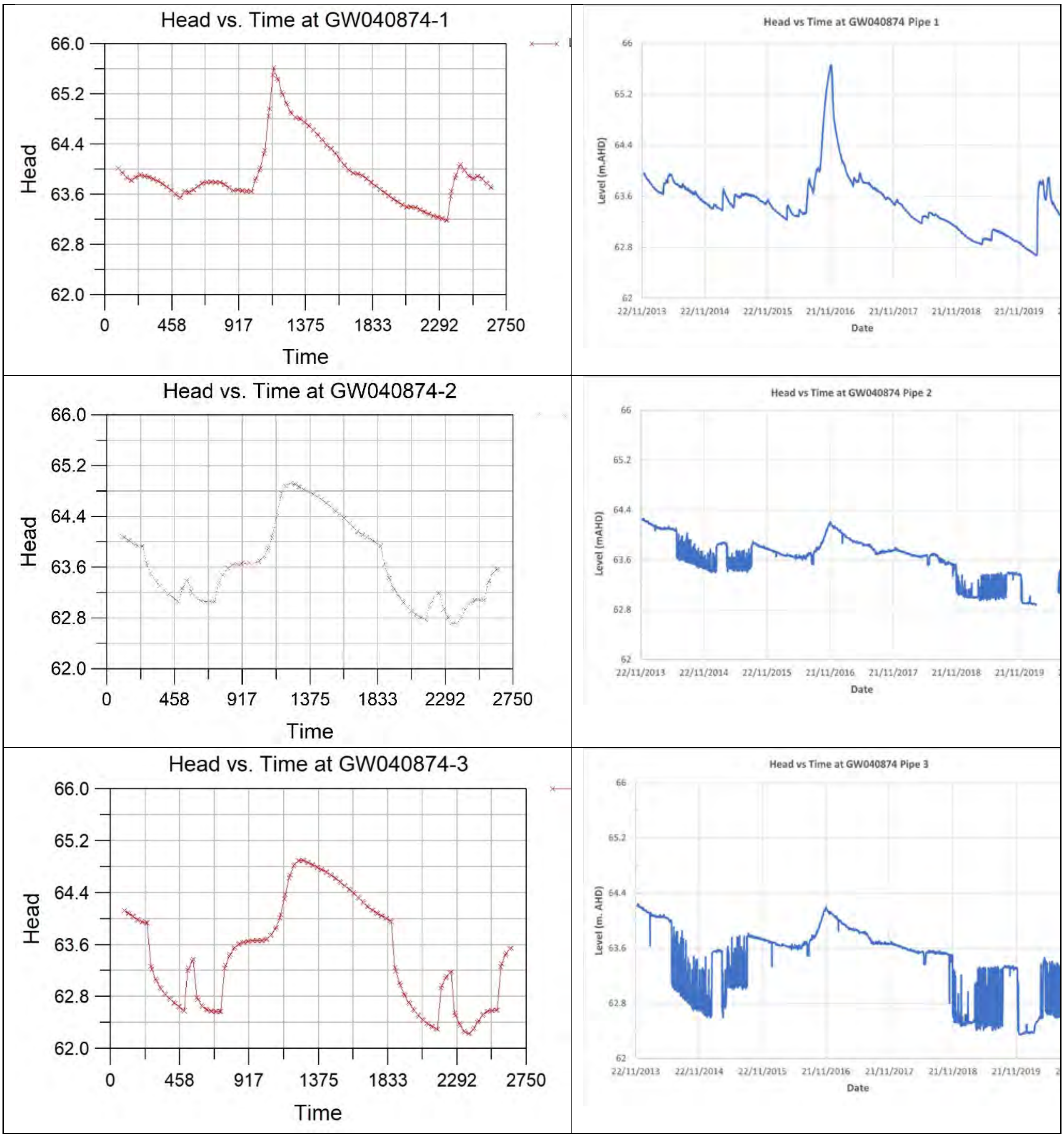


Figure 28: Calibration Hydrographs

Figure 29 shows contours on the potentiometric surface in Layer 3 (the main aquifer) for stress period 78 in mid-2019.

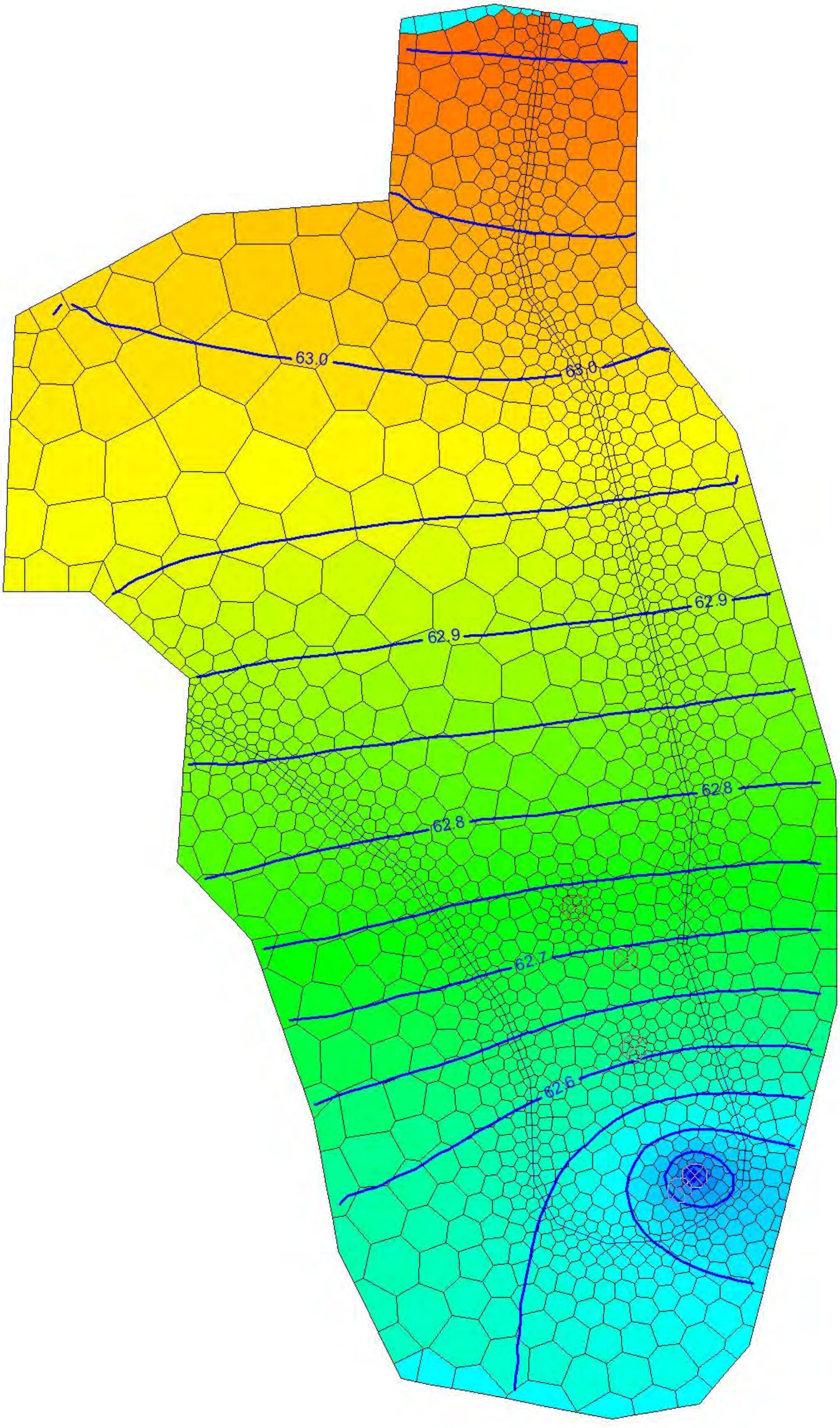


Figure 29: Contours on potentiometric surface in Layer 6, Stress Period 78

The model mass balance for five example time steps is provided in Table 9. All flows are in ML/day unless otherwise stated. Negative figures are groundwater system outflows.

TABLE 9
Model Mass Balance for Selected Time Steps

Step	Month	River Stage (m)	Average Flow	Wellfield	River	GHB	Recharge	Storage	Error (%)
36	Oct 2016	72.49	26800	0	3.492	-0.014	0.0034	3.487	$-5.7x10^{-5}$
52	Feb 2018	63.09	0	0	-0.489	-0.307	$1.1x10^{-6}$	-0.493	$-1.8x10^{-4}$
74	Dec 2019	63.07	0	-0.154	-0.087	0.007	$4.2x10^{-6}$	0.233	$4.0x10^{-4}$
76	Feb 2020	67.59	9340	-0.154	1.454	0.005	$1.0x10^{-4}$	1.306	$3.3x10^{-5}$
78	Apr 2020	66.51	5570	-0.154	1.174	0.004	$8.2x10^{-5}$	-1.024	$2.2x10^{-5}$

Figure 30 is a plot of the net flows (flux) between the river and the upper aquifer over the calibration period.

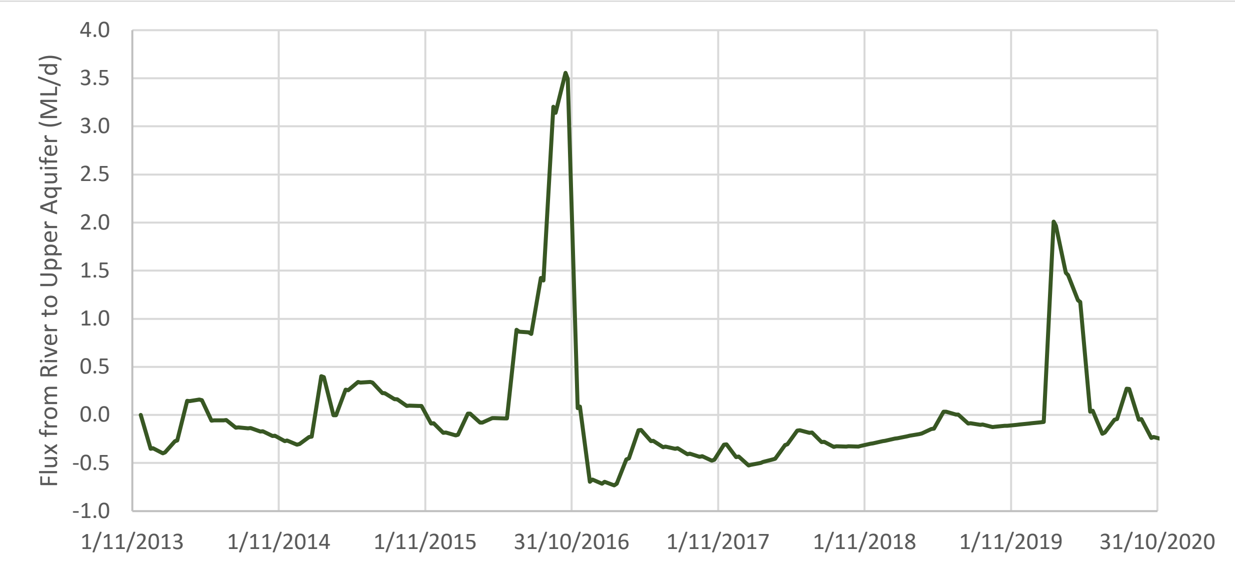


Figure 30: Net flows between river and aquifer

It can be seen from Table 8 and Figure 30 that:

- Inflows from the river to the aquifer system (Layers 1 and 2) range from 1.2 to 1.5 ML/d (0.27 to 0.34 ML/d/km) in the modelled reach at low-moderate flows (with the borefield active). At higher flows, with no borefield pumping, the inflow is up to 3.5 ML/d (0.8 ML/d/km) during the modelled period and could have been much higher at other times during the period of flow record.

- Outflows to the river during periods when it was not flowing ranged from 0.1 ML/d with the borefield operating, to 0.5 ML/d with the borefield not operating.

- Outflow from the river (aquifer recharge) during major flood peaks is followed immediately by a period of reverse flow as the charged aquifer discharges back to the river.

- Inflows across the northern boundary and outflows across the southern boundary are negligible.

- Recharge inflows are negligible.

- Model mass balance errors are very low.

A MODPATH simulation was also run for the calibration dataset. Reverse particle tracking was used to simulate travel from a source in the riverbed to the pumping bores (only TWS1 was used during calibration).

This is a worst-case scenario as TWS1 is the closest bore to the river. Flow times were long in relation to the length of the calibration period and estimated to be of the order of many decades.

9.3 Predictive Model Runs

9.3.1 Surface Water Model Runs

Predictive runs of the model were based on the outputs from the surface water modelling completed by Water NSW. Head (level) in the weir-pool is one of the two main stressors for the aquifer – the other being pumping from the town water supply bores.

Water NSW modelled a number of scenarios, as listed in Table 7 above.

Runs with the existing weir scenario (Runs 864 and 867) are not relevant to the groundwater modelling as the weir and whole weirpool are currently upstream from the model area; weirpool levels thus have negligible effect to river-aquifer interaction around Union Bend. The calibration runs adequately address this scenario for the groundwater model.

For the other scenarios, the output for daily timesteps provided in the Water NSW spreadsheets was converted to average monthly heads to match the groundwater model time steps. The weir pool levels were input as river heads to the transient groundwater model, which was run with the calibrated parameters and boundary conditions.

For the period July 2007 to June 2019, weirpool average EC was calculated by a simple salt-balance method (using EC as a surrogate for salinity) using weirpool inflows and outflows, and weirpool volume output from the Water NSW model and inflow salinity based on historical records for the corresponding period. Average monthly evaporation data from the Bureau of Meteorology was used to estimate evaporative concentration. For the earlier period, a mean EC value derived from the available historical data was used for the input salinity. An attempt was made to correlate historical salinity with flow measurements, but the correlation was unusable poor. It was assumed that, in future, appropriate measures with be employed to ensure that the weir-pool is well-mixed and does not become stratified with saline water at the base.
The model input and output for each of the modelled scenarios is provided in Appendix D. For each scenario, graphs showing:

<u>Input</u>

- The model input river head for each monthly timestep 1900 to 2019
- The inflow to the weirpool and the calculated weirpool EC

<u>Output</u>

- The modelled aquifer water levels, aquifer EC and vertical leakage flows from the river to the upper aquifer.

9.3.2 Groundwater Model Runs

Model input and output are summarised graphically in Appendix D.

Inputs

The groundwater model inputs derived from the surface flow data are pool water level and pool salinity (as EC). Pool inflow is not a groundwater model input was used in the salinity calculation. It can be seen that at the scale of the graphs, the differences between the inputs are small. Pool level differences are, however, reasonably obvious, whereas salinity differences are present, but subtle and well within the considerable margin of error in the salinity calculation.

Outputs

The plots of net flux from river to aquifer show that, for all scenarios, the net flux is overwhelmingly positive – the aquifer is recharged from the river most of the time. The median total flux within the model domain is about 0.35 ML/day, with maxima of 0.7 to 0.8 ML/d. This is similar to the pumping rate from the aquifer during drought periods, so that river recharge would barely maintain full-time pumping. However, the borefield is only used when surface water is unavailable due to level or quality considerations, so the long-term average pumping rate is considerably less than the peak demand.

Compared with current conditions the median volumetric flux between the aquifer and the river is similar. However, the pattern is very different. Currently we see very large (up to 3.5 ML/d peak flows into the aquifer associated with major flood events, followed by a rapid transition to slowly-declining return flows as the flood-wave recedes. These return flows continue until the next flood.

The 250/300 trigger regime (861 and 866 with the 862 and 868 sensitivity cases, generates a higher frequency of outflows from the aquifer to the river than does the 100/200 regime (860 and 865).

Aquifer head (water level in bores) for all the future scenarios will differ significantly from the current regime. The most obvious differences are:

- water levels typically about 1m higher in all aquifers than under the current regime;
- much less "peakiness"- variation in water level – in the upper aquifer, although aquifer levels still primarily driven by river (weirpool) levels;
- water levels in the lower aquifer almost entirely driven by borefield pumping;
- development of a clear and persistent downwards vertical hydraulic gradient.

The differences between scenarios are minor and largely restricted to the upper aquifer.

With regard to salinity, all scenarios show a similar trend of:

- decreasing salinity in the upper aquifer (due to greater recharge with fresh water from the weir pool); and
- increasing salinity (approximately 15% over 120 years) in the middle and lower aquifer due to the stronger vertical hydraulic gradient inducing higher leakage flows from the upper aquifer, which is currently quite saline due to past recharge with saline water from the river and salt concentration by evapotranspiration in the low rainfall recharge fraction.

10.0 ASSESSMENT

10.1 Knowledge Gaps and Questions

The primary objective of this study is to assess the risk of contamination of Wilcannia's emergency ground water supply due to poor river water quality during an extended drought period, following the relocation of the weir downstream.

When this assessment commenced, two key questions were identified.

1. To what extent does the observed downward hydraulic gradient and pressure transmission from the river to the supply aquifer result in the transmission of water and the transport of contaminants such as salt or algal toxins to the aquifer i.e., what are the likely fluid flow and contaminant transport rates?
2. How much buffer storage of uncontaminated water is likely to be present in the aquifer at the start of a dry period, and how long can pumping be sustained until contaminant breakthrough occurs?

In order to answer these questions, some simpler, technical questions were formulated.

3. What are the hydraulic conductivities and porosities of the observed ground materials – sand, clayey/silty sand, sandy clay and clay?
4. What is the bulk transmissivity of the mixed deposits between the riverbed and the screened intervals of the town water supply bores?
5. How is the distribution of lithologies and associated hydraulic properties likely to vary vertically and along the length of the new weir pool?
6. What is the likely range of driving head differentials?
7. What is the composition of the river water under a range of flow conditions?
8. Is there any evidence previous surface water flow to the boreholes?
9. What will be the average discharge rate from the boreholes?
10. What is the likely duration of low-flow periods?

Answering these questions has allowed the risks to be assessed.

10.2 Conclusions

Questions 3 and 4

On the basis of analysis of the pumping test results and a better understanding of the formation lithology derived from the available bore logs, following characteristics were derived for the sands that comprise the predominant aquifer materials:

- Transmissivity 340 m^2/d
- Storativity 1.5 x 10^{-4}
- Hydraulic Conductivity 40 m/d
- Specific Storage 2 x 10^{-5} m^{-1}
- Aquitard conductivity 5 x 10^{-4} m/d

Using these values as a base, model calibration allowed the refined values set out in Table 6 above to be developed.

Question 5

An inspection of the channel has been carried out. Floor material observed in the pools and the dry channel bed was predominantly and quite uniformly cream-brown clayey silt and silty clay with some sand. There were occasional patches of grey clay in depressions in the channel floor. No sand deposits were observed. Bank slopes were typically 45° and bank materials were predominantly silt. Given the composition of these materials, a quite uniform hydraulic conductivity of the order of 1 x 10^{-7} metres per second (m/s) (0.1 m/d) would be expected.

It was not possible to complete the frequency-domain electromagnetic survey along the river bed over the length of the proposed weir-pool, but the survey was carried out along the lowest accessible part of the river bank. This was estimated to be typically 2 to 3 m above the river bed.

Question 6

It was noted in Section 2.5 above that a flow of 100 ML/d is approximately equivalent to a river stage of 64 mAHD and a flow of 1,000 ML/d to a stage of 64.5 mAHD. Recurrence intervals for one and three month durations for these events are 3.3 years and 10 years, and 3 years and 7 years respectively.

During three of the four flood and recession events for which hydrographs were reviewed, river levels fell below aquifer levels in the monitoring bores when the river stage fell below 64 m. During the recession from the fourth event, the transition occurred at a much higher stage – about 66 m. Due to the hydraulic gradient between the bore and the river, the transition point at the river-bed may be a little lower. Poor water quality – defined here as an EC above 1,500 dS/m, approximately equivalent to the drinking water guideline of 900 mg/L TDS, becomes prevalent when the river stage is below 64.5 m.

On the basis of the assessment carried out early in 2020, the critical river stage interval was assessed to be 64.0 m to 64.5 m (on recession), when the water quality is poor but there is still a driving head from the river to the aquifer. The flow statistics indicate that periods with river levels below 64.5 m occur only slightly more frequently than periods with levels below 64.0 m. It is therefore likely that river stages in the interval between 64.0 and 64.5 m previously occurred most commonly as a transition to a lower stage. When the stage dropped below 64.0 m the poor quality water that had infiltrated through the river-bed began to flow back to the river or pools.

It is clear from the hydrographs and the flow duration curves that most inflow from the river to the aquifer occurs at higher stages (above 64.5 m), when the head differential is much higher (up to 74 m) and water quality is good.

There is a brief period immediately after a cease-to-flow event when the river stage is high and water quality poor (up to 3,500 dS/m in the recent event). However, this period lasts less than two days, which may be significant ecologically, but is insignificant from a groundwater recharge perspective.

During the most recent dry period, the situation has been different, with groundwater levels remaining below river levels throughout. This is most probably due to prolonged pumping from the town emergency borefield, and in particular from TWS 1. Recent measurements of electrical conductivity indicate the presence of elevated salinity in the upper aquifer, due to recharge of this water and also possibly some saline drainage from the base of the vegetation root zone.

In assessing future conditions, there was concern that if poor quality water was allowed to accumulate in the proposed weir pool and the stage in that pool was maintained at a higher level than the groundwater level in the upper aquifer (which may then be depressed by pumping). If that were to occur, slugs of poor-quality water may enter the aquifer and continue to migrate towards the bores under the higher driving head that would occur when the weirpool refilled to capacity. However, impact on the borefield would be unlikely to occur during a single drought event – the impact would develop cumulatively over the longer term.

Groundwater modelling has now indicated that under current conditions, surface water flux through the river bed ranges from zero to 3.55 ML/d and that during periods of low river flow the shallow aquifer discharges to the river channel at rates between zero and 0.77 ML/d.

In future, regardless of the weir operating regime adopted, conditions will differ significantly from the current conditions. The most obvious differences are:

- groundwater levels will typically about 1m higher in all aquifers;

- water level in the upper aquifer will be more stable, without the high peaks driven by flood flows, although upper aquifer water levels will still be primarily driven by river (weirpool) levels;
- water levels in the lower aquifer will be almost entirely driven by borefield pumping;
- a persistent downwards vertical hydraulic gradient will develop.

The differences between operational scenarios are minor and will be largely restricted to the upper aquifer.

With regard to salinity, all scenarios show a similar trend of:

- decreasing salinity in the upper aquifer (due to greater recharge with fresh water from the weir pool); and
- increasing salinity (approximately 15% over 120 years) in the middle and lower aquifer due to the stronger vertical hydraulic gradient inducing higher leakage flows from the upper aquifer, which is currently quite saline due to past recharge with saline water from the river and salt concentration by evapotranspiration in the low rainfall recharge fraction.

The 250/300 trigger regime (861 and 866 with the 862 and 868 sensitivity cases, generates a higher frequency of outflows from the aquifer to the river than does the 100/200 regime (860 and 865).

Question 7
EC above 1,500 dS/m becomes prevalent at river stages below 64.5 m (equivalent to flows below 1,000 ML/d). The maximum recorded EC is 6,000 µS/c. Poor quality can also occur, though much less frequently, at stages up to 67.5 m.

As described above, modelling indicates that, in future, there will be a general progressive and accelerating decrease in salinity (about 10% over 120 years) in the currently-saline upper aquifer, due to infiltration of fresher water from the weirpool. It is assumed that appropriate measures with be employed to ensure that the weir-pool is well-mixed and does not become stratified with saline water at the base.

Conversely, salinity in the lower aquifers will increase due to increased downward leakage driven by higher heads in the upper aquifer. However, over a 120 year period it should remain within potable water criteria.

Question 8
The salinity of groundwater pumped from the town water supply boreholes, while acceptable, is higher than that of good quality river water. As the river is likely to have been the main source of recharge to the aquifers, this is evidence of some poor quality recharge from the river at some time in the past. The stratified salinity in the aquifer system, with more saline water in the upper aquifer, and progressively fresher water in the deeper aquifer provides further evidence of this. The age of the water cannot be established unless isotope analysis is carried out.

Question 9
Town borehole No.1 (TWS 1) has been pumped continuously at 5 to 6 L/s (0.5 ML/d) and has a nominal capacity of 7 L/s. TWS 3 was test pumped at rate of 7.5 L/s (0.65 ML/d) for 48 hours, with a drawdown of 4.8 m at the well.

Question 10
As indicated in Section 2.5, it can be seen from the flow-duration curves that under current conditions the river would be expected to cease to flow for more than a month approximately once in four years, and for more than three months once in about 20 years. However, these curves are based on historical statistics and do not allow for the effects of a drying climate and abstraction for irrigation upstream. It has been assessed from examination of the stage-discharge graph that a flow of 100 ML/d is approximately equivalent to a river stage of 64 mAHD and a flow of 1,000 ML/d to a stage of 64.5 mAHD. Recurrence intervals for these events are 3.3 years and 10 years, and 3 years and 7 years respectively for one and three month duration.

Surface water modelling carried out by Water NSW has now provided an indication of water levels in the weirpool over a 120 year period replicating 1900-2019 flow conditions. For all operating scenarios, there are relatively few (varying between 1 and 5) occasions during this period when the water level in the weirpool is predicted to fall significantly below 65.5 m AHD these major events typically last several months. Generally, the level will remain above 65.7 m AHD with the number of excursions into the 67.5 to 67.7 range dependent upon the operating scenario adopted.

10.3 Concluding Summary

In summary, and in answer to the overall question 1 and 2 identified above, it is considered very unlikely that, provided measures are implemented to ensure mixing in the weirpool, the town water supply bores, which extract water from the deep aquifer, will suffer a major deterioration in water quality during single drought events of compatible duration to those that have occurred during the past 120 years. This is the case due to the bores obtaining their water from the deepest aquifer in a three-aquifer system, and due to the lengthy leakage pathway between the river and the bores. There is, however, likely to be a progressive, but slow deterioration of water quality in the long term.

10.0 RECOMMENDATIONS

On the basis of the information collated and assessed in this report, it appears unlikely that the new weirpool would have a deleterious effect on groundwater quality pumped from the bores in the Wilcannia emergency supply borefield provided that water quality is managed to avoid stratification and an accumulation of poor quality (high EC) water at the base of the pool. In any event, travel times to the bores are long, and any impacts will be slow to develop.

It is recommended that the situation be reviewed after the new weirpool has been in operation for 12 months, and again after the system has been operational for about five years.

This review process would be assisted if:

- Real-time water level loggers (or preferably combined water level and electrical conductivity loggers) were installed in the three pipes in GW040892, and the existing real-time water-level loggers in GW040874 were upgraded to measure conductivity as well.

- Records of pumping times and rates from all the town bores, and of regular water quality measurements during operation were also maintained.

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APPENDIX A

DPIE Water - Work Summary Reports

WaterNSW
Work Summary

GW010163

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): NOT KNOWN

Work Type: Well
Work Status:
Construct.Method:
Owner Type:

Commenced Date:
Completion Date: 01/01/1951

Final Depth: 15.20 m
Drilled Depth:

Contractor Name: (None)
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m):
Salinity Description: Good
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	invalid code	RES 19334
Licensed:			

Region: 60 - Lower Murray / Darling
CMA Map: 7534

River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: (Unknown)
Northing: 6504612.000
Easting: 723828.000
Latitude: 31°34'18.5"S
Longitude: 143°21'30.5"E

GS Map: -
MGA Zone: 54
Coordinate Source: GD.,ACC.MAP

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
15.20	15.20	0.00	(Unknown)	9.80					

***** End of GW010163 *****

WaterNSW
Work Summary

GW036839

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore - Nested (3)
Work Status: Instrumented
Construct.Method: Rotary
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 01/03/1990

Final Depth: 132.00 m
Drilled Depth: 133.50 m

Contractor Name: (None)
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	MURTEE	6//757019
Licensed:			

Region: 85 - Far West
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 3.09 m (A.H.D.)
Elevation Source: Unknown

Northing: 6503290.000
Easting: 736670.500

Latitude: 31°34'52.3"S
Longitude: 143°29'38.4"E

GS Map: -
MGA Zone: 54
Coordinate Source: GD.,PR. MAP

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1	1	Casing	P.V.C.	0.00	50.00	101			
1	1	Opening	Slots - Horizontal	37.00	43.00	101		1	A: 3.17mm
2	2	Casing	P.V.C.	0.00	70.00	101			
2	2	Opening	Slots - Horizontal	58.00	64.00	101		2	Plastic, A: 3.17mm
3	3	Casing	Drilled	0.00	0.00				
3	3	Casing	P.V.C.	0.00	132.00	101			
3	3	Opening	Slots - Horizontal	99.00	105.00	101		3	A: 3.17mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
37.00	43.00	6.00	Unconsolidated	14.70		4.15			
58.00	64.00	6.00	Unconsolidated	15.70		4.50			
99.00	105.00	6.00	Unconsolidated	15.70		2.10			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	3.00	3.00	Loam Red Sandy	Loam	
3.00	17.00	14.00	Clay Grey	Clay	
17.00	49.00	32.00	Clay Yellow Water Supply	Clay	
49.00	53.00	4.00	Clay Yellow Sandy	Clay	
53.00	57.00	4.00	Clay Multicoloured	Clay	
57.00	76.00	19.00	Sand Fine Coarse Water Supply	Sand	
76.00	114.00	38.00	Sand Coarse Water Supply	Sand	

114.00	120.00	6.00	Clay Carbonaceous	Clay	
120.00	127.00	7.00	Clay Sandy Carbonaceous	Clay	
127.00	132.00	5.00	Siltstone	Siltstone	
132.00	133.50	1.50	Siltstone Sandstone	Siltstone	

Remarks

12/08/1991: HOLE 1 50M CAS NO 1 SCN NO 1.
12/08/1991: HOLE 2 70M CAS NO 3 SCN NO 3.
12/08/1991: HOLE 3 132M CAS NO 5&6 SCN NO 5.
14/10/2008: Nat Carling, 14-Oct-2008: Updated RL's, coordinates & cadastre (was entered as 'TSR 358'), based in info provided in State Water Survey database, provided by Jim Salmon.
04/03/2011: Pipe 1 has data logger
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW036839 *****

WaterNSW
Work Summary

GW039479

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE, STOCK

Work Type: Bore - GAB
Work Status:
Construct.Method: Rotary
Owner Type: Other Govt

Commenced Date: 13/12/1991
Completion Date: 15/12/1991

Final Depth: 26.75 m
Drilled Depth: 28.00 m

Contractor Name: DLWC GROUNDWATER DRILLING
Driller: Michael Norman Wilson
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 9.160
Salinity Description:
Yield (L/s): 2.140

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	invalid code	
Licensed:			

Region: 80 - Macquarie-Western
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6505010.000
Easting: 727292.000

Latitude: 31°34'03.1"S
Longitude: 143°23'41.5"E

GS Map: -
MGA Zone: 54
Coordinate Source: Map Interpre

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	28.00	254			Rotary Mud
1		Annulus	(Unknown)	0.00	28.00				Graded, Q:1.100m3
1		Backfill	Backfill	26.75	28.00	254			
1	1	Casing	Steel	0.00	22.75	168			
1	1	Opening	Screen - Wire Wound	22.75	24.75	168		0	Steel, Screwed, A: 1.40mm
1	1	Casing	Steel	24.75	26.75	168			Seated on Bottom

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
22.75	24.75	2.00	Unknown	9.16	13.55	2.14	26.75		275.00

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	7.00	7.00	Grey clay	Unknown	
7.00	11.00	4.00	Grey clayey sand	Unknown	
11.00	13.00	2.00	Yellow & grey clay	Unknown	
13.00	18.00	5.00	Grey clay	Unknown	
18.00	20.00	2.00	Coarse grey sand	Unknown	
20.00	22.00	2.00	Fine grey sand	Unknown	
22.00	26.00	4.00	Coarse grey sand	Unknown	
26.00	28.00	2.00	Silcrete	Unknown	

Remarks

15/12/1991: Form A Remarks:
Bore not licenced prior to construction. Approved by Principal Hydrogeologist as an emergency measure.
15/11/2006: The location of bore is changed to 6738//DP822061 from 4142//DP766647 as per information supplied by Russell Bow, Wilcannia Shire Engineer on 13th November 2006. Previously location was marked as 727250E, 6504750N Zone 54 AMG 66. The change of location is entered by Hari S Haridharan, Hydrogeologist, Dubbo.

***** End of GW039479 *****

WaterNSW
Work Summary

GW040872

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Rotary Mud
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 08/12/2002

Final Depth: 92.00 m
Drilled Depth: 93.20 m

Contractor Name: DLWC GROUNDWATER DRILLING
Driller: Daniel William Orr
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 10.620
Salinity Description:
Yield (L/s): 3.840

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:		UNKNOWN	
Licensed:			

Region: 80 - Macquarie-Western
CMA Map:
River Basin: - Unknown
Area/District:
Grid Zone:
Scale:

Elevation: 2.84 m (A.H.D.)
Elevation Source: Unknown
Northing: 6498505.100
Easting: 728884.500
Latitude: 31°37'33.2"S
Longitude: 143°24'47.2"E

GS Map: -
MGA Zone: 54
Coordinate Source: Unknown

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	33.00	203			Rotary Mud

1		Annulus	(Unknown)	0.00	18.00	203	90		Ungraded
1		Annulus	Bentonite	18.00	19.00	203	90		
1		Annulus	Waterworn/Rounded	19.00	33.00	203	90		Graded, Q:0.400m3
1	1	Casing	Pvc Class 12	-1.00	5.00	90	80		Glued
1		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
1	1	Opening	Slots - Horizontal	21.00	27.00	90	80	1	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
1	1	Casing	Pvc Class 12	27.00	33.00	90	80		Glued
2		Hole	Hole	0.00	66.00	203			Rotary Mud
2		Annulus	(Unknown)	0.00	54.00	203			Ungraded
2		Annulus	Bentonite	54.00	55.00	203	90		
2		Annulus	Waterworn/Rounded	55.00	66.00	203			Graded, Q:0.300m3
2	2	Casing	Pvc Class 12	-1.00	57.00	90	80		Glued
2		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
2	2	Opening	Slots - Horizontal	57.00	60.00	90	80	2	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
2	2	Casing	Pvc Class 12	60.00	66.00	90	80		Glued
3		Hole	Hole	0.00	93.20	203			Rotary Mud
3		Annulus	(Unknown)	0.00	78.00	203			Ungraded
3		Annulus	Bentonite	78.00	79.00	203			
3		Annulus	Waterworn/Rounded	79.00	93.20	203			Graded, Q:1.100m3
3	3	Casing	Pvc Class 12	-1.00	82.00	90	80		Glued
3		Casing	Casing Protector	-1.00	1.00	168	6		Cemented
3	3	Opening	Slots - Horizontal	82.00	88.00	90		3	Mechanically Slotted, PVC Class 12, SL: 35.0mm, A: 1.00mm
3	3	Casing	Pvc Class 12	88.00	92.00	90	80		Seated on Bottom, Glued

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
21.00	27.00	6.00	Unknown	10.38		3.33			8500.00
57.00	60.00	3.00	Unknown	10.59		3.57			20000.00
82.00	88.00	6.00	Unknown	10.62		3.84		01:00:00	20000.00

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Sand, very silty	Sand	
1.00	2.00	1.00	Sand, very fine, silty, slightly clayey red brown	Sand	
2.00	3.00	1.00	Clay, mid grey with calcrete chips	Clay	
3.00	6.00	3.00	Clay, as above, with som reddish brown clay	Clay	
6.00	7.00	1.00	Clay, pale grey with some chips of ironstone	Clay	
7.00	12.00	5.00	Clay, mottled with some fine sands	Clay	
12.00	14.00	2.00	Clay, pale with bits of brown and mottled streaks of yellow	Clay	
14.00	17.00	3.00	Clay, grey, pink, red & brown with some chips	Clay	
17.00	21.00	4.00	Clay, yellow grey, few grains of coarse and fewer chips	Clay	
21.00	22.00	1.00	Sandy Clay, very	Sandy Clay	Tikiri Tennakoon, 28/10/2010: Assigned code.
22.00	24.00	2.00	Sand, pale grey, fine and rounded	Sand	
24.00	32.00	8.00	Sand, fine, whitish yellow	Sand	
32.00	44.00	12.00	Sand, fine, yellow	Sand	
44.00	45.00	1.00	Ironstone	Ironstone	
45.00	47.00	2.00	Sand, fine, yellow	Sand	
47.00	50.00	3.00	Sand, fine, whitish yellow	Sand	

50.00	50.50	0.50	Ironstone	Ironstone	
50.50	52.00	1.50	Sand, fine, whitish yellow	Sand	
52.00	55.00	3.00	Sand, fine, white	Sand	
55.00	57.00	2.00	Sand, fine, whitish yellow	Sand	
57.00	62.00	5.00	Sand, medium-coarse, grey	Sand	
62.00	66.00	4.00	Sand, grey, medium	Sand	
66.00	72.00	6.00	Sand, medium, light grey	Sand	
72.00	78.00	6.00	Sand, medium-coarse, light grey, with lignite	Sand	
78.00	87.00	9.00	Sand. medium-coarse, grey	Sand	
87.00	92.00	5.00	Sand, medium-coarse, dark grey	Sand	
92.00	93.20	1.20	Sandstone, change to medium grey, fine	Sandstone	

Remarks

08/12/2002: Form A Remarks:
Wilcannia TWS - Investigation bores (Mike Williams - DLWC principal Hydrogeologist - CNR)
07/03/2003: centralisers installed in all holes
17/03/2003: Sump installed 88-92m (GW40872/3), 60-66m (GW040872/2) 27-33m (GW040872/1)
26/09/2012: Primary Client changed from PA200 to GWA on 26/09/2012.
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW040872 *****

WaterNSW
Work Summary

GW040873

Licence:
Licence Status:

Authorised Purpose(s):
Intended Purpose(s): TEST BORE

Work Type: Bore
Work Status: Instrumented
Construct.Method: Rotary Mud
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 16/12/2002
Final Depth:
Drilled Depth:

Contractor Name: DLWC GROUNDWATER DRILLING
Driller: Daniel William Orr
Assistant Driller:

Property:
GWMA:
GW Zone:
Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:		UNKNOWN	
Licensed:			

Region: 80 - Macquarie-Western
CMA Map:
River Basin: - Unknown
Area/District:
Grid Zone:
Scale:

Elevation: 2.82 m (A.H.D.)
Elevation Source: Unknown
Northing: 6500145.100
Easting: 725531.500
Latitude: 31°36'42.1"S
Longitude: 143°22'38.6"E

GS Map: -
MGA Zone: 54
Coordinate Source: Unknown

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	34.00	203			Rotary Mud
1		Annulus	(Unknown)	0.00	18.00	203	90		Ungraded
1		Annulus	Bentonite	18.00	19.00	203	90		
1		Annulus	Waterworn/Rounded	19.00	34.00	203	90		Graded, Q:0.300m3
1	1	Casing	Pvc Class 12	-1.00	24.00	90	80		Glued
1		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
1	1	Opening	Slots - Horizontal	24.00	27.00	90	80	1	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
1	1	Casing	Pvc Class 12	27.00	33.00	90	80		Seated on Bottom, Glued
2		Hole	Hole	0.00	50.00	203			Rotary Mud
2		Annulus	(Unknown)	0.00	29.00	203	90		Ungraded
2		Annulus	Bentonite	29.00	30.00	203			
2		Annulus	Waterworn/Rounded	30.00	50.00	203	90		Graded, Q:0.400m3
2	2	Casing	Pvc Class 12	-1.00	34.00	90	80		Glued
2		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
2	2	Opening	Slots - Horizontal	34.00	40.00	90	80	2	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
2	2	Casing	Pvc Class 12	40.00	46.00	90	80		Seated on Bottom, Glued
3		Hole	Hole	0.00	124.50	203			Rotary Mud
3		Annulus	(Unknown)	0.00	89.00	203			Ungraded
3		Annulus	Bentonite	89.00	90.00	203	90		
3		Annulus	Waterworn/Rounded	90.00	124.50	203			Graded, Q:0.700m3
3	3	Casing	Pvc Class 12	-1.00	94.00	90	80		Seated on Bottom, Glued
3		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
3	3	Opening	Slots - Horizontal	94.00	100.00	90		3	Mechanically Slotted, PVC Class 12, SL: 35.0mm, A: 1.00mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
24.00	27.00	3.00	Unknown	10.38		3.10		01:00:00	
34.00	40.00	6.00	Unknown	10.08		2.91		01:00:00	
94.00	100.00	6.00	Unknown	11.07		3.40		01:00:00	20000.00

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Topsoil, black	Topsoil	
1.00	5.00	4.00	Clay, dark brown	Clay	
5.00	8.00	3.00	Clay, light brown	Clay	
8.00	12.00	4.00	Clay, light brown, with fine sand	Clay	
12.00	14.00	2.00	Clay, light brown	Clay	
14.00	15.00	1.00	Clay, light brown, with sand	Clay	
15.00	17.00	2.00	Sand, light brown white	Sand	
17.00	18.00	1.00	Clay, light brown	Clay	
18.00	22.00	4.00	Clay, mid brown	Clay	
22.00	23.00	1.00	Clay, light brown	Clay	
23.00	24.00	1.00	Clay, light brown, with some sand	Clay	
24.00	27.00	3.00	Sand, white, with small amount of clay	Sand	
27.00	34.00	7.00	Sand, white, with moderate amount of clay	Sand	
34.00	50.00	16.00	Sand, white	Sand	
50.00	58.00	8.00	Sand, light brown	Sand	
58.00	61.00	3.00	Sand, coarse, light brown and grey	Sand	
61.00	65.00	4.00	Sand, coarse, grey	Sand	
65.00	68.00	3.00	Sand, medium coarse, grey	Sand	
68.00	72.00	4.00	Sand, fine medium, light grey	Sand	
72.00	88.00	16.00	Sand, medium coarse, grey	Sand	
88.00	90.00	2.00	Sand, medium, very coarse, dark grey, with coal deposits 89-90m	Sand	
90.00	101.00	11.00	Sand, very coarse, to fine gravel	Sand	
101.00	106.00	5.00	Lignite, and Shale	Lignite	Tikiri Tennakoon, 28/10/2010: Interpreted as Lignite.
106.00	124.00	18.00	Sandy Clay, light brown	Sandy Clay	Tikiri Tennakoon, 28/10/2010: Assigned code.
124.00	124.50	0.50	Bedrock	Bedrock	

Remarks

16/12/2002: Form A Remarks:
Wilcannia TWS - Investigation (Michael Williams- CNR - Principal Hydrogeologist)
17/03/2003: Centralisers Installed - all bores
17/03/2003: Sump installed from 100-106m (GW040873/3), 40-46m (GW040873/2) 27-33m (GW40873/1)
04/03/2011: Pipe 1 has data logger
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW040873 *****

WaterNSW
Work Summary

GW040874

Licence: **Licence Status:**

Authorised Purpose(s):
Intended Purpose(s): TEST BORE

Work Type: Bore
Work Status: Instrumented
Construct.Method: Rotary Mud
Owner Type: NSW Office of Water

Commenced Date: **Final Depth:** 60.00 m
Completion Date: 12/01/2003 **Drilled Depth:** 67.00 m

Contractor Name: DLWC GROUNDWATER DRILLING
Driller: Daniel William Orr
Assistant Driller:

Property: **Standing Water Level (m):** 9.200
GWMA: **Salinity Description:**
GW Zone: **Yield (L/s):** 3.270

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:		UNKNOWN	
Licensed:			

Region: 80 - Macquarie-Western **CMA Map:**
River Basin: - Unknown **Grid Zone:** **Scale:**
Area/District:

Elevation: 2.89 m (A.H.D.) **Northing:** 6503003.100 **Latitude:** 31°35'09.2"S
Elevation Source: Unknown **Easting:** 725857.500 **Longitude:** 143°22'48.7"E

GS Map: - **MGA Zone:** 54 **Coordinate Source:** Unknown

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	32.00	203			Rotary Mud
1		Annulus	(Unknown)	0.00	13.50	203	90		Ungraded
1		Annulus	Bentonite	13.50	14.50	203	90		
1		Annulus	Waterworn/Rounded	14.50	32.00	203	90		Graded, Q:0.300m3
1	1	Casing	Pvc Class 12	-1.00	17.00	90	80		Glued
1		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
1	1	Opening	Slots - Horizontal	17.00	23.00	90	80	1	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
1	1	Casing	Pvc Class 12	23.00	26.00	90	80		Seated on Bottom, Glued
2		Hole	Hole	0.00	60.00	203			Rotary Mud
2		Annulus	(Unknown)	0.00	40.00	203	90		Ungraded
2		Annulus	Bentonite	40.00	41.00	203	90		
2		Annulus	Waterworn/Rounded	41.00	60.00	203	90		Graded, Q:0.300m3
2	2	Casing	Pvc Class 12	-1.00	42.00	90	80		Glued
2		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
2	2	Opening	Slots - Horizontal	42.00	48.00	90	80	2	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
2	2	Casing	Pvc Class 12	48.00	54.00	90	80		Seated on Bottom, Glued
3		Hole	Hole	0.00	67.00	203			Rotary Mud
3		Annulus	(Unknown)	0.00	50.00	203			Ungraded
3		Annulus	Bentonite	50.00	51.00	203	90		
3		Annulus	Waterworn/Rounded	51.00	67.00	203	90		Graded, Q:0.300m3
3	3	Casing	Pvc Class 12	-1.00	54.00	90	80		Glued
3		Casing	Casing Protector	-1.00	1.00	168	155		Cemented
3	3	Opening	Slots - Horizontal	54.00	57.00	90	80	3	Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 1.00mm
3	3	Casing	Pvc Class 12	57.00	60.00	90	80		Seated on Bottom, Glued

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
17.00	23.00	6.00	Unknown	9.60		0.91		01:00:00	800.00
42.00	48.00	6.00	Unknown	8.10		2.85		01:00:00	
54.00	57.00	3.00	Unknown	9.20		3.27		01:00:00	

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Topsoil, Black	Topsoil	
1.00	9.00	8.00	Clay, dark grey	Clay	
9.00	14.50	5.50	Clay, light brown	Clay	
14.50	20.50	6.00	Sand, medium coarse, light grey	Sand	
20.50	21.00	0.50	Sticky Clay, light brown	Clay	
21.00	23.00	2.00	Sand, medium coarse	Sand	
23.00	32.00	9.00	Clay, lightbrown, sticky	Clay	
32.00	34.00	2.00	Clay, black, sticky	Clay	
34.00	42.00	8.00	Clay, lightbrown, sticky	Clay	
42.00	48.00	6.00	Sand, medium, light brown	Sand	
48.00	51.00	3.00	Sandy Clay, lightbrown	Sandy Clay	Tikiri Tennakoon, 28/10/2010: Assigned code.
51.00	57.00	6.00	Sand, lightgrey, fine	Sand	
57.00	60.00	3.00	Sandy Clay, grey	Sandy Clay	Tikiri Tennakoon, 28/10/2010: Assigned code.
60.00	67.00	7.00	Clay, grey	Clay	

Remarks

12/01/2003: Form A Remarks:
Wilcannia TWS Investigation - Michael Williams CNR - Principal Hydrogeologist
17/03/2003: Centralisers installed - all bores
17/03/2003: Sump from 57-60m (GW040874/3) , 48-54m (GW040874/2), 23-26m (GW040874/1)
04/03/2011: All three pipes have data loggers.
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW040874 *****

WaterNSW
Work Summary

GW040891

Licence:
Licence Status:

Authorised Purpose(s):
Intended Purpose(s): TEST BORE

Work Type: Bore
Work Status: Filled
Construct.Method: Cable Tool (Mu
Owner Type: Local Govt

Commenced Date:
Completion Date: 27/08/2003
Final Depth: 54.00 m
Drilled Depth: 54.00 m

Contractor Name: DIPNR Groundwater Drilling
Driller: Phillip Lihou
Assistant Driller:

Property:
GWMA:
GW Zone:
Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	LT 4143 DP 766648
Licensed:			

Region: 80 - Macquarie-Western
CMA Map: 7534
River Basin: 425 - DARLING RIVER
Grid Zone:
Scale:
Area/District:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown
Northing: 6503535.000
Easting: 725911.000
Latitude: 31°34'52.0"S
Longitude: 143°22'50.3"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	54.00	457			Cable Tool (Mud Stabilised)
1		Annulus	(Unknown)	0.00	35.00	457	273		
1		Annulus	Waterworn/Rounded	35.00	54.00	457	273		Graded, Q:3.200m3
1	1	Casing	Steel - Erw	0.00	53.00	273	263		Seated on Backfill, Welded - Butt
1	1	Opening	Screen - Round Wire	46.00	52.00	273	263	1	Stainless Steel, Welded - Butt, A: 1.00mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
18.30	20.40	2.10	Unknown						
45.20	52.00	6.80	Unknown						

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Topsoil, grey	Topsoil	
1.00	6.00	5.00	Sandy Clay, fine, light brown	Invalid Code	
6.00	14.00	8.00	Alternate bands of sand & clay	Clay	
14.00	16.00	2.00	Clay, yellow	Clay	
16.00	18.30	2.30	Sandy Clay	Invalid Code	
18.30	20.40	2.10	Sand, fine, light brown	Sand	
20.40	45.20	24.80	Clay, sticky, various colours	Clay	
45.20	52.00	6.80	Sand, fine, yellow/white	Sand	
52.00	54.00	2.00	Sandy Clay, light grey	Invalid Code	

Remarks

27/08/2003: Form A Remarks:
Wilcannia TWS. "Yobel"
Abandoned & backfilled with casing left in works to 53m. Sump was installed from 52m to 53m.
Grout seal was used from 0 to 35m. Gravel pack was poured or shovelled into annulus.
Assistant driller was S Cullen & D Orr, total of 3 drillers.

***** End of GW040891 *****

WaterNSW
Work Summary

GW040892

Licence:
Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Equipped
Construct.Method: Cable Tool (Mu
Owner Type: Local Govt

Commenced Date:
Completion Date: 08/04/2003
Final Depth: 67.00 m
Drilled Depth: 67.00 m

Contractor Name: DIPNR Groundwater Drilling
Driller: Phillip Lihou
Assistant Driller:

Property:
GWMA:
GW Zone:
Standing Water Level (m): 10.350
Salinity Description:
Yield (L/s): 3.240

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	LT 4143 DP 766648
Licensed:			

Region: 80 - Macquarie-Western
CMA Map: 7534
River Basin: 425 - DARLING RIVER
Grid Zone:
Scale:
Area/District:

Elevation: 2.90 m (A.H.D.)
Elevation Source: Unknown
Northing: 6503497.100
Easting: 725742.500
Latitude: 31°34'53.4"S
Longitude: 143°22'44.0"E

GS Map: -
MGA Zone: 54
Coordinate Source: GD.,PR. MAP

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	67.00	254			Cable Tool (Mud Stabilised)
1		Annulus	Waterworn/Rounded	1.00	67.00	254	65		Graded, Q:3.000m3
1		Annulus	Bentonite	19.50	20.00	254	65		
1		Annulus	Bentonite	39.50	40.00	254	65		
1	1	Casing	Pvc Class 12	0.00	18.00	65	55		Seated on Backfill, Glued
1	1	Opening	Slots - Horizontal	14.00	17.00	65	55	1	Casing - Machine Slotted, PVC Class 12, Glued, A: 1.00mm
1	2	Casing	Pvc Class 12	0.00	32.00	65	55		Seated on Backfill, Glued
1	2	Opening	Slots - Horizontal	28.00	31.00	65	55	1	Casing - Machine Slotted, PVC Class 12, Glued, A: 1.00mm
1	3	Casing	Pvc Class 12	0.00	55.00	65	55		Seated on Backfill, Glued
1	3	Opening	Slots - Horizontal	48.00	54.00	65	55	1	Casing - Machine Slotted, PVC Class 12, Glued, A: 1.00mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
10.20	22.50	12.30	Unknown	10.35		0.84			256.00
27.00	32.20	5.20	Unknown	10.26		1.10			256.00
45.50	54.00	8.50	Unknown	10.28		1.30			448.00

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Topsoil, light grey	Topsoil	
1.00	3.60	2.60	Sandy Clay, grey	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.

3.60	10.20	6.60	Alt bands, finely brown sand & clay	Sand	
10.20	22.50	12.30	Sand, fine, light brown	Sand	
22.50	23.60	1.10	Clay, yellow	Clay	
23.60	27.00	3.40	Sand & Clay bands	Sand	
27.00	32.20	5.20	Sand, light brown, fine	Sand	
32.20	45.50	13.30	Clay, Sticky	Clay	
45.50	54.00	8.50	Sand, fine, yellow/white	Sand	
54.00	56.10	2.10	Sandy Clay	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
56.10	59.30	3.20	Clay, grey	Clay	
59.30	60.10	0.80	Sand, fine, light grey	Sand	
60.10	62.30	2.20	Sandy Clay	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
62.30	67.00	4.70	Shale, dark brown	Shale	

Remarks

08/04/2003: Form A Remarks:
Wilcannia TWS Monitoring. Coordinates slightly off property on the reserve across Darling River.
Assistant driller was Scott Cullen, total of 2 drillers. All 3 pipes were seated on backfill. Bentonite seal was used from 10.5m to 20m & 39.5m to 40m. Gravel pack was poured or shovelled into annulus. Casing Protector (203mm) from -1m to 1m.
26/09/2012: Primary Client changed from PA200 to GWA on 26/09/2012.
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW040892 *****

WaterNSW
Work Summary

GW040893

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): TEST BORE

Work Type: Bore
Work Status: Filled
Construct.Method: Cable Tool (Mud Stabilised)
Owner Type: Local Govt

Commenced Date:
Completion Date: 04/06/2003

Final Depth: 45.00 m
Drilled Depth: 45.00 m

Contractor Name: DIPNR Groundwater Drilling
Driller: Phillip Lihou
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	LT 4143 DP 766648
Licensed:			

Region: 80 - Macquarie-Western
CMA Map: 7534
River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown
Northing: 6503535.000
Easting: 725911.000
Latitude: 31°34'52.0"S
Longitude: 143°22'50.3"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	45.00	250			Cable Tool (Mud Stabilised)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
18.30	20.40	2.10	Unknown						

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Topsoil, grey	Topsoil	
1.00	6.00	5.00	Sandy Clay, fine	Invalid Code	
6.00	14.00	8.00	Alternate bands of Sand & Clay	Clay	
14.00	16.00	2.00	Clay, yellow	Clay	
16.00	20.40	4.40	Sand, fine	Sand	
20.40	45.00	24.60	Clay, sticky	Clay	

Remarks

04/06/2003: Form A Remarks:
Wilcannia TWS. "Yobel".
Abandoned & backfilled with Clay from 0 to 45m.
Assistant driller was James Coceancic, total of 2 drillers.

***** End of GW040893 *****

WaterNSW
Work Summary

GW040897

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): TEST BORE

Work Type: Bore - GAB
Work Status: Supply Obtained
Construct.Method: Cable Tool (Mu
Owner Type: Local Govt

Commenced Date:
Completion Date: 27/08/2003

Final Depth: 57.00 m
Drilled Depth: 57.00 m

Contractor Name: DIPNR Groundwater Drilling
Driller: Jayson Gregory Ray
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 9.100
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	4143//766648
Licensed:			

Region: 85 - Far West
CMA Map: 7534
River Basin: 425 - DARLING RIVER
Grid Zone:
Scale:
Area/District:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown
Northing: 6503002.000
Easting: 725788.000
Latitude: 31°35'09.4"S
Longitude: 143°22'46.1"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	57.00	425			Cable Tool (Mud Stabilised)
1		Annulus	Waterworn/Rounded	1.50	57.00	425	273		Graded, Q:6.000m3
1	1	Casing	Steel - Erw	0.00	57.00	273	261		Seated on Bottom, Welded - Butt
1	1	Opening	Screen - Wedge Wire	49.00	55.00	273	261	0	Stainless Steel, Welded - Butt, A: 1.00mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
47.60	51.20	3.60	Unknown	9.10					
51.40	55.00	3.60	Unknown	9.10					

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Topsoil, grey	Topsoil	
1.00	7.00	6.00	Sandy Clay	Invalid Code	
7.00	15.00	8.00	Sand & Clay Bands	Sand	
15.00	17.30	2.30	Clay, yellow	Clay	
17.30	20.90	3.60	Sand, brown	Sand	
20.90	47.60	26.70	Clay	Clay	
47.60	51.20	3.60	Sand, fine	Sand	
51.20	51.40	0.20	Clay Band	Clay	
51.40	55.20	3.80	Sand, fine	Sand	
55.20	57.00	1.80	Clay, grey	Clay	

Remarks

27/08/2003: Form A Remarks:
Wilcannia TWS. Location needs checking, slightly off property in Darling River.
James Coceancic was assistant driller, total of 2 driller. Sump was installed from 55m to 57m. Gravel pack was poured or shovelled into annulus. 3 Chlorine tablets were dropped from top of bore on completion.
04/11/2013: The GPS coordinate recorded by Licensing officers are used to update the correct location today. Hari S Haridharan.

***** End of GW040897 *****

WaterNSW
Work Summary

GW042427

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 28/04/1992

Final Depth: 9.60 m
Drilled Depth: 13.00 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 9.480
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	RES ADJ 5826//768724
Licensed:			

Region: 85 - Far West
CMA Map: 7534

River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 72.19 m (A.H.D.)
Elevation Source: (unknown)

Northing: 6503905.000
Easting: 717748.000

Latitude: 31°34'45.6"S
Longitude: 143°17'40.6"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	13.00	0			Auger

1	1	Casing	P.V.C.	-1.00	9.60	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Sandy Clay Loam, fine, grey	Invalid Code	
1.00	1.50	0.50	Sandy Clay, fine, reddish brown	Invalid Code	
1.50	2.00	0.50	Sandy Clay, fine, redbrown	Invalid Code	slight calcium carbonate (concretionary)
2.00	3.50	1.50	Sandy Clay, fine, redbrown	Invalid Code	moderate calcium carbonate (concretionary)
3.50	4.00	0.50	Sandy Clay, fine-medium, light brown-greybrown	Invalid Code	
4.00	5.00	1.00	Clay, medium, grey	Clay	slight calcium carbonate (concretionary)
5.00	7.50	2.50	Sand, fine, grey	Sand	
7.50	13.00	5.50	Sand, grey, coarse & fine	Sand	

Remarks

28/04/1992: Form A Remarks:
Darling River Water Quality Enhancement project. Water level monitored by hand.
07/10/2008: Nat Carling, 7-Oct-2008: Updated cadastre & coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042427 *****

WaterNSW
Work Summary

GW042428

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 29/04/1992

Final Depth: 14.70 m
Drilled Depth: 15.00 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 10.790
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	RES ADJ 2//757463
Licensed:			

Region: 85 - Far West
CMA Map: 7534

River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 75.04 m (A.H.D.)
Elevation Source: (unknown)
Northing: 6502552.000
Easting: 721955.000
Latitude: 31°35'26.7"S
Longitude: 143°20'21.2"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	15.00	0			Auger

1	1	Casing	P.V.C.	-0.70	14.70	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.00	1.00	Sandy Clay, fine, dull greybrown	Invalid Code	moderate calcium carbonate (concretionary)
1.00	4.50	3.50	Sandy Clay, fine, dull reddish brown	Invalid Code	moderate calcium carbonate (concretionary)
4.50	11.00	6.50	Sand, very fine, grey	Sand	
11.00	13.00	2.00	Sand, yellowish grey	Sand	
13.00	14.50	1.50	Sand/clayey sand, grey-grebrown	Sand	
14.50	15.00	0.50	Sandy Clay, greybrown	Invalid Code	

Remarks

29/04/1992: Form A Remarks:
Darling River Water Quality Enhancement Project - water level currently monitored by hand.
11/05/2007: Nat Carling, 11-May-2007: Adjusted coordinates through ArcMap, based on Geology map provided with report.
07/10/2008: Nat Carling, 7-Oct-2008: Updated cadastre & coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042428 *****

WaterNSW
Work Summary

GW042429

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 04/04/1992

Final Depth: 11.72 m
Drilled Depth: 15.00 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 10.420
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	WILCANNIA SO	3445//765734
Licensed:			

Region: 85 - Far West
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 74.17 m (A.H.D.)
Elevation Source: (unknown)

Northing: 6502983.000
Easting: 724364.000

Latitude: 31°35'11.0"S
Longitude: 143°21'52.1"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	15.00	0			Auger

1	1	Casing	P.V.C.	-0.68	11.72	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.50	1.50	Clayey Sand, fine, red brown	Clayey Sand	moderate calcium carbonate (concretioanry) at 1.5m Tikiri Tennakoon, 29/10/2010: Assigned code.
1.50	3.00	1.50	Clayey sand/sandy clay, light brown	Clayey Sand	moderate calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
3.00	4.00	1.00	Sandy Clay, light brown - grey	Sandy Clay	moderate calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
4.00	5.00	1.00	Sandy Clay, fine-medium, greybrown	Sandy Clay	moderate calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
5.00	6.00	1.00	Clay, medium, greybrown-grey	Clay	moderate calcium carbonate (concretionary)
6.00	6.50	0.50	Sandy Clay, fine, grey	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
6.50	7.50	1.00	Sandy Clay, fine, grey	Sandy Clay	high calcium carbonate (concretionary) calcite layer/s 6.5-7m Tikiri Tennakoon, 29/10/2010: Assigned code.
7.50	12.50	5.00	Sand, fine, grey	Sand	slight clay
12.50	15.00	2.50	Sand/clayey sand, yellowish grey	Sand	

Remarks

04/04/1992: Form A Remarks:
Darling River Water Quality Enhancement project . Water level monitored by hand.
11/05/2007: Nat Carling, 11-May-2007: Adjusted coordinates through ArcMap, based on Geology map provided.
07/10/2008: Nat Carling, 7-Oct-2008: Updated coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042429 *****

WaterNSW
Work Summary

GW042430

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 29/04/1992

Final Depth:
Drilled Depth: 16.00 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 9.990
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	WILCANNIA SO	RD ADJ 4143//766648
Licensed:			

Region: 85 - Far West
CMA Map: 7534
River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 74.87 m (A.H.D.)
Elevation Source: (unknown)
Northing: 6502664.000
Easting: 727249.000
Latitude: 31°35'19.3"S
Longitude: 143°23'41.8"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	16.00	0			Auger

1	1	Casing	P.V.C.	0.00	0.00	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	2.00	2.00	Sandy Clay Loam, fine, dull light greybrown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
2.00	3.00	1.00	Clay, light, medium, greybrown	Clay	
3.00	4.00	1.00	Sandy Clay, fine-medium, yellowish greybrown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
4.00	5.00	1.00	Sandy Clay, fine-medium, light brown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
5.00	6.00	1.00	Sandy Clay, light brown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
6.00	8.00	2.00	Clayey sand, very fine, grey-yellowish grey	Sandy Clay	slight calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
8.00	9.00	1.00	Sandy Clay, grey	Sandy Clay	moderate calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
9.00	12.00	3.00	Sandy Clay, fine-medium,	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
12.00	15.00	3.00	Sand, very fine, yellowish grey	Sand	slight clay
15.00	16.00	1.00	Sandy Clay, yellow-grey	Sandy Clay	cemented Tikiri Tennakoon, 29/10/2010: Assigned code.

Remarks

29/04/1992: Form A Remarks:
Darling Rivver Water Quality Enhancement project. Water level currently monitored by hand. Casing details and completed depth not provided.
11/05/2007: Nat Carling, 11-May-2007: Adjusted coordinates through ArcMap, based on Geology map provided.
07/10/2008: Nat Carling, 7-Oct-2008: Updated cadastre & coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042430 *****

WaterNSW
Work Summary

GW042431

Licence:
Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 29/04/1992
Final Depth:
Drilled Depth: 13.00 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:
Standing Water Level (m): 9.820
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	WILCANNIA SO	RD ADJ 538//761514
Licensed:			

Region: 85 - Far West
CMA Map: 7534

River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 75.23 m (A.H.D.)
Elevation Source: (unknown)
Northing: 6500204.000
Easting: 728275.000
Latitude: 31°36'38.4"S
Longitude: 143°24'22.7"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	13.00	0			Auger

1	1	Casing	P.V.C.	0.00	0.00	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.50	0.50	Sandy Clay Loam, fine, dull lightbrown	Sandy Clay Loam	Tikiri Tennakoon, 29/10/2010: Assigned code.
0.50	3.00	2.50	Clay, medium, dull lightbrown	Clay	slight fine sand
3.00	4.00	1.00	Clay Loam, lightbrown	Clay Loam	Tikiri Tennakoon, 29/10/2010: Assigned code.
4.00	5.00	1.00	Sandy Clay, yellowish brown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
5.00	6.00	1.00	Sandy Clay, yellowish greybrown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
6.00	7.00	1.00	Sandy Clay, fine, yellowbrown	Sandy Clay	slight calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
7.00	8.50	1.50	Sand, very fine, yellow	Sand	
8.50	13.00	4.50	Sand, yellow	Sand	

Remarks

29/04/1992: Form A Remarks:
Darling River Water Quality Enhancement project. Water level currently monitored by hand. Casing/completed depth details not provided.
07/10/2008: Nat Carling, 7-Oct-2008: Added cadastre, updated coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042431 *****

WaterNSW
Work Summary

GW042432

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 30/04/1992

Final Depth: 21.10 m
Drilled Depth: 23.50 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 11.000
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	WILCANNIA SO	RD ADJ 538//761514
Licensed:			

Region: 85 - Far West
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 74.01 m (A.H.D.)
Elevation Source: (unknown)

Northing: 6498646.000
Easting: 728936.000

Latitude: 31°37'28.5"S
Longitude: 143°24'49.1"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	23.50	0			Auger

1	1	Casing	P.V.C.	-1.00	21.10	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.50	0.50	Sandy Clay, very fine, dull light grey	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
0.50	2.00	1.50	Sandy Clay, fine, dull light grey - greybrown	Sandy Clay	moderate Calcium Carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
2.00	2.50	0.50	Sandy Clay, fine-medium, light brown	Sandy Clay	high calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
2.50	3.50	1.00	Sandy Clay, fine-medium, light brown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
3.50	4.50	1.00	Sandy Clay/clayey sand, yellowish grey brown	Sandy Clay	moderate calcium carbonate (concretionary) Tikiri Tennakoon, 29/10/2010: Assigned code.
4.50	5.00	0.50	Sandy Clay, fine-medium, greybrown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
5.00	5.50	0.50	Clayey sand, yellow	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
5.50	6.00	0.50	Sandy Clay, light grey brown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
6.00	6.50	0.50	Clay, hard, grey	Clay	
6.50	7.00	0.50	Clay, hard, grey-dark redbrown	Clay	
7.00	9.00	2.00	Clay, hard, dark redbrown	Clay	
9.00	13.00	4.00	Clay, medium, dark redbrown	Clay	
13.00	14.50	1.50	Clay, medium, reddish brown	Clay	
14.50	17.50	3.00	Clay, medium, brown	Clay	
17.50	18.50	1.00	Clay, light, medium, brown	Clay	
18.50	20.00	1.50	Clay, medium, brown	Clay	
20.00	21.00	1.00	Silty Clay, lightbrown	Silty Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
21.00	23.00	2.00	Clay, medium, brown	Clay	
23.00	23.50	0.50	Sandy Clay - fine-medium, yellow	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.

Remarks

30/04/1992: Form A Remarks:
Darling River Water Quality Enhancement project. Water level currently monitored by hand.
07/10/2008: Nat Carling, 7-Oct-2008: Added cadastre, updated coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042432 *****

WaterNSW
Work Summary

GW042433

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 29/04/1992

Final Depth: 13.90 m
Drilled Depth: 14.50 m

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 9.800
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	WILCANNIA SO	538//761514
Licensed:			

Region: 85 - Far West
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 73.35 m (A.H.D.)
Elevation Source: (unknown)

Northing: 6496887.000
Easting: 729720.000

Latitude: 31°38'25.0"S
Longitude: 143°25'20.3"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	14.50	0			Auger

1	1	Casing	P.V.C.	-1.00	13.90	50			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	1.50	1.50	Sandy Clay Loam, fine, dull greybrown	Sandy Clay Loam	Tikiri Tennakoon, 29/10/2010: Assigned code.
1.50	5.00	3.50	Clay, medium, dull brownish grey	Clay	slight gypsum
5.00	6.00	1.00	Clay, hard, greybrown	Clay	
6.00	7.00	1.00	Clay, hard, greybrown	Clay	
7.00	10.00	3.00	Clayey sand, very fine to very fine sand, light yellowish brown	Clayey Sand	Tikiri Tennakoon, 29/10/2010: Assigned code.
10.00	11.50	1.50	Sand, fine, brownish grey	Sand	
11.50	13.00	1.50	Clayey sand, grey	Clayey Sand	Tikiri Tennakoon, 29/10/2010: Assigned code.
13.00	14.50	1.50	Sand, fine, yellowish grey	Sand	

Remarks

29/04/1992: Form A Remarks:
Darling River Water Quality Enhancement project. Water level currently monitored by hand..
07/10/2008: Nat Carling, 7-Oct-2008: Added cadastre, updated coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042433 *****

WaterNSW
Work Summary

GW042434

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): MONITORING BORE

Work Type: Bore - Nested (2)
Work Status: Manual Observations,6-12 Months
Construct.Method: Auger
Owner Type: NSW Office of Water

Commenced Date:
Completion Date: 30/04/1992

Final Depth:
Drilled Depth:

Contractor Name: DWR GROUNDWATER DRILLING - LEETON
Driller:
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	WERUNDA	GUNYULKA	RD ADJ 538//761514
Licensed:			

Region: 85 - Far West
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 73.45 m (A.H.D.)
Elevation Source: (unknown)

Northing: 6494950.000
Easting: 730491.000

Latitude: 31°39'27.3"S
Longitude: 143°25'51.2"E

GS Map: -
MGA Zone: 54
Coordinate Source: GPS - Global

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	14.50	0			Auger

1	1	Casing	P.V.C.	-1.00	11.40	50			
2	2	Casing	P.V.C.	0.00	0.00				

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.00	0.00	Sandy Clay Loam, fine, light grey brown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
1.50	2.50	1.00	Sandy Clay Loam, fine, light grey brown	Sandy Clay	slight gypsum Tikiri Tennakoon, 29/10/2010: Assigned code.
2.50	6.00	3.50	Clay, medium, light greybrown	Clay	
6.00	7.50	1.50	Sandy Clay, light, medium, light greybrown	Sandy Clay	Tikiri Tennakoon, 29/10/2010: Assigned code.
7.50	8.50	1.00	Clayey sand, light grey	Clayey Sand	Tikiri Tennakoon, 29/10/2010: Assigned code.
8.50	13.00	4.50	Clayey sand	Clayey Sand	Tikiri Tennakoon, 29/10/2010: Assigned code.
13.00	14.50	1.50	Sand, grey, coarse & fine	Sand	

Remarks

30/04/1992: Darling River Water Quality Enhancement Project. Water level currently monitored by hand.
10/09/2003: Casing borken and pipe inaccessible as of 2002.
commment entered 9 Sept 2003 by M.SETON (DUBBO)
07/10/2008: Nat Carling, 7-Oct-2008: Added cadastre, updated coordinates, based on State Water Survey Database info provided by Jim Salmon.

***** End of GW042434 *****

WaterNSW
Work Summary

GW803951

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): DOMESTIC

Work Type: Bore
Work Status: Supply Obtained
Construct.Method: Rotary Air
Owner Type: Private

Commenced Date:
Completion Date: 14/10/2008

Final Depth: 24.00 m
Drilled Depth: 24.00 m

Contractor Name: Cresswell Drilling
Driller: Leon John Cresswell
Assistant Driller: Robbie Cresswell

Property:
GWMA:
GW Zone:

Standing Water Level (m): 10.600
Salinity Description: Excellent
Yield (L/s): 1.000

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	95//757463
Licensed:			

Region: 85 - Far West
CMA Map: 7534
River Basin: 425 - DARLING RIVER
Area/District:
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown
Northing: 6507025.000
Easting: 729213.000
Latitude: 31°32'56.4"S
Longitude: 143°24'52.6"E

GS Map: -
MGA Zone: 54
Coordinate Source: GIS - Geogra

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	24.00	200			Rotary Air
1	1	Casing	Pvc Class 12	-0.60	15.00	150	134		Glued
1	1	Opening	Slots - Horizontal	15.00	21.00	150		0	Casing - Plasma-cut Slot, PVC Class 12, Glued, SL: 50.0mm, A: 25.00mm
1	1	Casing	Pvc Class 12	21.00	24.00	150	134		Seated on Bottom, Glued, S: 21.00-24.00m

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
13.00	21.00	8.00	Unknown	10.60	13.00	1.00		01:30:00	

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	2.00	2.00	Topsoil, grey, river Clay	Topsoil	
2.00	5.00	3.00	Clay, lighter grey, traces red/brown Clay	Clay	
5.00	6.00	1.00	Clay, yellow	Clay	
6.00	10.00	4.00	Sandstone, traces Clay	Sandstone	
10.00	12.00	2.00	Sandstone, traces fine Silica Sand	Sandstone	
12.00	21.00	9.00	Sand, coarse/Gravel, Quartz, Siltstone	Sand	
21.00	24.00	3.00	Sandstone, yellow/grey	Sandstone	

Remarks

14/10/2008: Form A Remarks:
Nat Carling, 27-Nov-2009: Coordinates based on location map provided with the Form A.

***** End of GW803951 *****

WaterNSW
Work Summary

GW804531

Licence:

Licence Status:

Authorised Purpose(s):
Intended Purpose(s): TOWN WATER SUPPLY

Work Type: Bore
Work Status: Supply Obtained
Construct.Method: Rotary Mud
Owner Type: Private

Commenced Date:
Completion Date: 08/08/2007

Final Depth: 54.00 m
Drilled Depth: 54.00 m

Contractor Name: Mannion Drilling
Driller: Jason Roger Mannion
Assistant Driller:

Property:
GWMA:
GW Zone:

Standing Water Level (m): 14.000
Salinity Description: Good
Yield (L/s): 10.000

Site Details

Site Chosen By:

	County	Parish	Cadastre
Form A:	YOUNG	WILCANNIA	7022//1124519
Licensed:			

Region: 85 - Far West
River Basin: 425 - DARLING RIVER
Area/District:

CMA Map: 7534
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source: Unknown

Northing: 6503287.000
Easting: 725806.000

Latitude: 31°35'00.1"S
Longitude: 143°22'46.6"E

GS Map: -
MGA Zone: 54
Coordinate Source: GIS - Geogra

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

Hole	Pipe	Component	Type	From (m)	To (m)	Outside Diameter (mm)	Inside Diameter (mm)	Interval	Details
1		Hole	Hole	0.00	54.00	320			Rotary Mud
1		Annulus	Bentonite/Grout	0.00	10.00	320	220		PL:Poured/Shovelled
1		Annulus	Waterworn/Rounded	10.00	54.00	320	220		Graded, PL:Poured/Shovelled
1	1	Casing	Pvc Class 12	-0.50	48.00	230	210		Seated on Bottom, Glued
1	1	Opening	Screen - Round Wire	48.00	54.00	220		0	Stainless Steel 304, Glued, A: 1.00mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
48.00	53.00	5.00	Unknown	14.00		10.00			

Drillers Log

From (m)	To (m)	Thickness (m)	Drillers Description	Geological Material	Comments
0.00	0.50	0.50	Topsoil	Topsoil	
0.50	2.00	1.50	Clay	Clay	
2.00	21.00	19.00	Sandy Clay	Sandy Clay	
21.00	48.00	27.00	Sandy Clay, brown	Sandy Clay	
48.00	53.00	5.00	Sand	Sand	
53.00	54.00	1.00	Clay	Clay	

Remarks

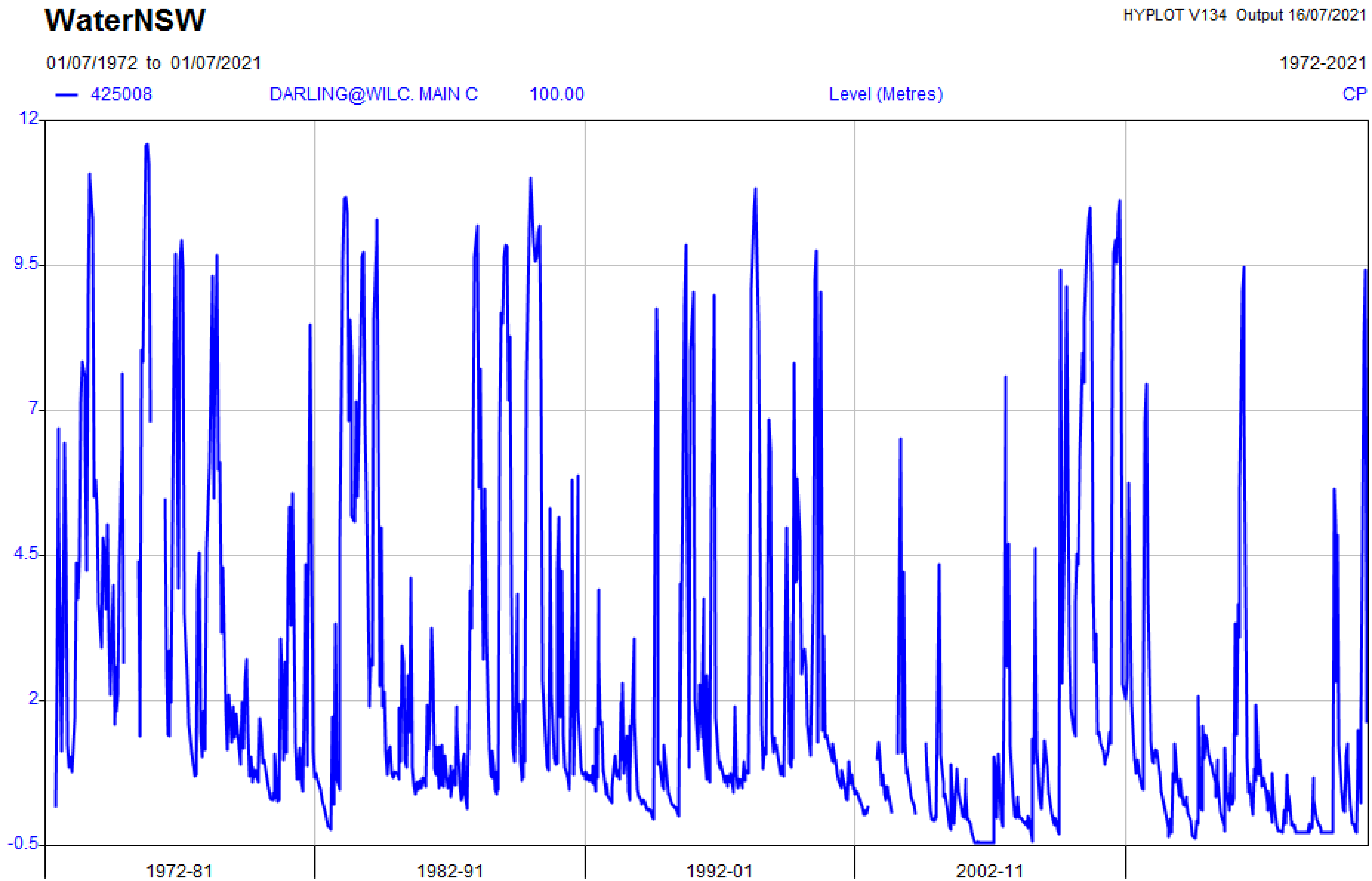
08/08/2007: Form A Remarks:

Nat Carling, 17-Jan-2012; All details were provided by Council. Coordinates based on location map provided with the Form-AG. Requested missing Form-A from the driller.
30/01/2012: Nat Carling, 30-Jan-2012; Updated details, as provided on driller's Form-A.
16/05/2012: Nat Carling, 15-May-2012; Attached new water licence, as directed.

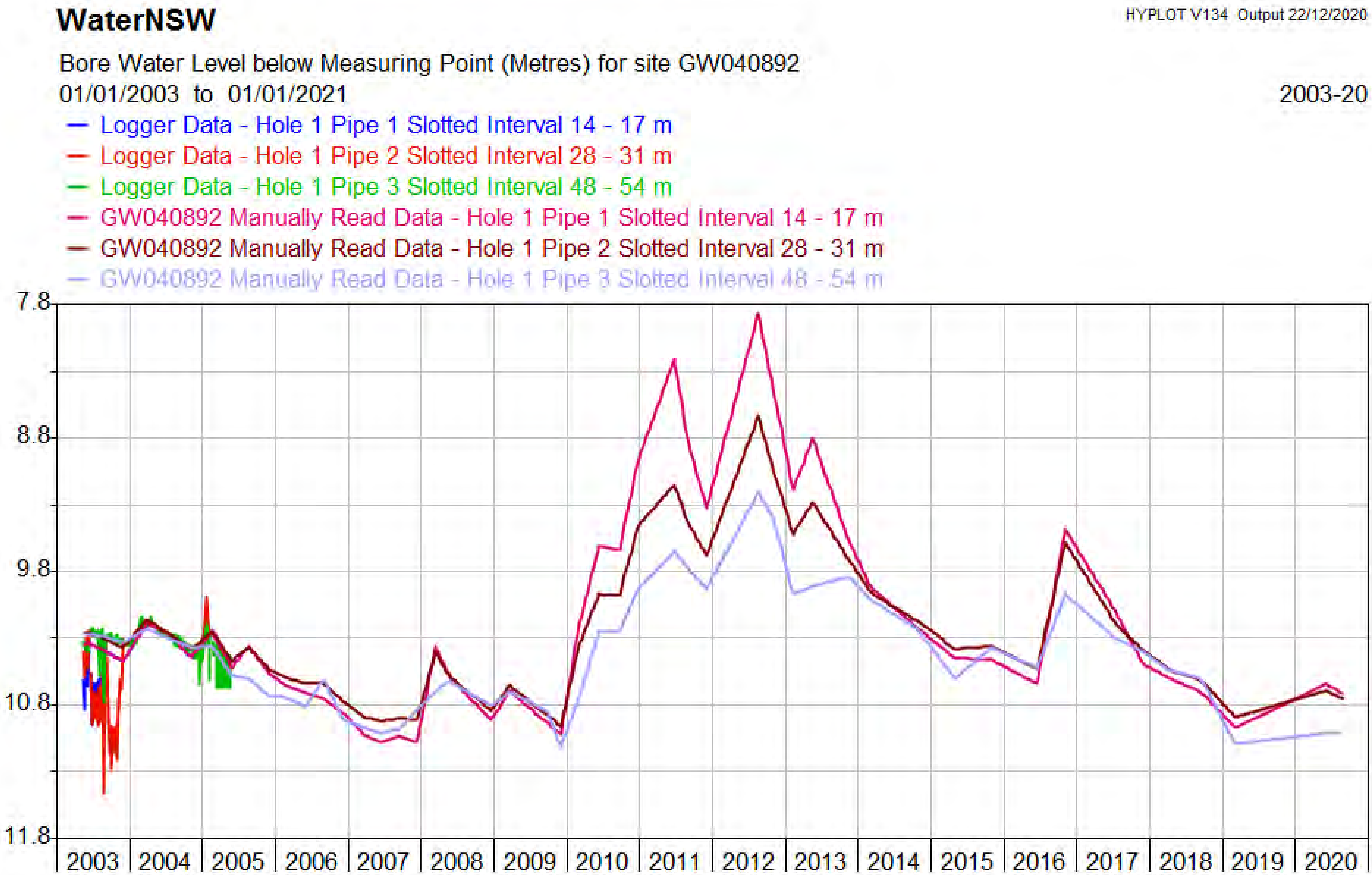
***** End of GW804531 *****

APPENDIX B

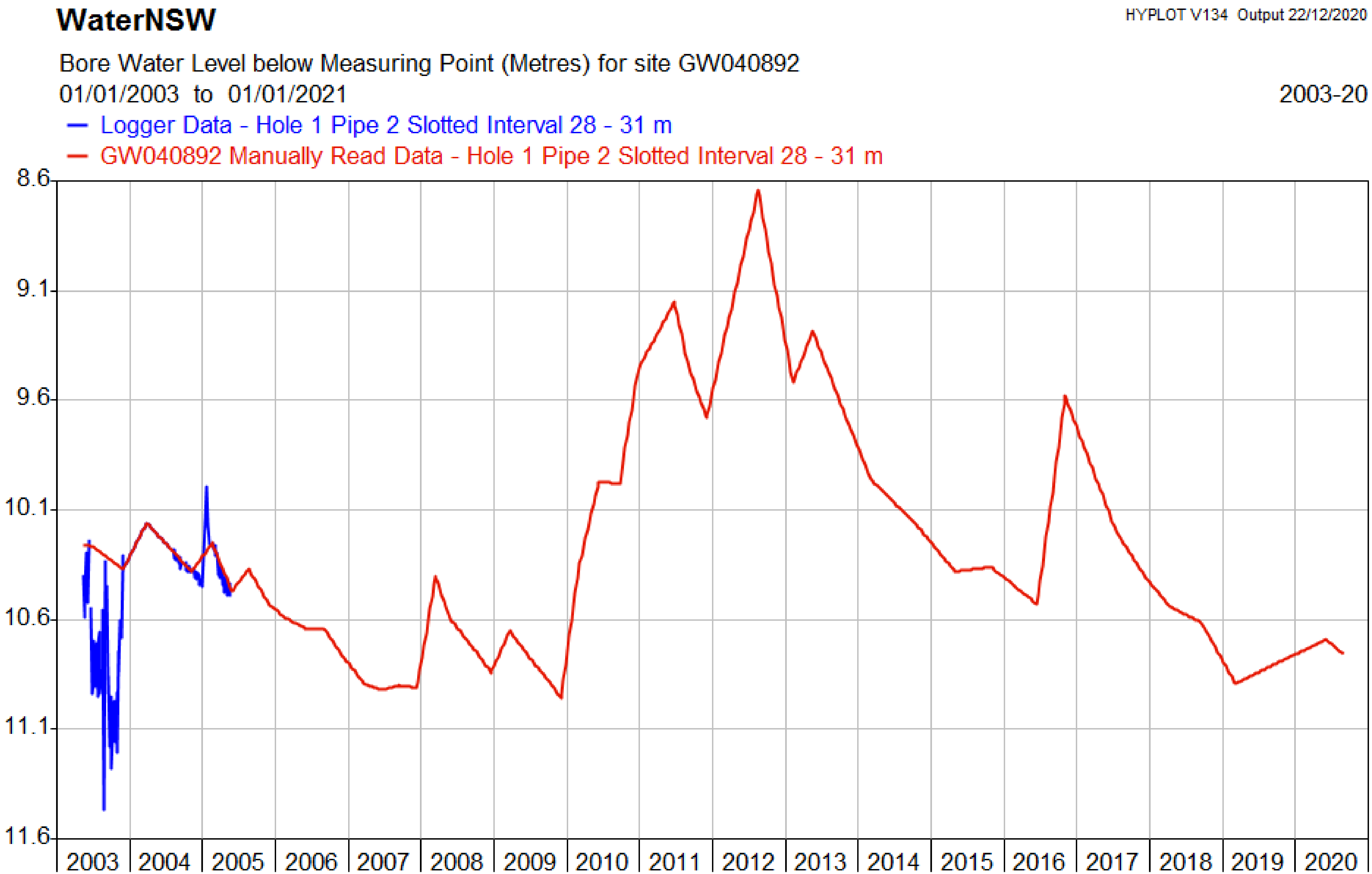
Bore Hydrographs



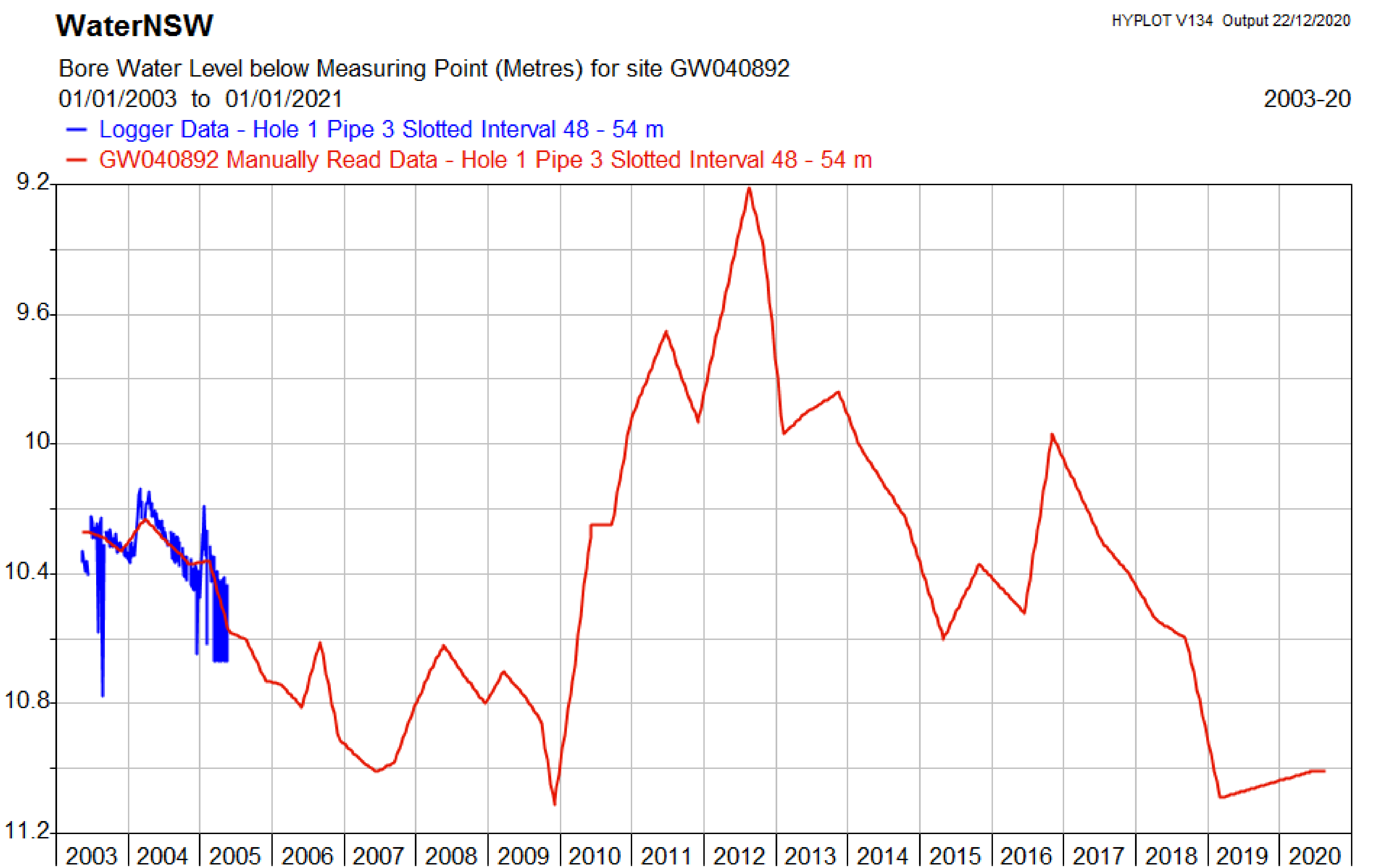
WaterNSW
HYPLOT V134 Output 16/07/2021
01/07/1972 to 01/07/2021
1972-2021
425008
DARLING@WILC. MAIN C
100.00
Level (Metres)
CP
12
9.5
7
4.5
2
-0.5
1972-81
1982-91
1992-01
2002-11

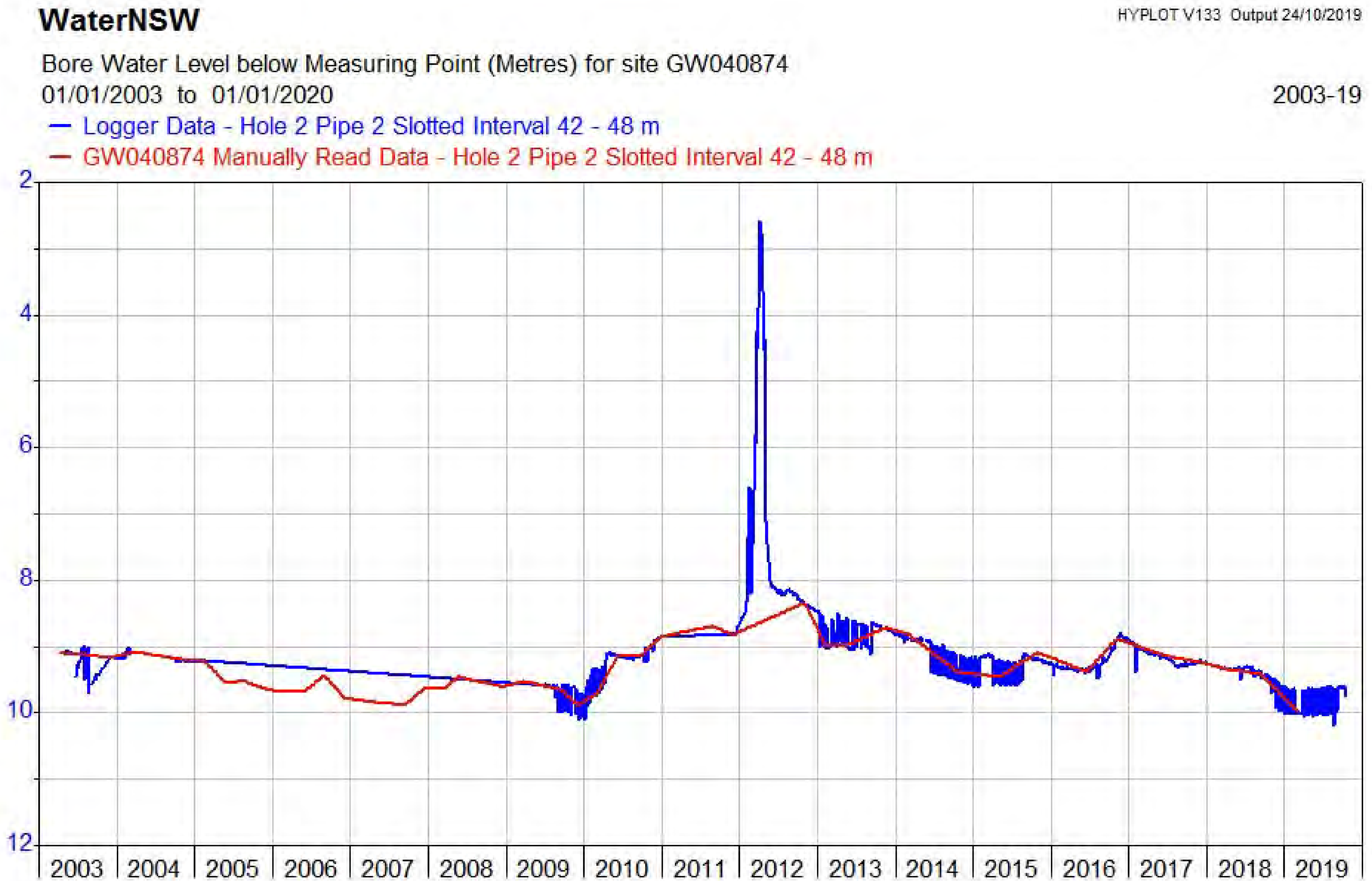


WaterNSW
HYPLOT V134 Output 22/12/2020
Bore Water Level below Measuring Point (Metres) for site GW040892
01/01/2003 to 01/01/2021
2003-20
Logger Data - Hole 1 Pipe 1 Slotted Interval 14 - 17 m
Logger Data - Hole 1 Pipe 2 Slotted Interval 28 - 31 m
Logger Data - Hole 1 Pipe 3 Slotted Interval 48 - 54 m
GW040892 Manually Read Data - Hole 1 Pipe 1 Slotted Interval 14 - 17 m
GW040892 Manually Read Data - Hole 1 Pipe 2 Slotted Interval 28 - 31 m
GW040892 Manually Read Data - Hole 1 Pipe 3 Slotted Interval 48 - 54 m
7.8
8.8
9.8
10.8
11.8
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

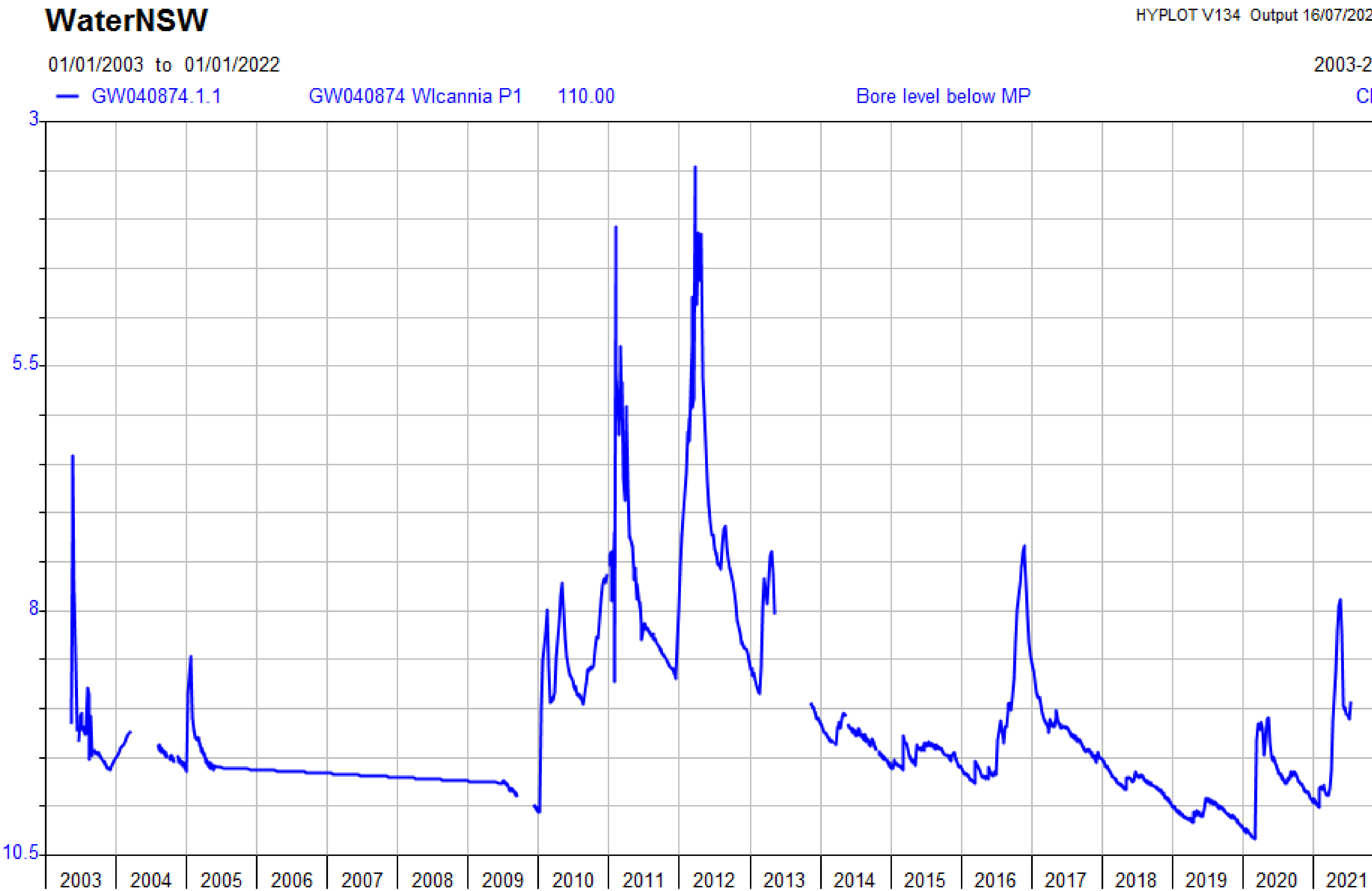


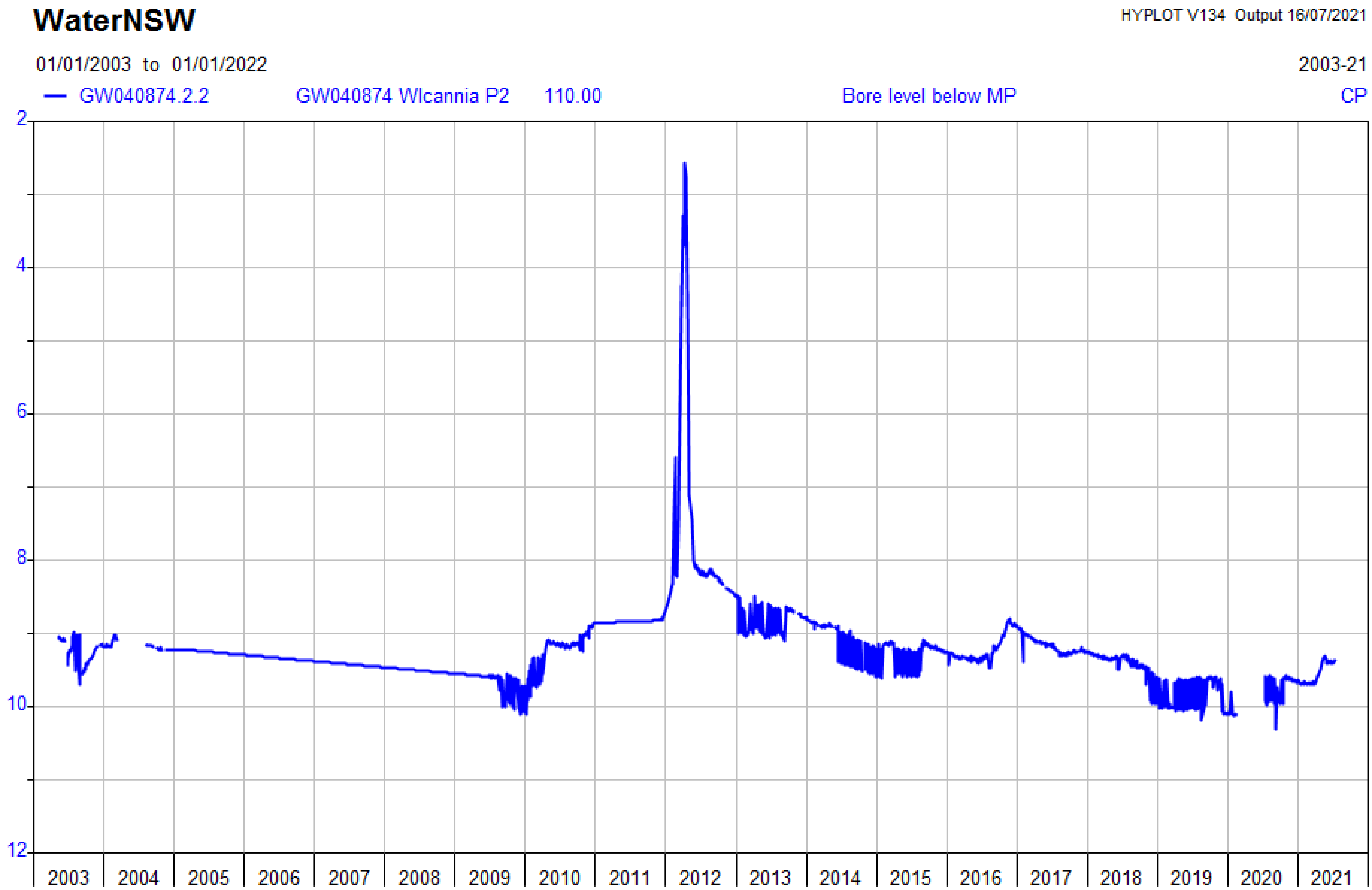
WaterNSW
HYPLOT V134 Output 22/12/2020
Bore Water Level below Measuring Point (Metres) for site GW040892
01/01/2003 to 01/01/2021
2003-20
Logger Data - Hole 1 Pipe 2 Slotted Interval 28 - 31 m
GW040892 Manually Read Data - Hole 1 Pipe 2 Slotted Interval 28 - 31 m
8.6
9.1
9.6
10.1
10.6
11.1
11.6
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

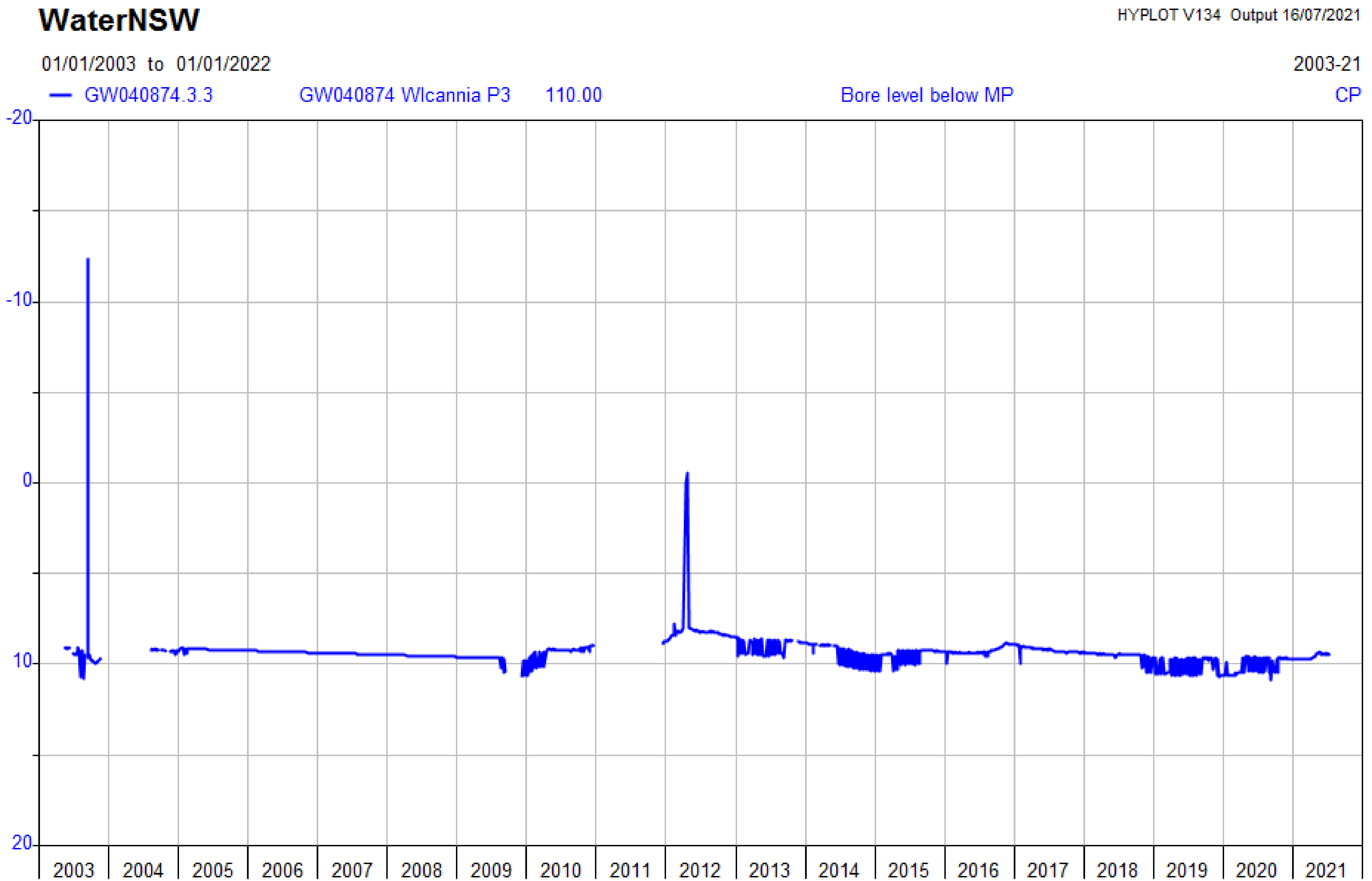

WaterNSW
HYPLOT V134 Output 22/12/2020
Bore Water Level below Measuring Point (Metres) for site GW040892
01/01/2003 to 01/01/2021
2003-20
Logger Data - Hole 1 Pipe 3 Slotted Interval 48 - 54 m
GW040892 Manually Read Data - Hole 1 Pipe 3 Slotted Interval 48 - 54 m
9.2
9.6
10
10.4
10.8
11.2
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

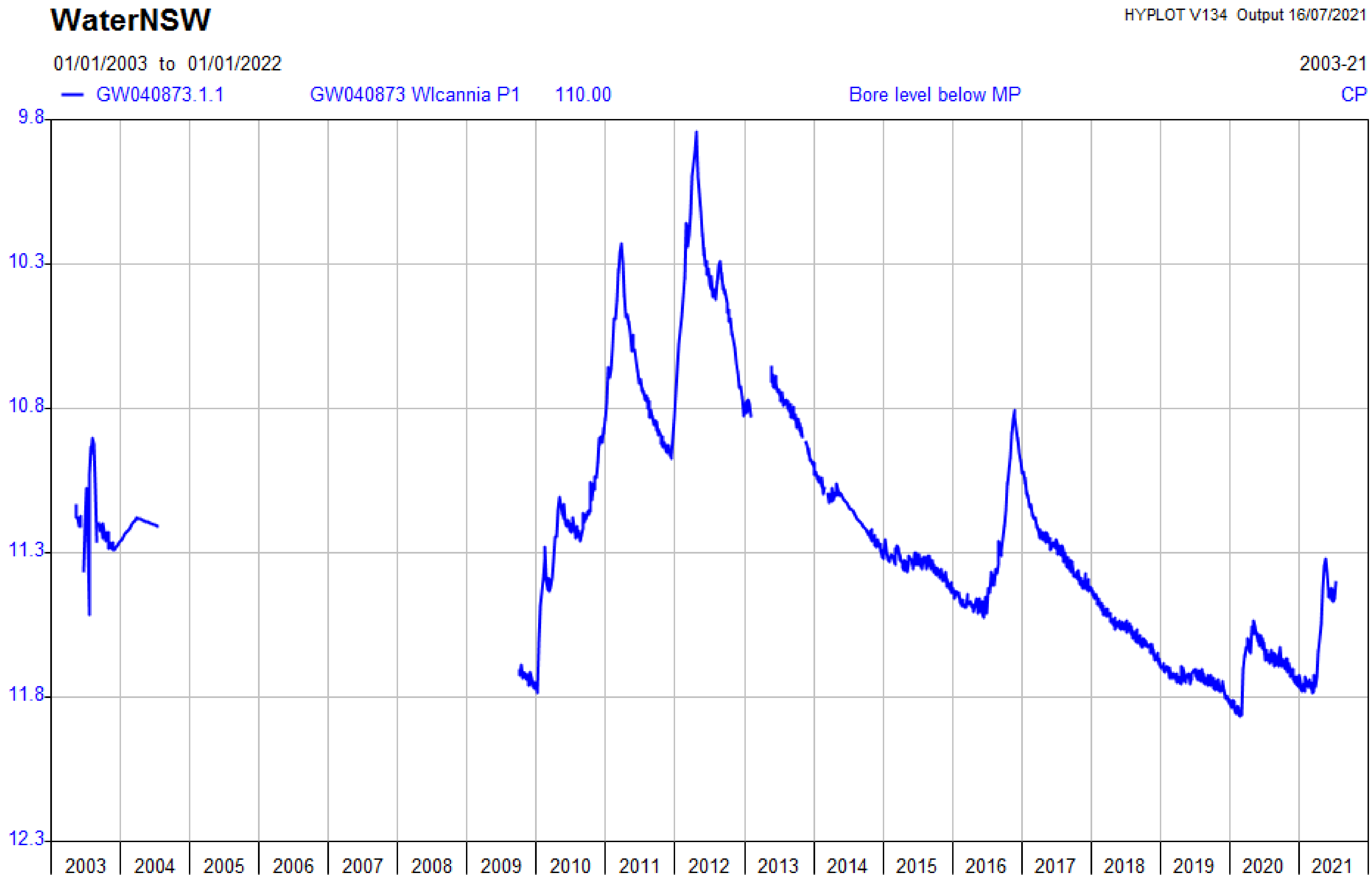


WaterNSW
HYPLOT V133 Output 24/10/2019
Bore Water Level below Measuring Point (Metres) for site GW040874
01/01/2003 to 01/01/2020
2003-19
Logger Data - Hole 2 Pipe 2 Slotted Interval 42 - 48 m
GW040874 Manually Read Data - Hole 2 Pipe 2 Slotted Interval 42 - 48 m
2
4
6
8
10
12
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019


WaterNSW
HYPLOT V134 Output 16/07/2021
01/01/2003 to 01/01/2022
2003-21
GW040874.1.1
GW040874 Wilcannia P1
110.00
Bore level below MP
CP
3
5.5
8
10.5
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


WaterNSW
HYPLOT V134 Output 16/07/2021
01/01/2003 to 01/01/2022
2003-21
GW040874.2.2
GW040874 Wlcannia P2
110.00
Bore level below MP
CP
2
4
6
8
10
12
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


WaterNSW
HYPLOT V134 Output 16/07/2021
01/01/2003 to 01/01/2022
2003-21
GW040874.3.3
GW040874 Wlcannia P3
110.00
Bore level below MP
CP
-20
-10
0
10
20
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021


WaterNSW
HYPLOT V134 Output 16/07/2021
01/01/2003 to 01/01/2022
2003-21
GW040873.1.1
GW040873 Wlcannia P1
110.00
Bore level below MP
CP
9.8
10.3
10.8
11.3
11.8
12.3
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

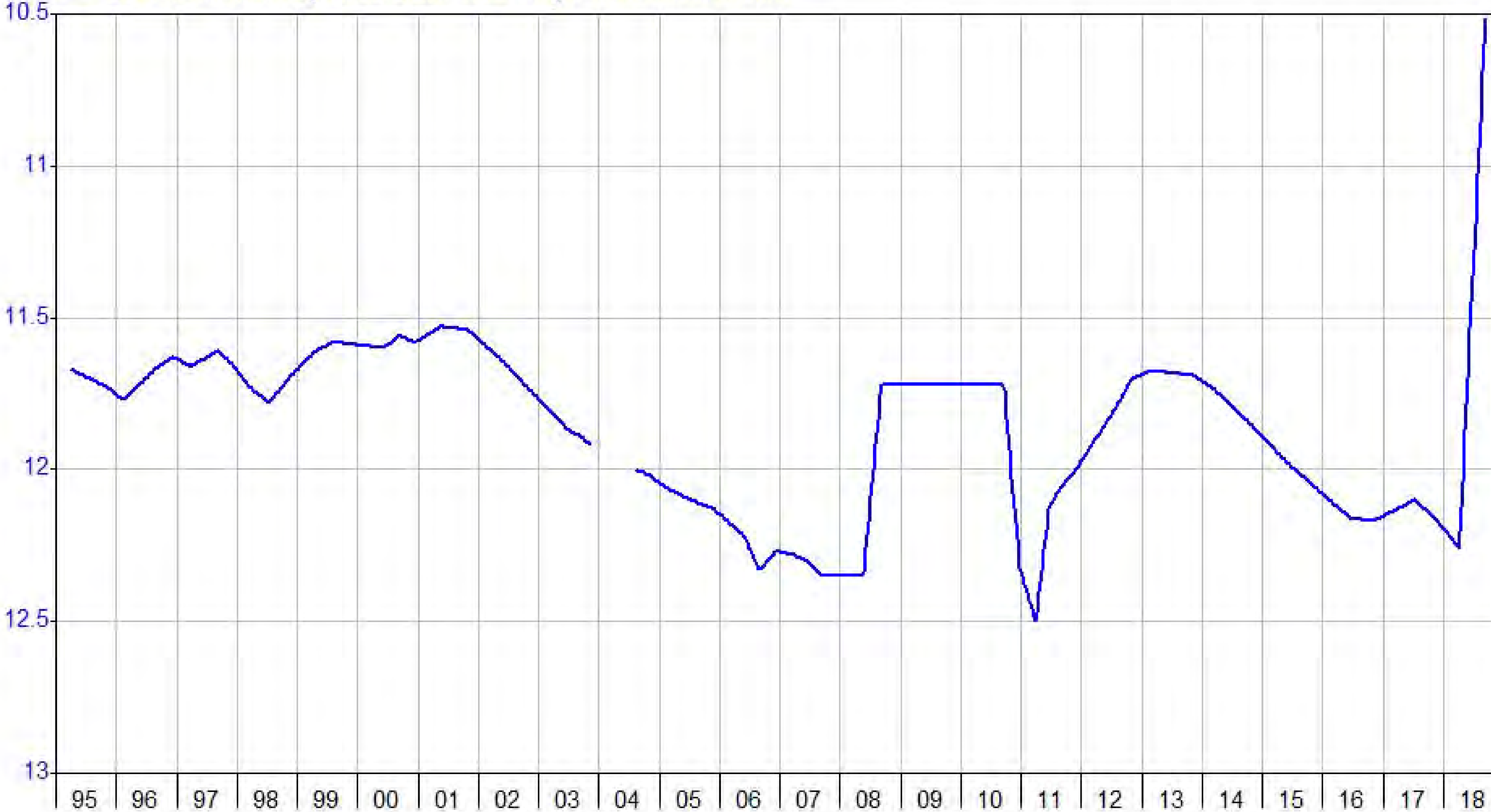
WaterNSW

HYPLOT V133 Output 21/12/2018

Bore Water Level below Measuring Point (Metres)

01/01/1995 to 01/01/2019 — 1995-2018

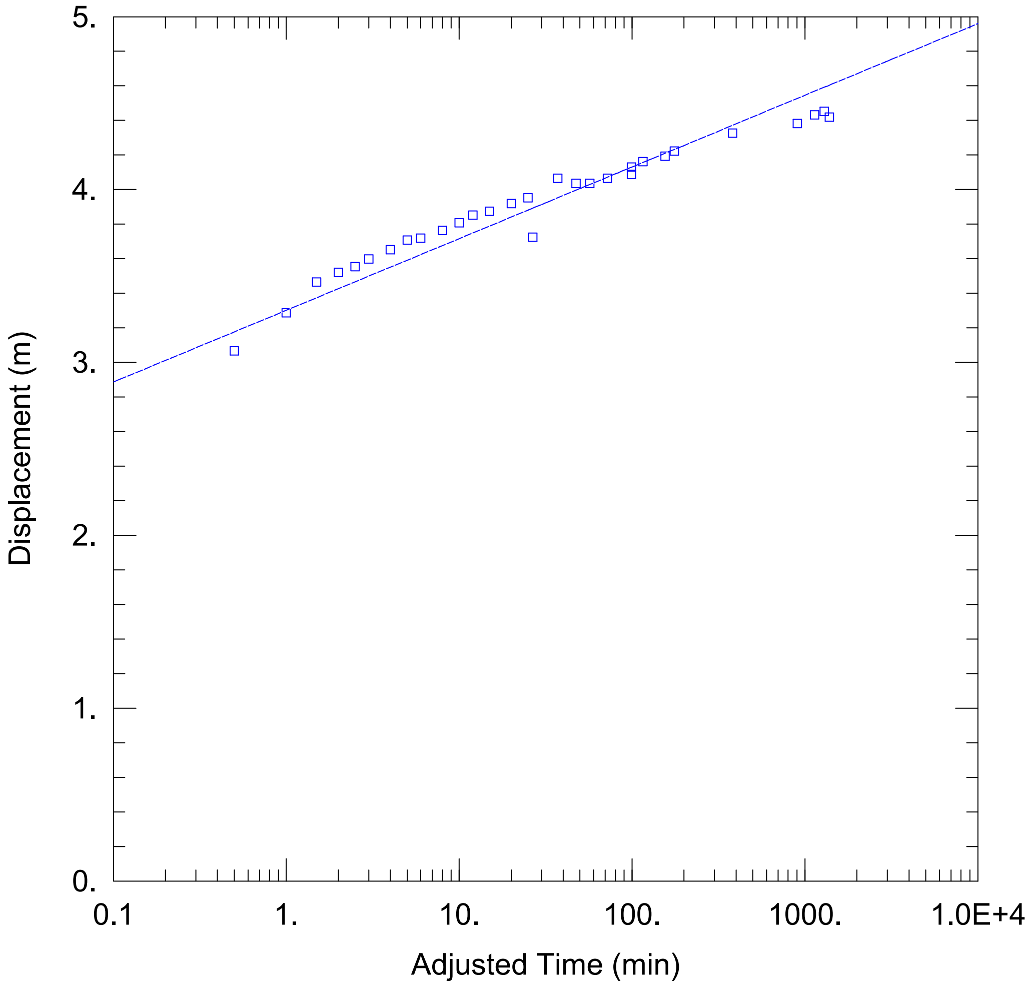
GW042429 Manually Read Data - Hole 1 Pipe 1 No screens found



APPENDIX C
Pumping Test Analysis

APPENDIX C

Pumping Test Analysis



49 HOUR CONSTANT RATE TEST

Data Set: C:\...\6_TWS3_No TWS1 short_pump.aqt
Date: 11/30/20 Time: 12:56:35

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS3	725766	6503300

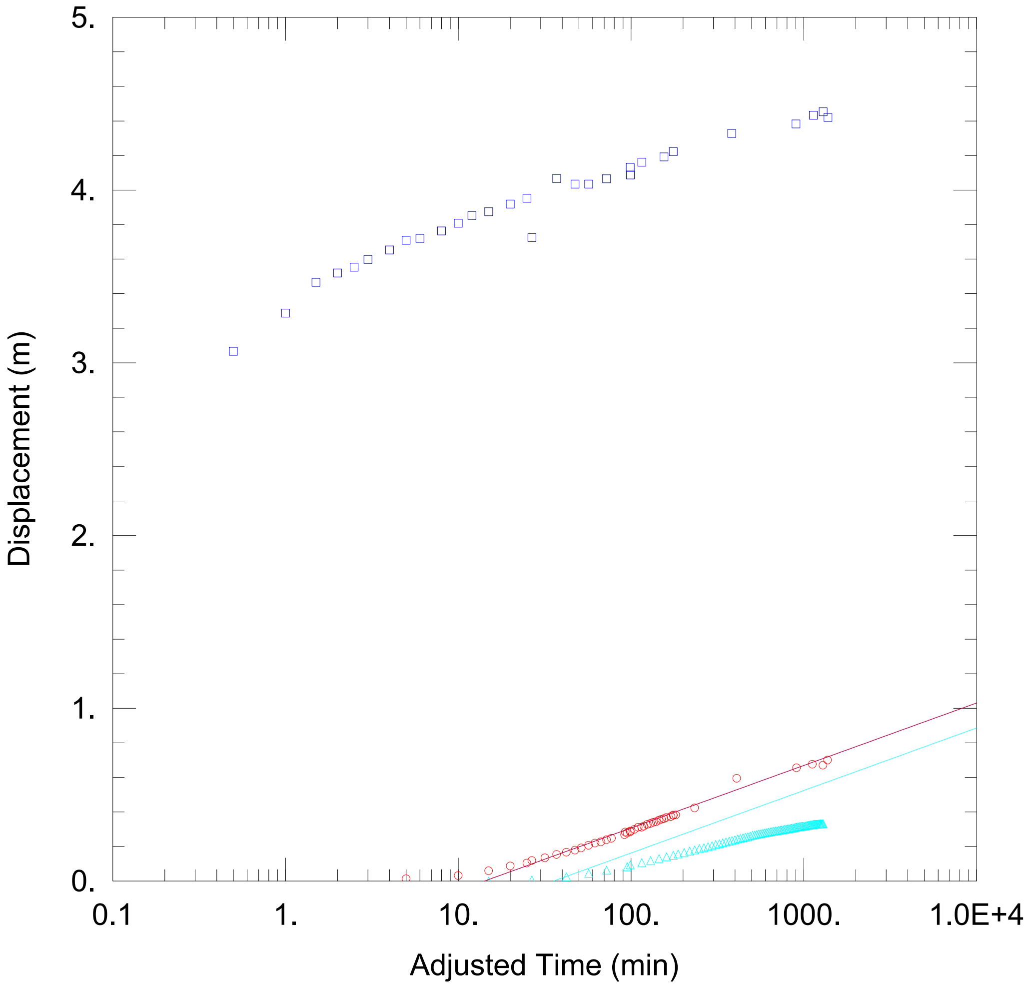
Observation Wells

Well Name	X (m)	Y (m)
□ TWS3	725766	6503300

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 285.3 m^2/day S = 1.217E-13



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3_No TWS1 short.aqt
Date: 11/13/20 Time: 13:12:34

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS3	725766	6503300

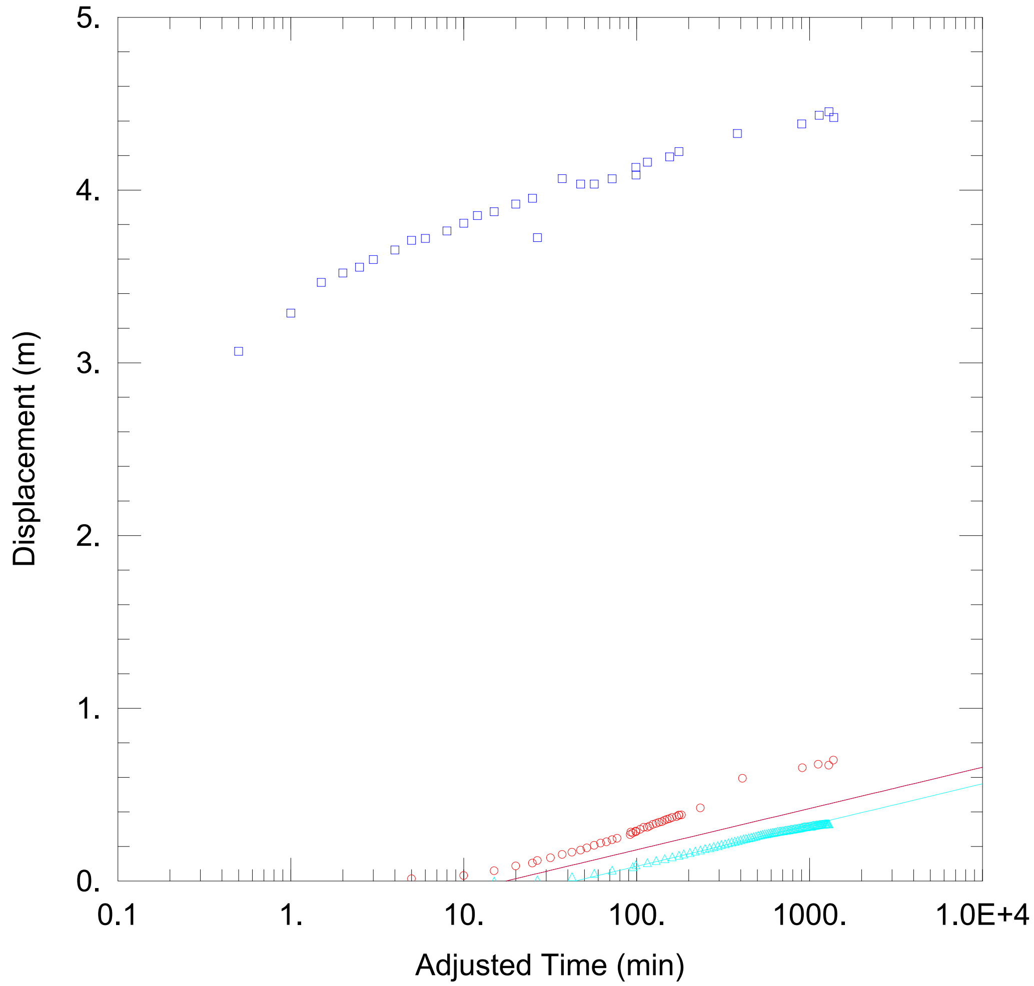
Observation Wells

Well Name	X (m)	Y (m)
□ TWS3	725766	6503300
○ GW040892-3	725748	6503489
△ GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 326.9 m^2/day S = 0.0001813



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3_No TWS1 short.aqt
Date: 11/13/20 Time: 13:13:58

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS3	725766	6503300

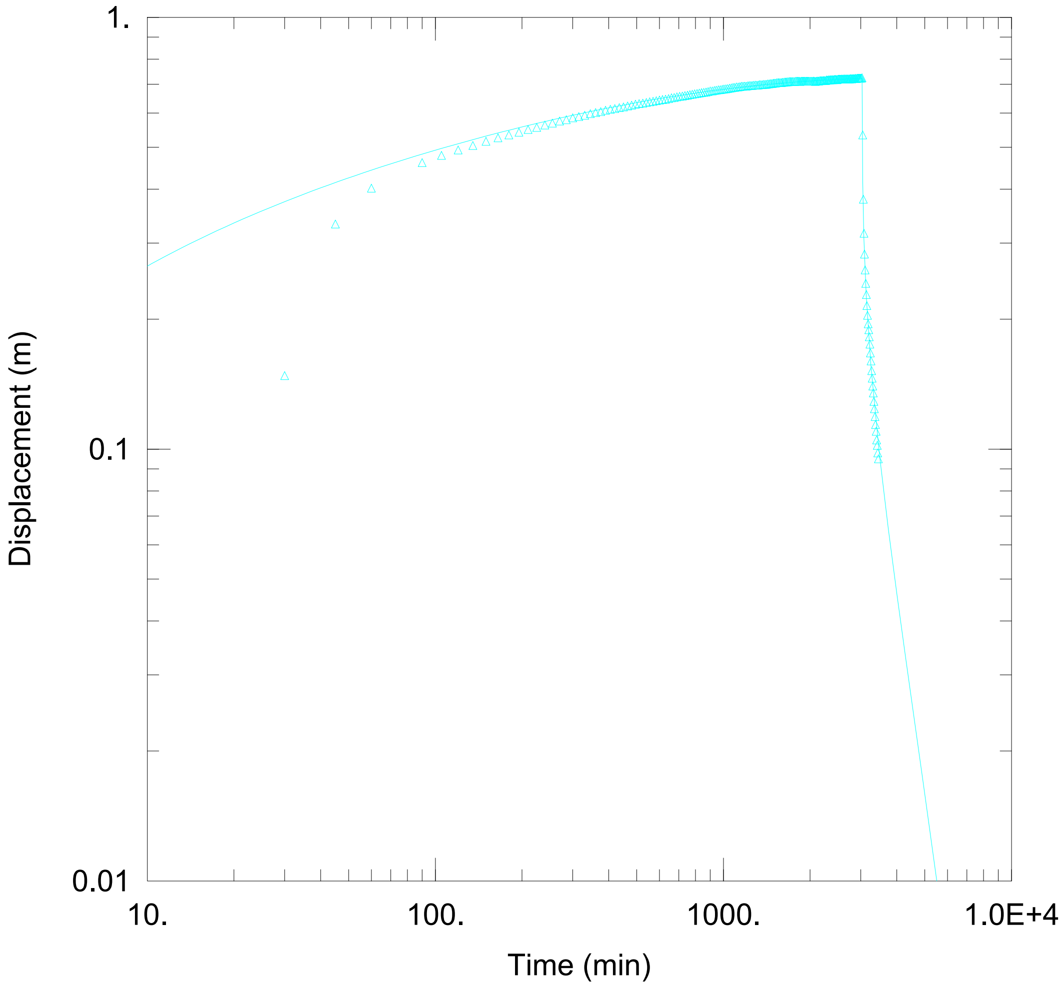
Observation Wells

Well Name	X (m)	Y (m)
□ TWS3	725766	6503300
○ GW040892-3	725748	6503489
△ GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 495.3 m^2/day S = 0.0003397



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3-874 short.aqt
Date: 11/13/20 Time: 14:08:19

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS1	725895	6503029

Observation Wells

Well Name	X (m)	Y (m)
△ GW040874-3	725862	6502998

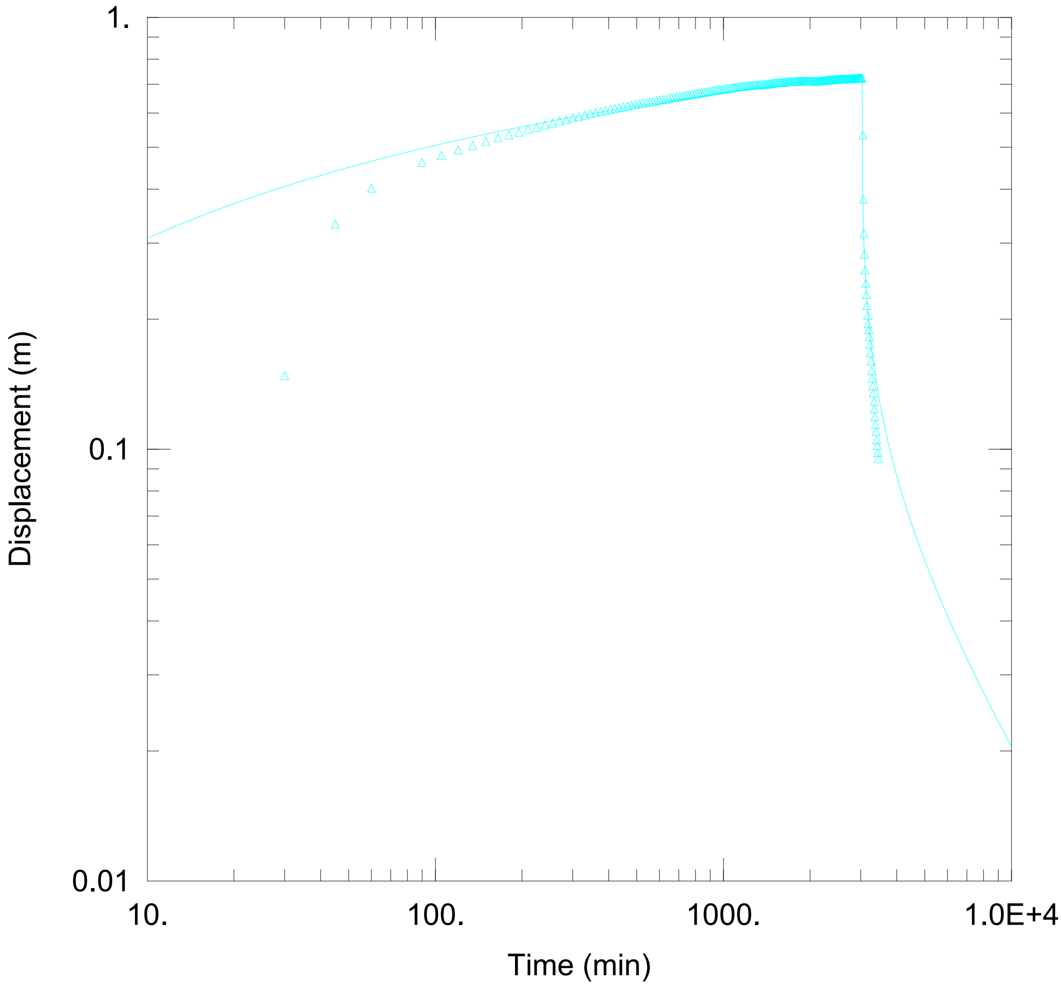
SOLUTION

Aquifer Model: Leaky

Solution Method: Hantush-Jacob

T = 343.5 m^2/day
r/B = 0.03173
b = 8.5 m

S = 0.0002
Kz/Kr = 1.



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3-874 short.aqt
Date: 11/13/20 Time: 14:00:08

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 3. m
Aquitard Thickness (b"): 100. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS1	725895	6503029

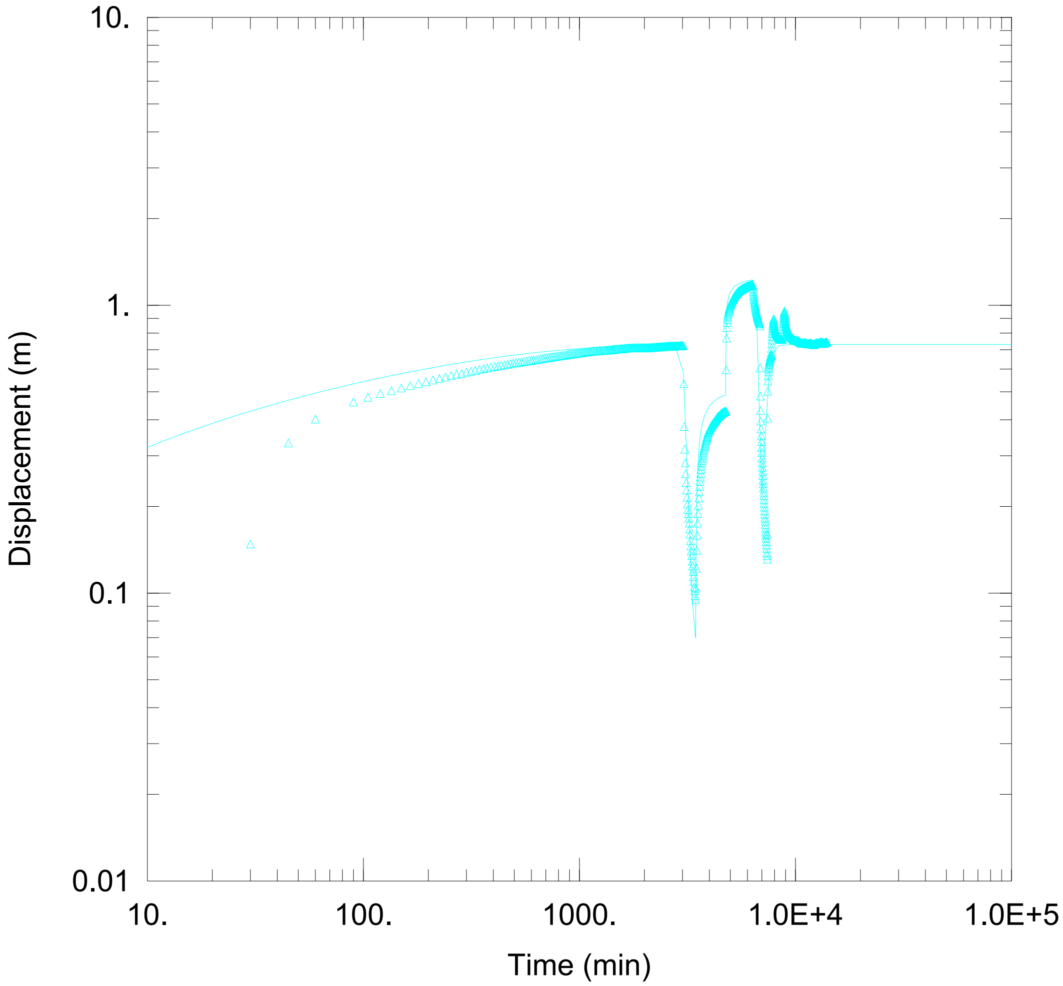
Observation Wells

Well Name	X (m)	Y (m)
△ GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 333.9 m^2/day
S = 0.00011
r/B' = 1.0E-5
ß' = 0.01862
r/B" = 0.
ß" = 0.



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3-874 corrected.aqt
Date: 11/13/20 Time: 14:12:04

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS3	725766	6503300
TWS1	725895	6503029

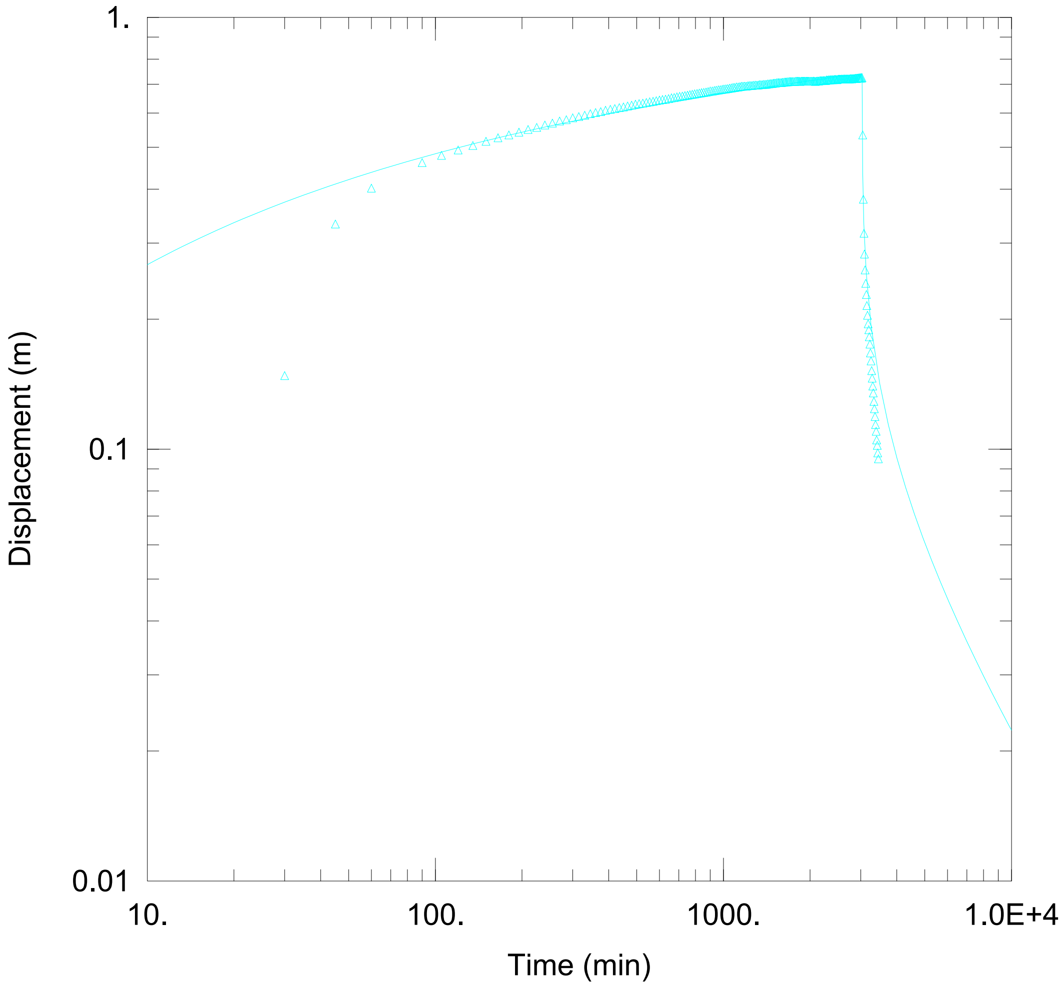
Observation Wells

Well Name	X (m)	Y (m)
△ GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 349.1 m^2/day
S = 0.00011
r/B = 0.2079
Kz/Kr = 1.
b = 8.5 m



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3-874 short.aqt
Date: 11/13/20 Time: 14:02:14

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 3. m
Aquitard Thickness (b"): 100. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS1	725895	6503029

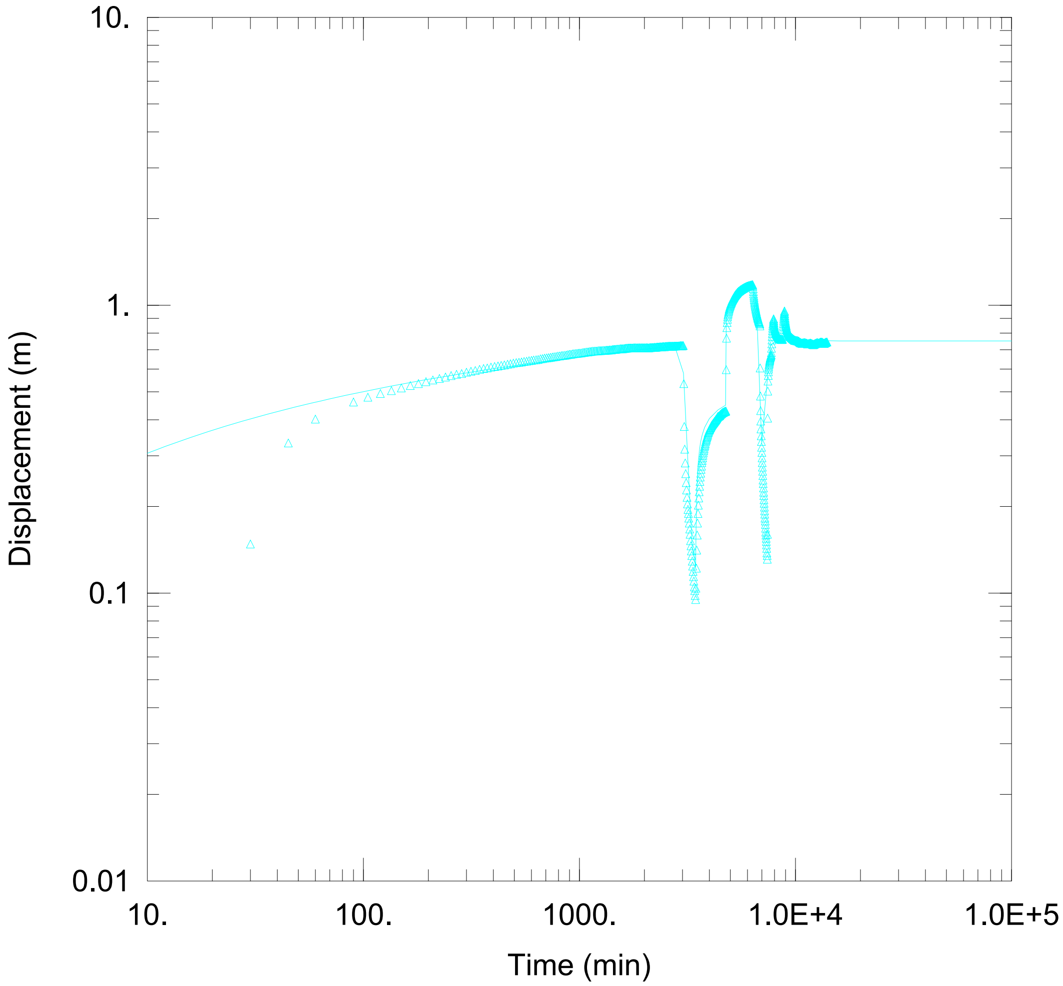
Observation Wells

Well Name	X (m)	Y (m)
△ GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 312.3 m^2/day
S = 0.0001921
r/B' = 1.0E-5
ß' = 0.01992
r/B" = 0.
ß" = 0.



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\TWS3-874 corrected.aqt
Date: 11/13/20 Time: 14:18:10

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m
Aquitard Thickness (b'): 3. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 100. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS3	725766	6503300
TWS1	725895	6503029

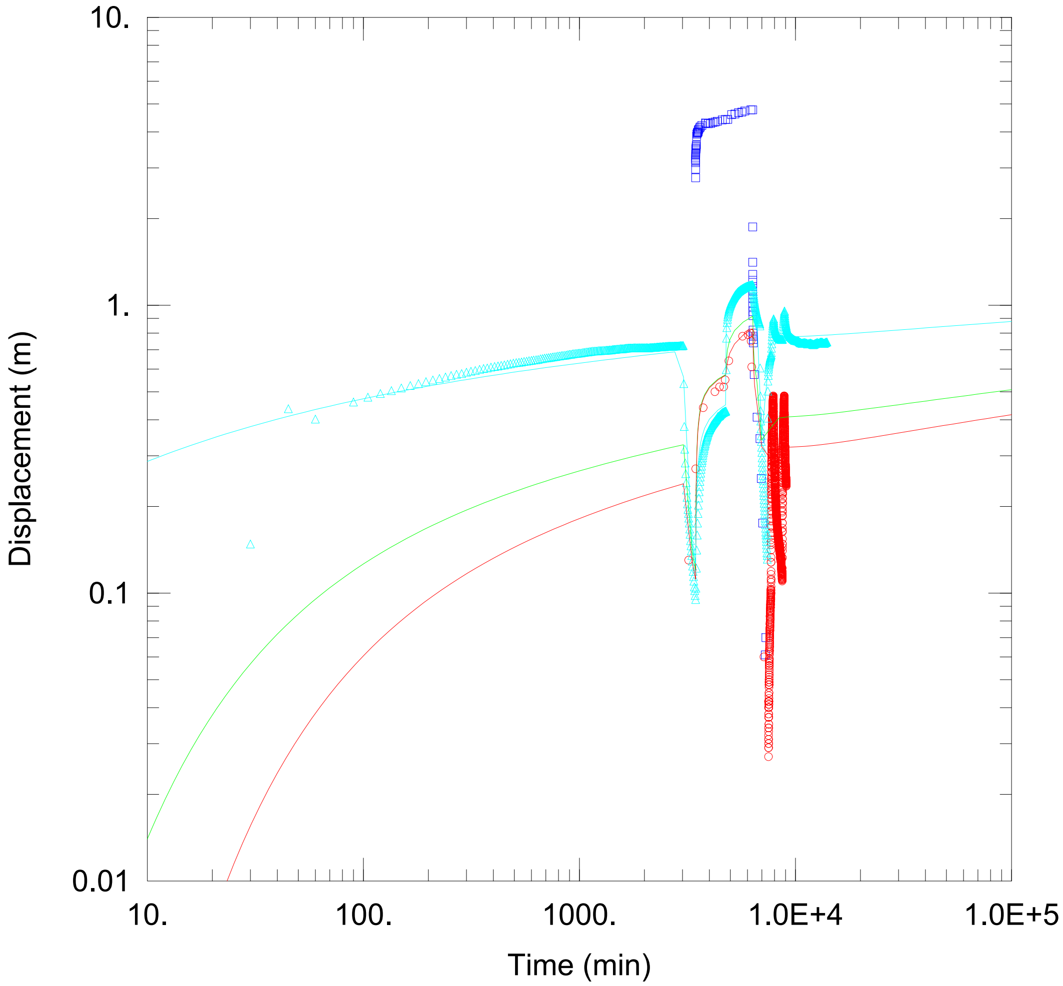
Observation Wells

Well Name	X (m)	Y (m)
GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 334.9 m^2/day
r/B' = 0.2184
r/B" = 0.
S = 0.00011
ß' = 0.1383
ß" = 0.



49 HOUR CONSTANT RATE TEST

Data Set: J:\AllJobs\Jobs2019\J1764 - Wilcannia\TWS BH3\8_TWS3-all corrected.aqt
Date: 11/19/20 Time: 08:04:00

PROJECT INFORMATION

Company: C.M.Jewell & Associates Pty Lt
Client: Water NSW
Project: J1764
Location: Wilcannia
Test Well: TWS3
Test Date: 7 September 2020

AQUIFER DATA

Saturated Thickness: 8.5 m
Aquitard Thickness (b'): 3. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 100. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TWS3	725766	6503300
TWS1	725895	6503029

Observation Wells

Well Name	X (m)	Y (m)
□ TWS3	725766	6503300
○ GW040892-3	725746	6503489
△ GW040874-3	725862	6502998

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

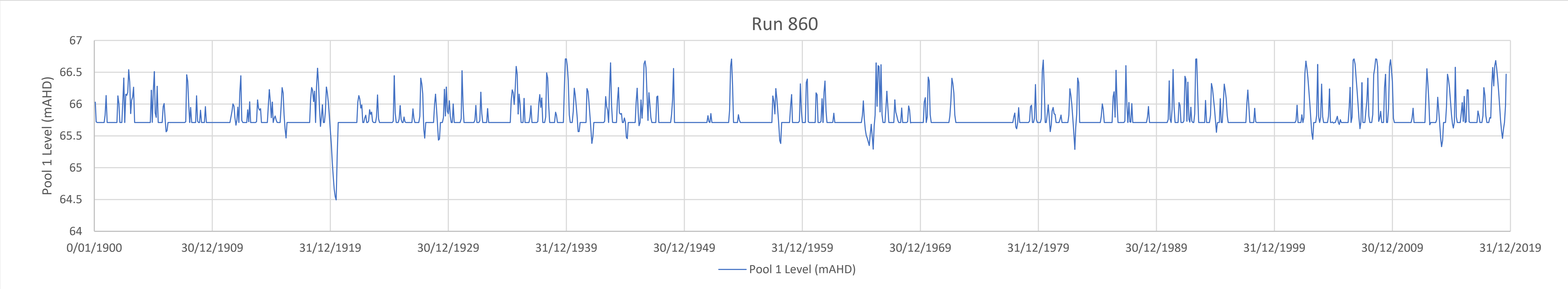
T = 358. m^2/day
S = 0.000123
1/B' = 5.0E-8 m^{-1}
ß'/r = 0.0003686 m^{-1}

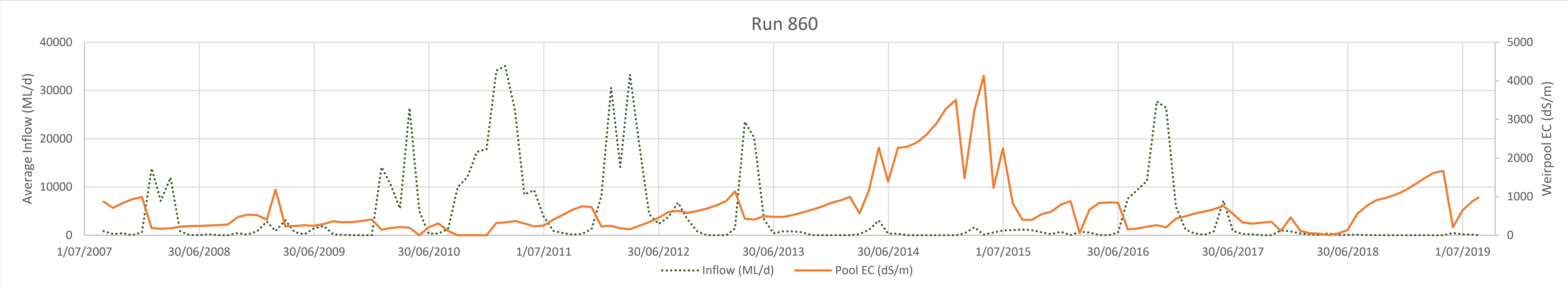
APPENDIX D

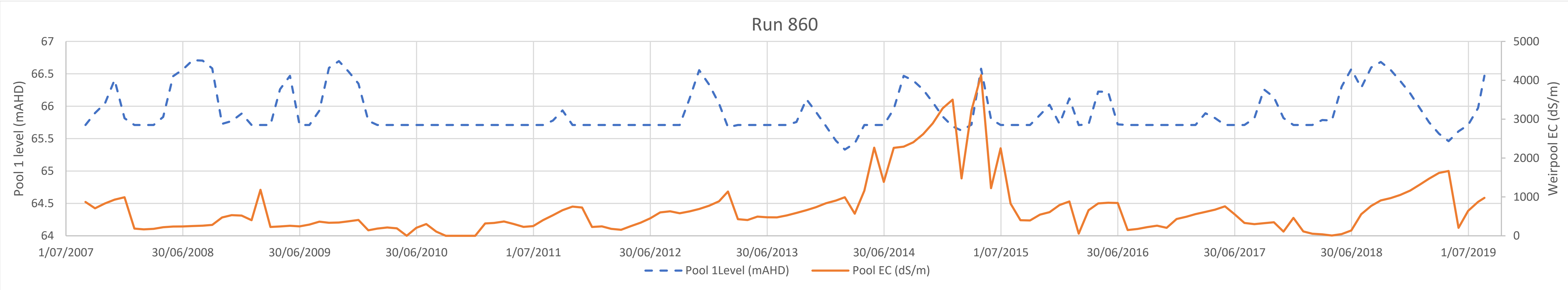
MODFLOW USG-T Model

MODFLOW future scenarios – WNSW Run 860

Input

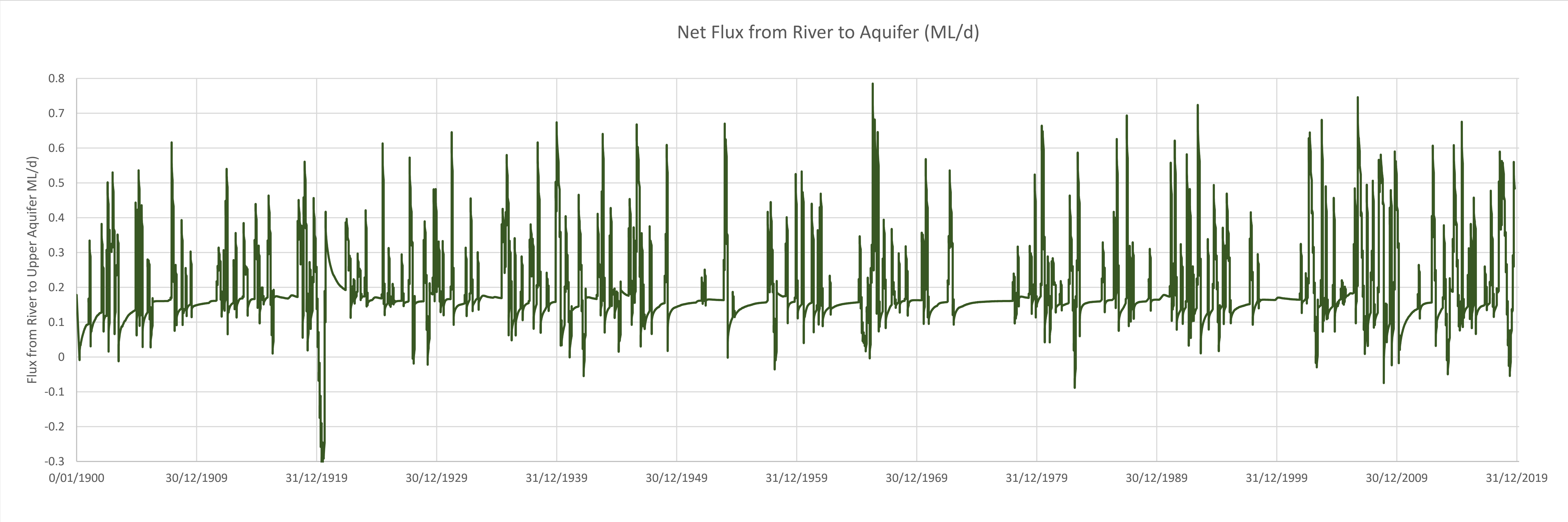


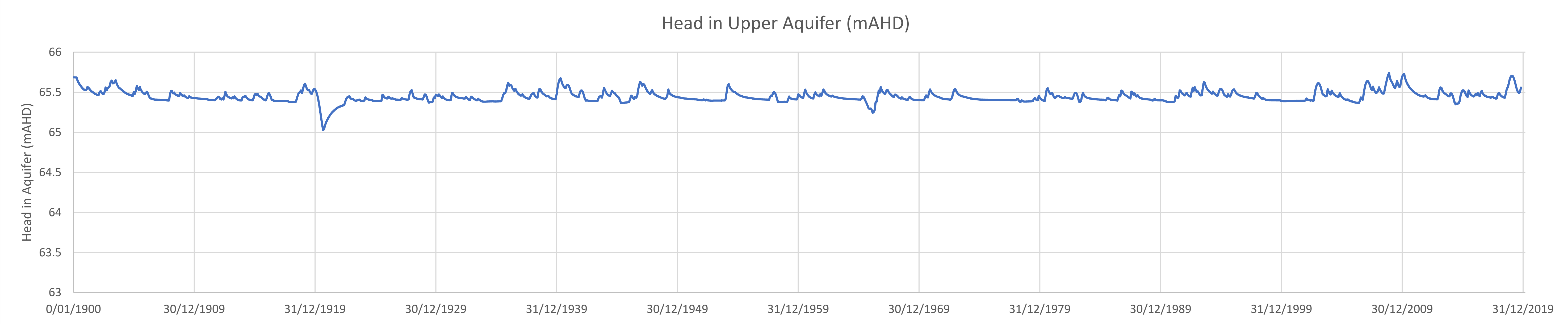


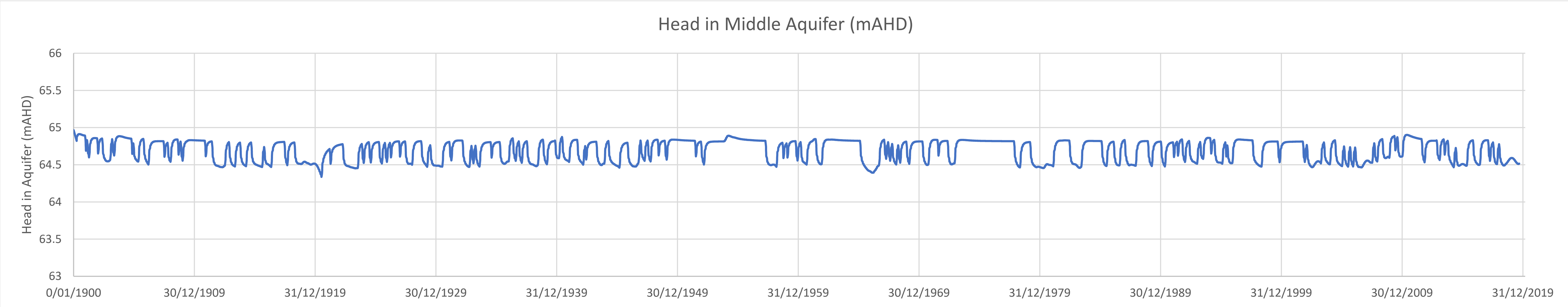


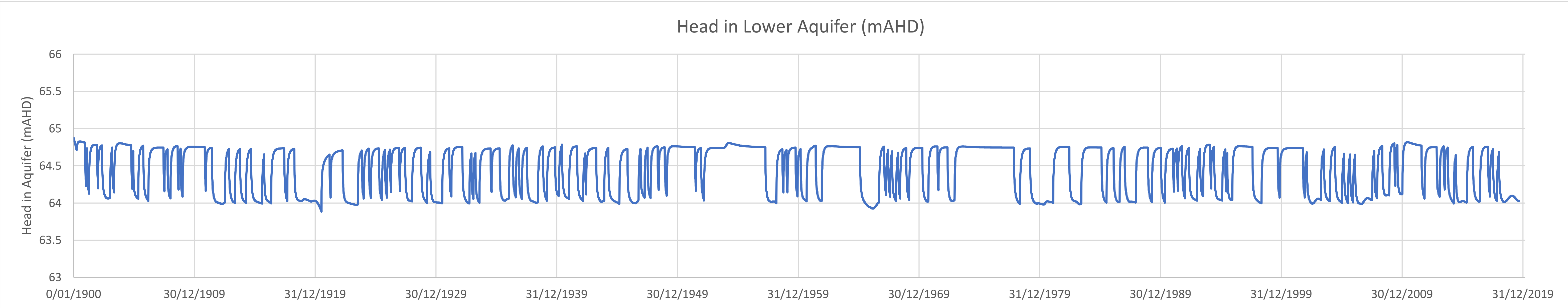
MODFLOW future scenarios – WNSW Run 860

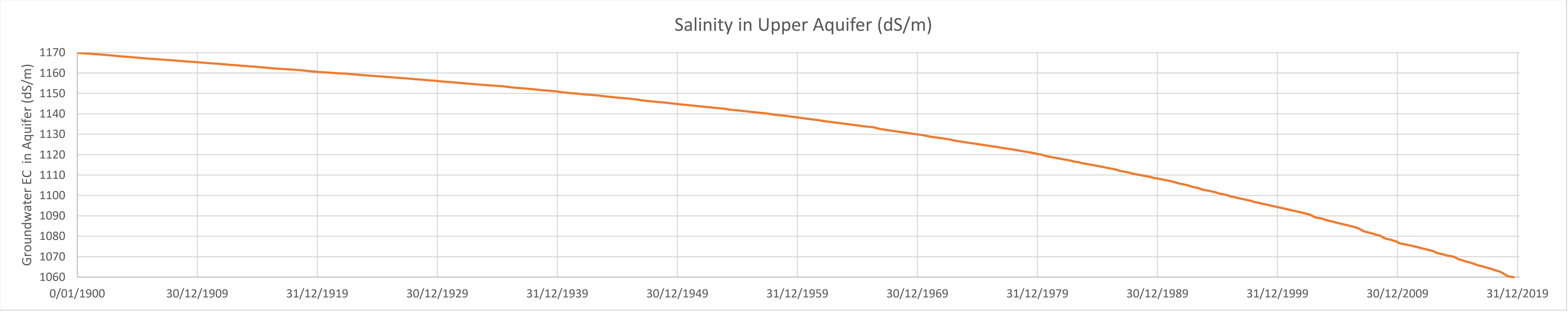
Output

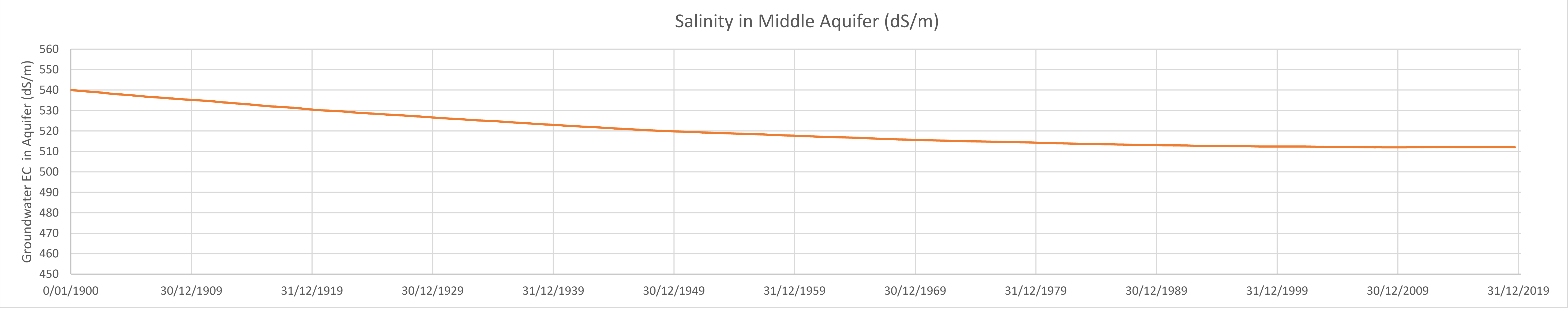


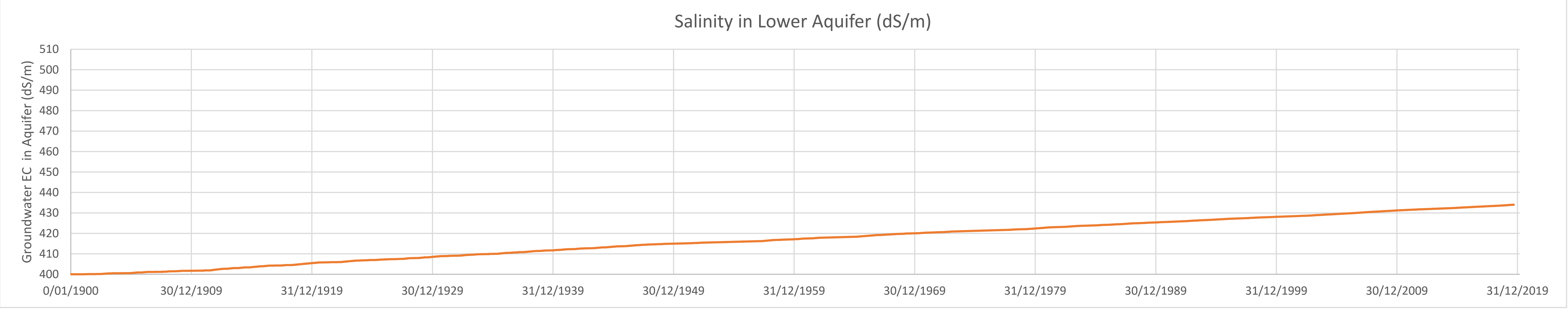

Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

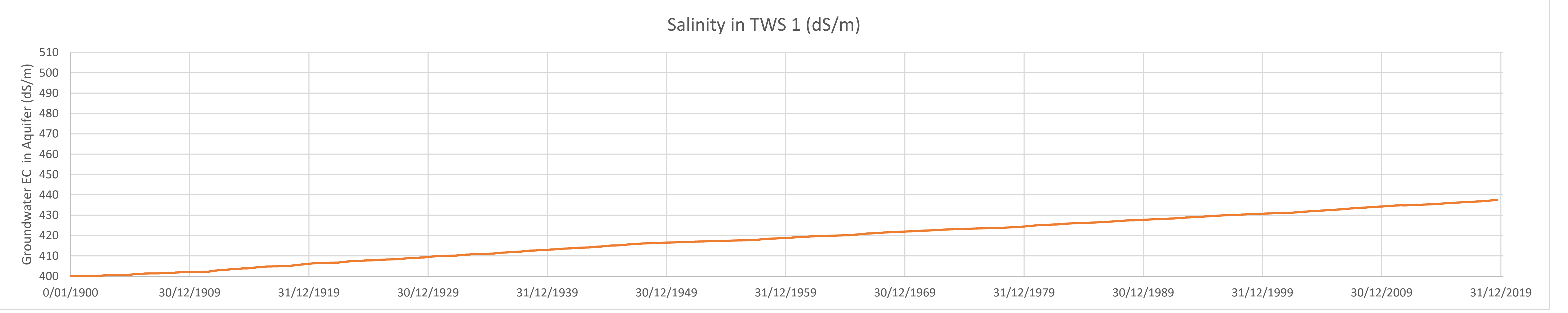

Head in Middle Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

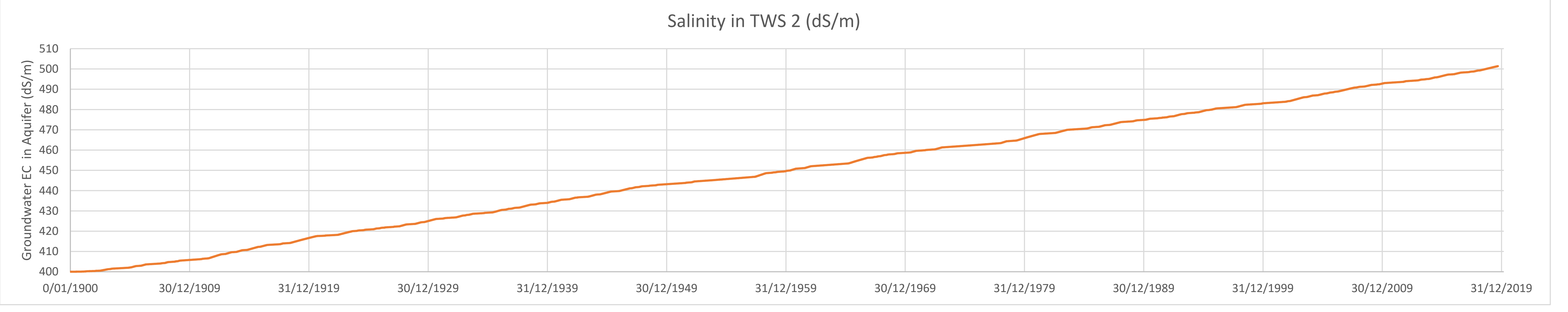

Head in Lower Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

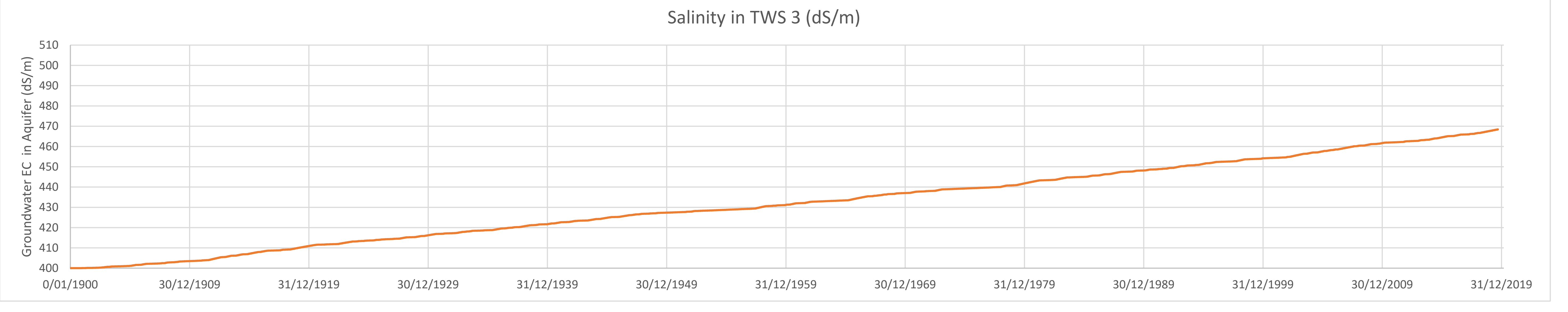

Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
560
550
540
530
520
510
500
490
480
470
460
450
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Lower Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

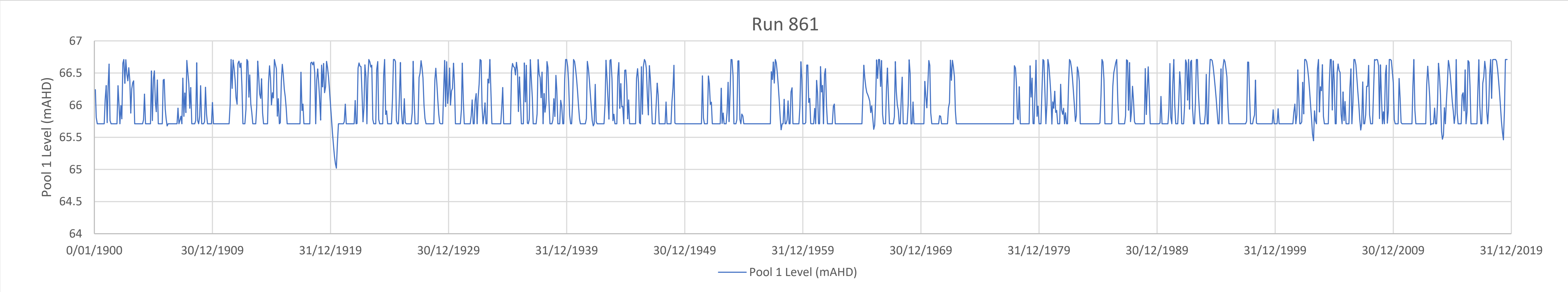

Salinity in TWS 1 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

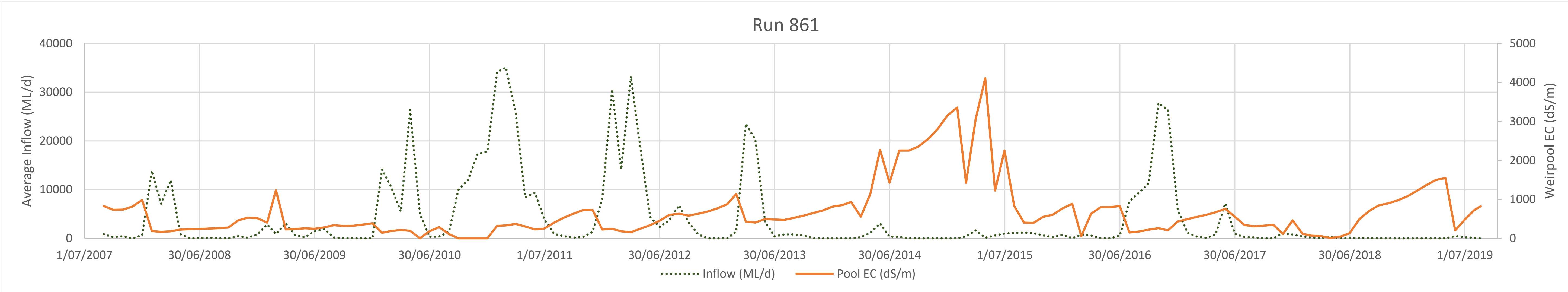

Salinity in TWS 2 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

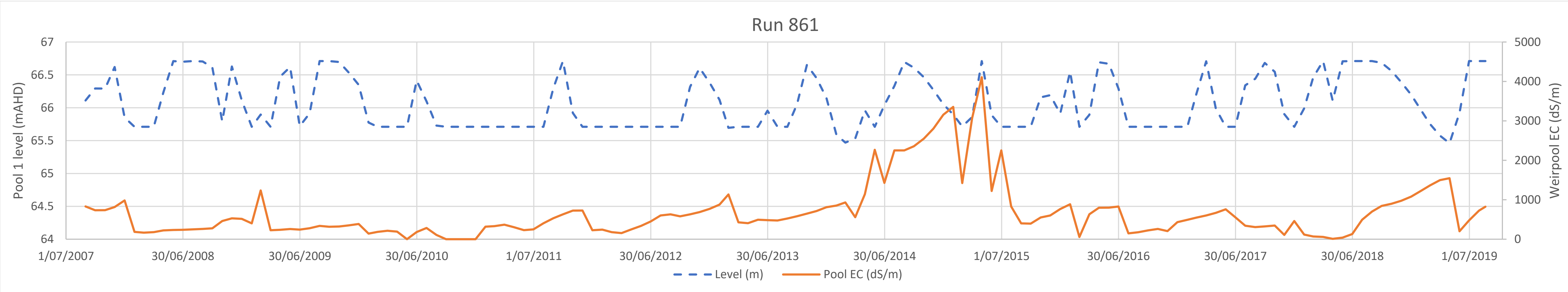

Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

MODFLOW future scenarios – WNSW Run 861

Input

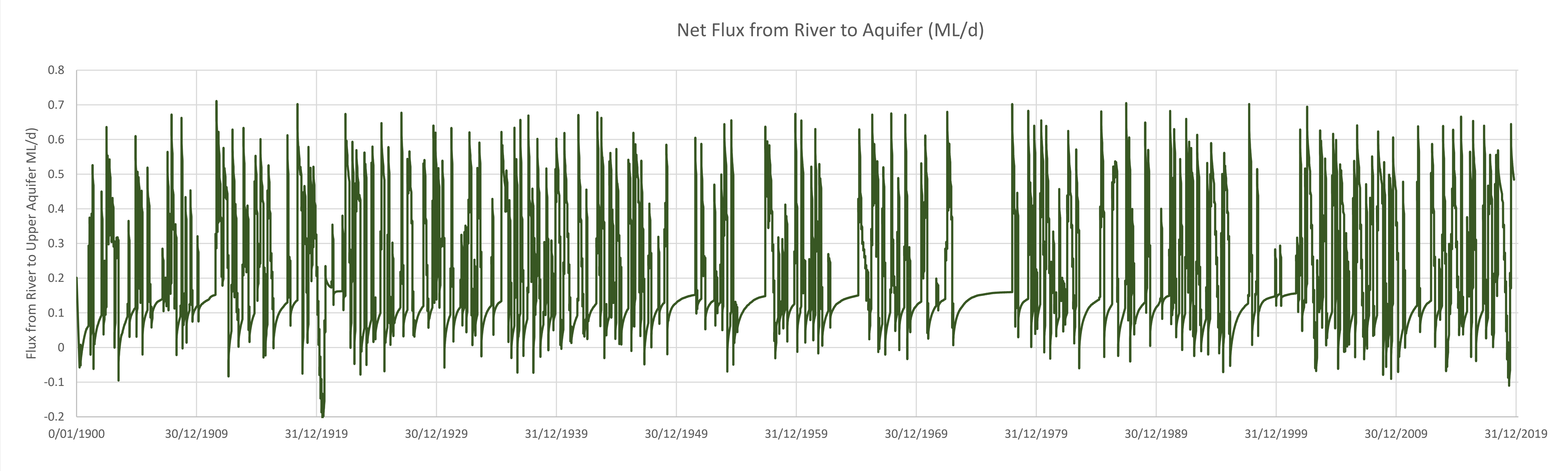


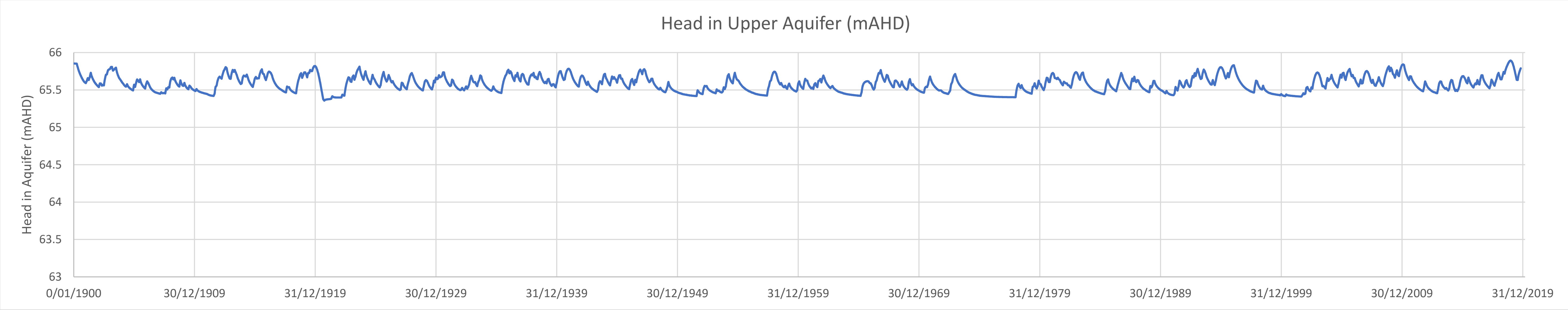


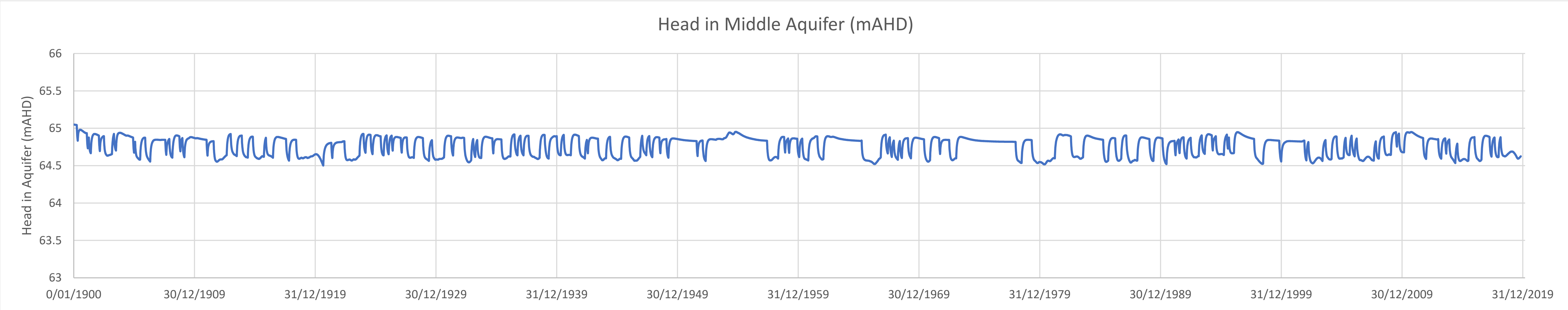


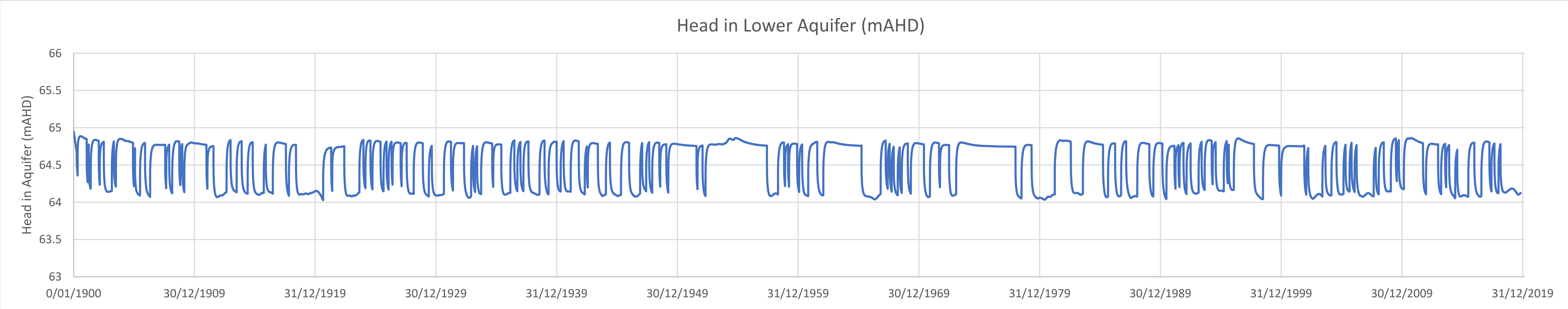
MODFLOW future scenarios – WNSW Run 861

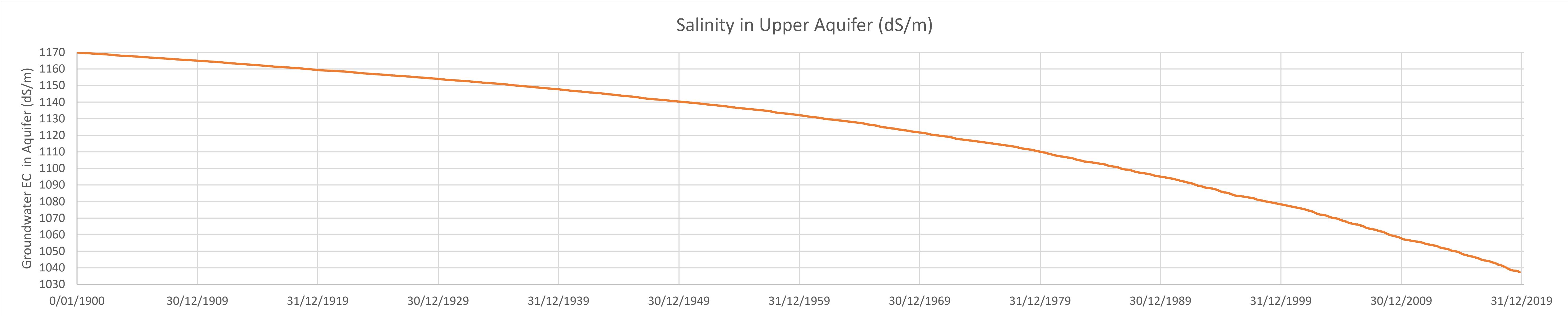
Output

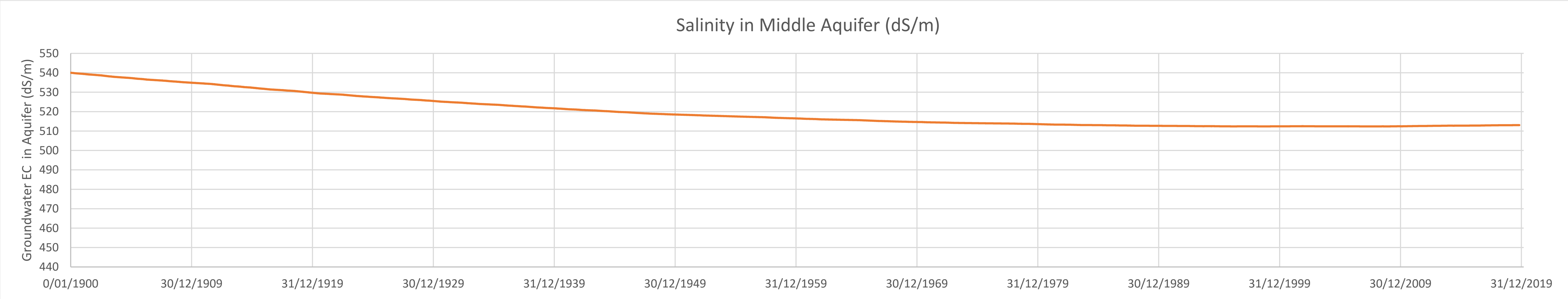


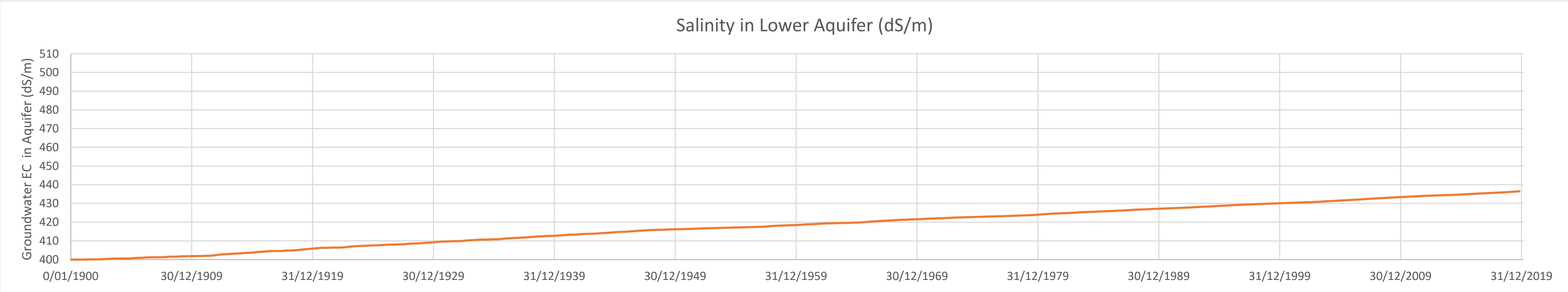

Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

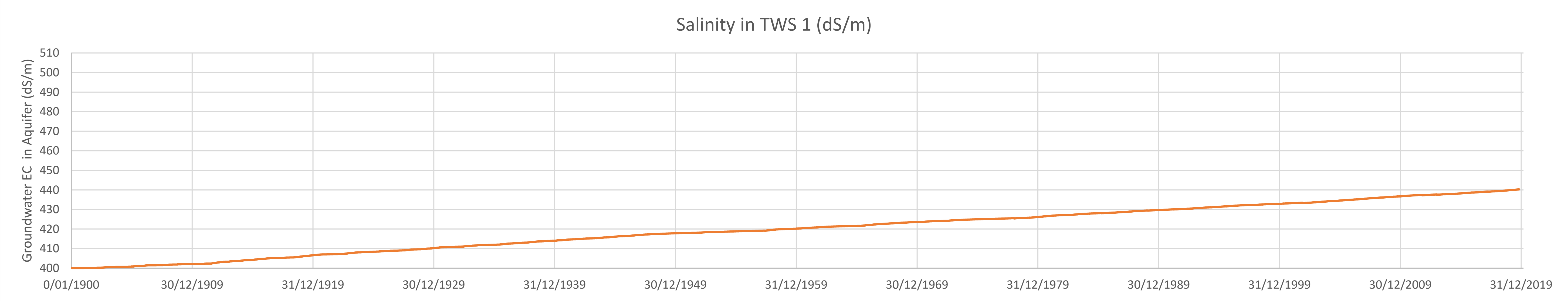

Head in Middle Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

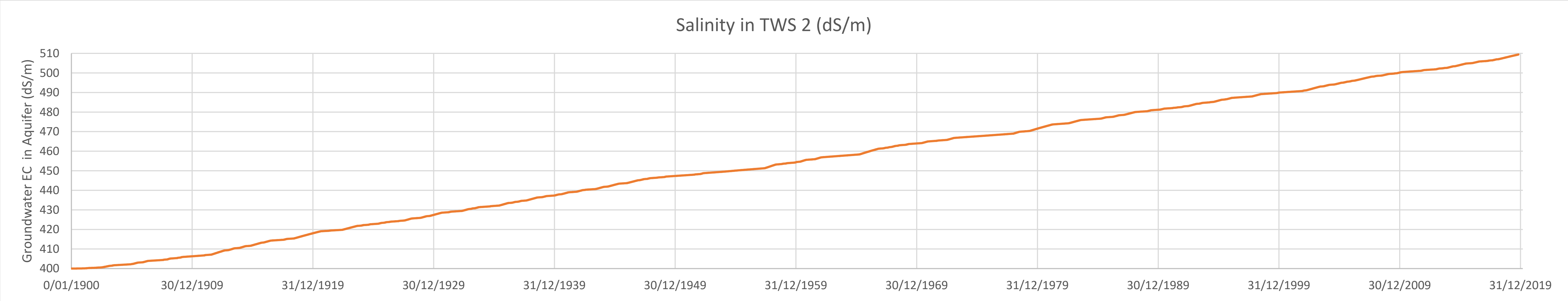

Head in Lower Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

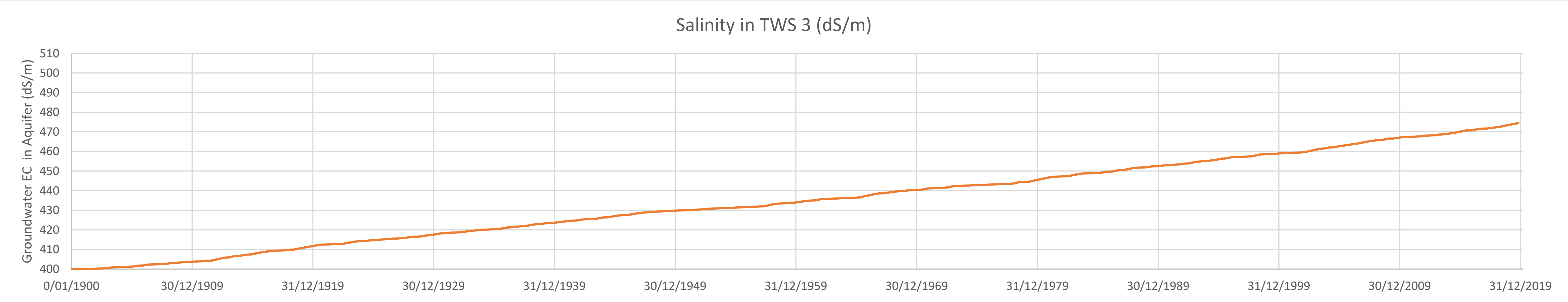

Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
550
540
530
520
510
500
490
480
470
460
450
440
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Lower Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

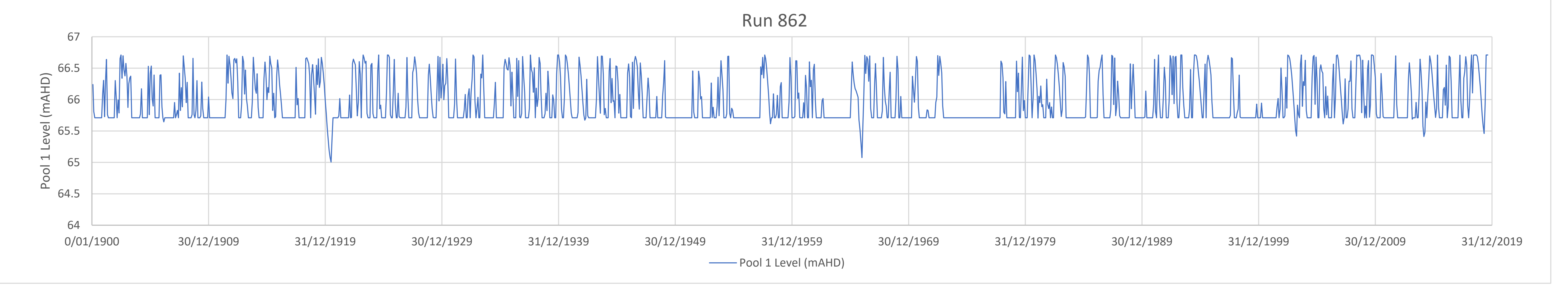

Salinity in TWS 1 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

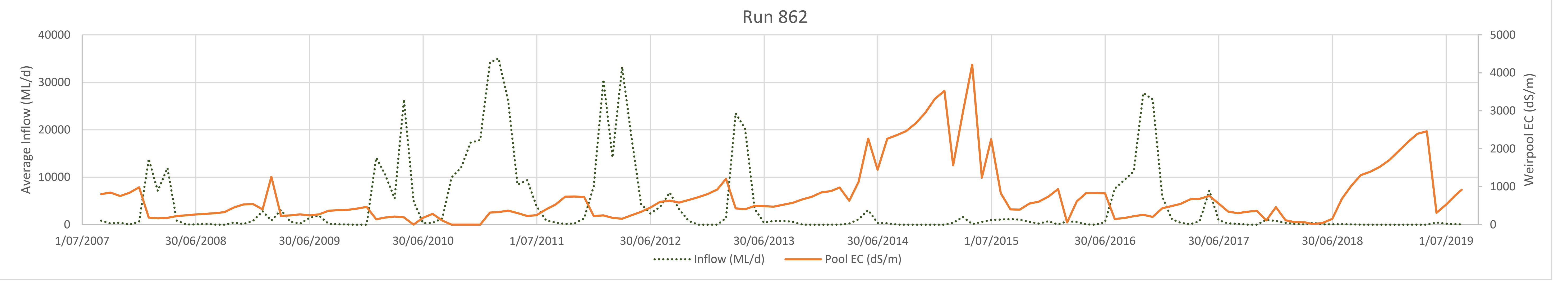

Salinity in TWS 2 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

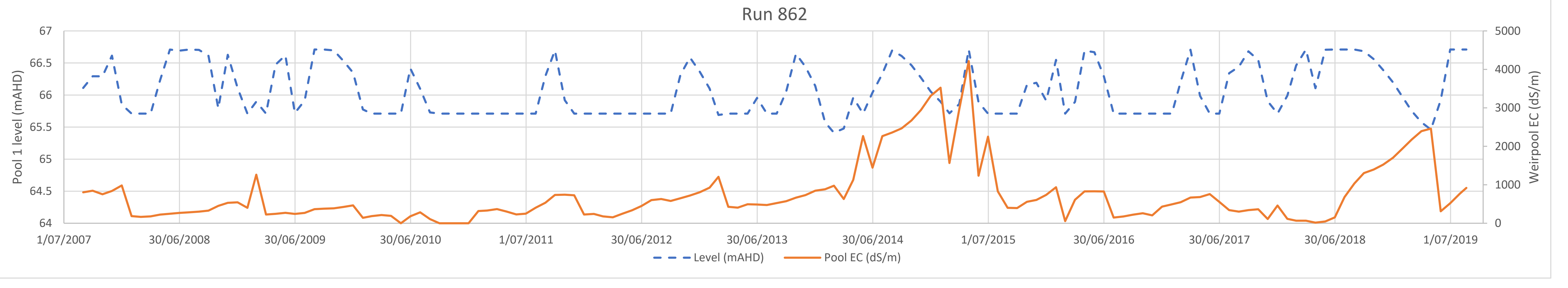

Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

MODFLOW future scenarios – WNSW Run 862

Input

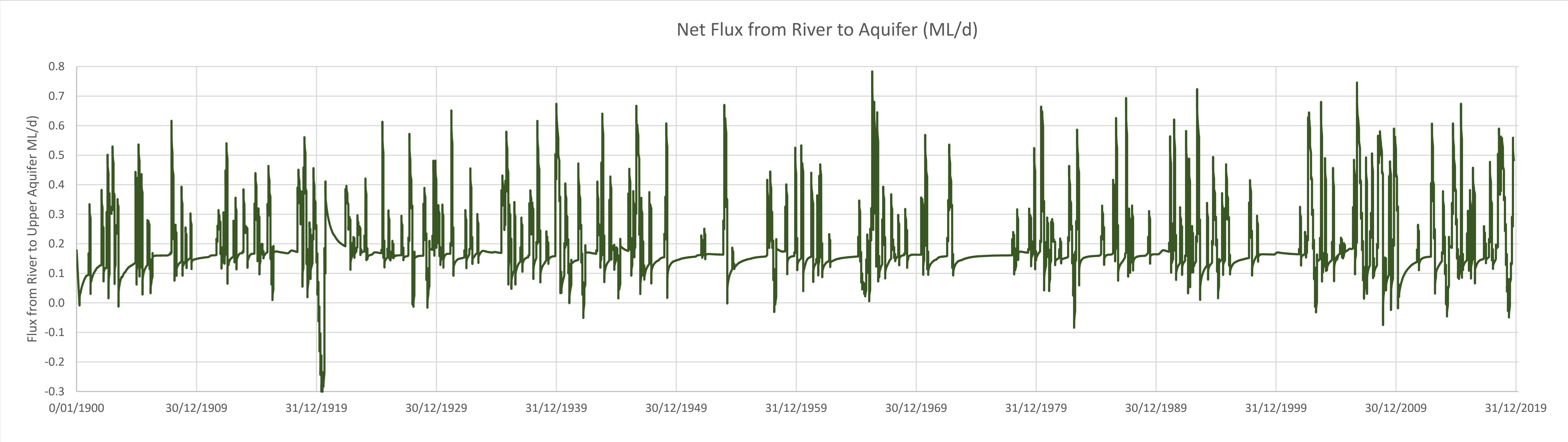


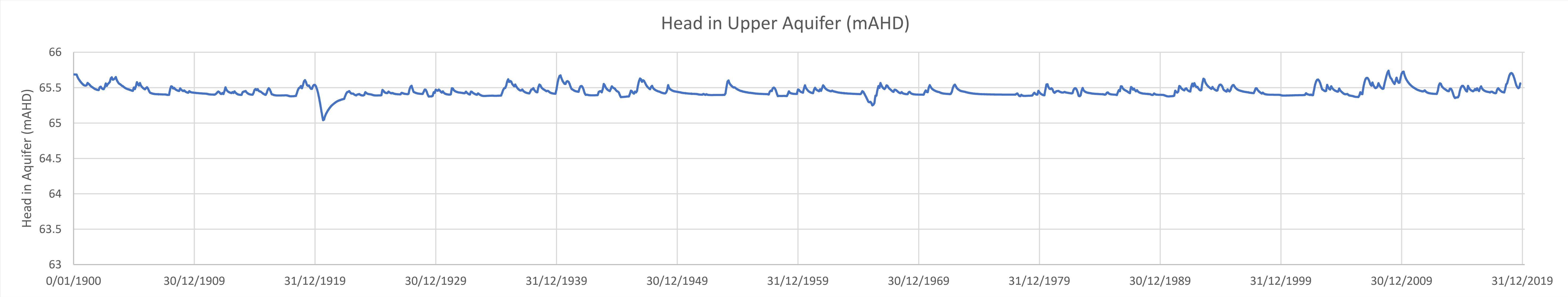


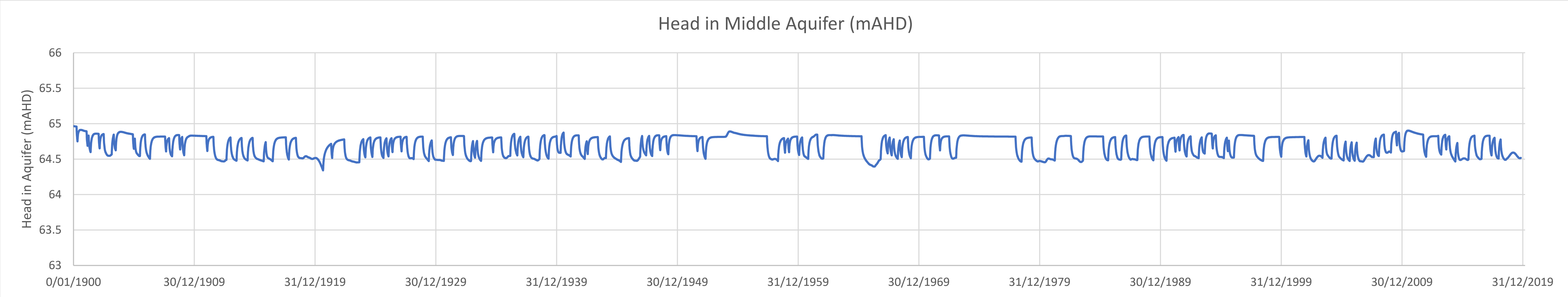


MODFLOW future scenarios – WNSW Run 862

Output




Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Head in Middle Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
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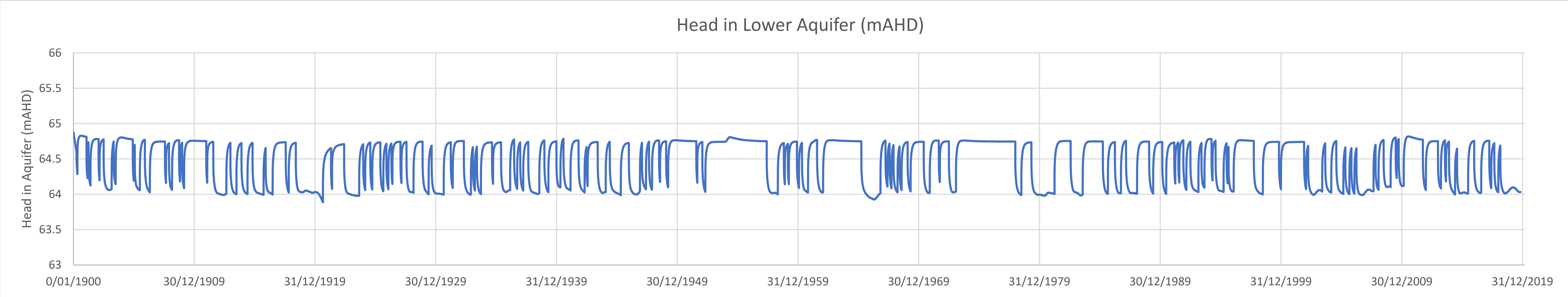
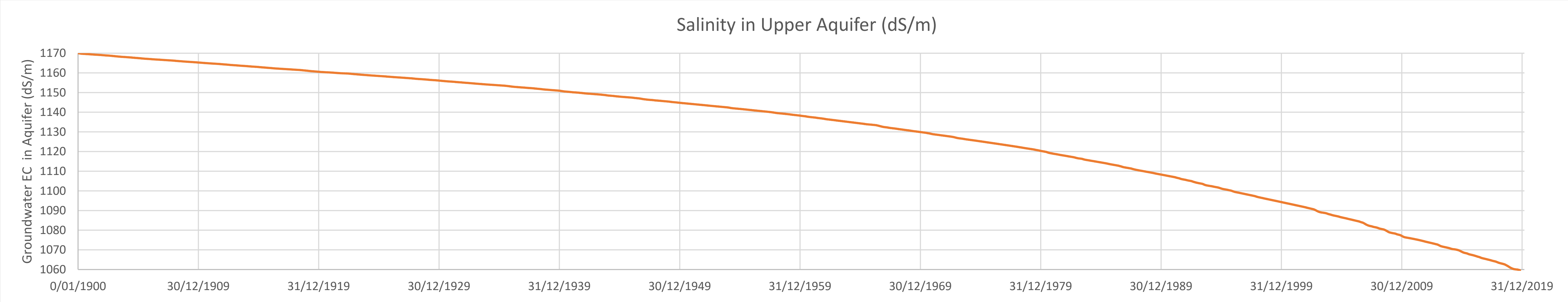
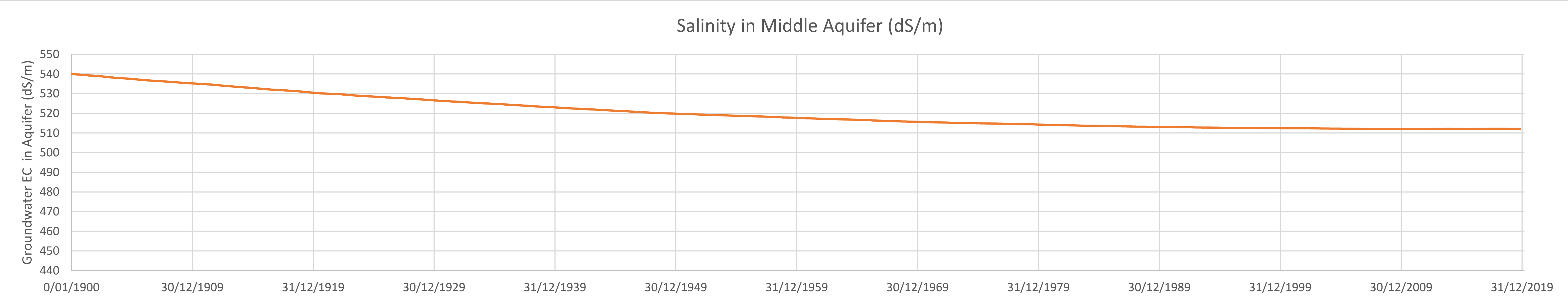
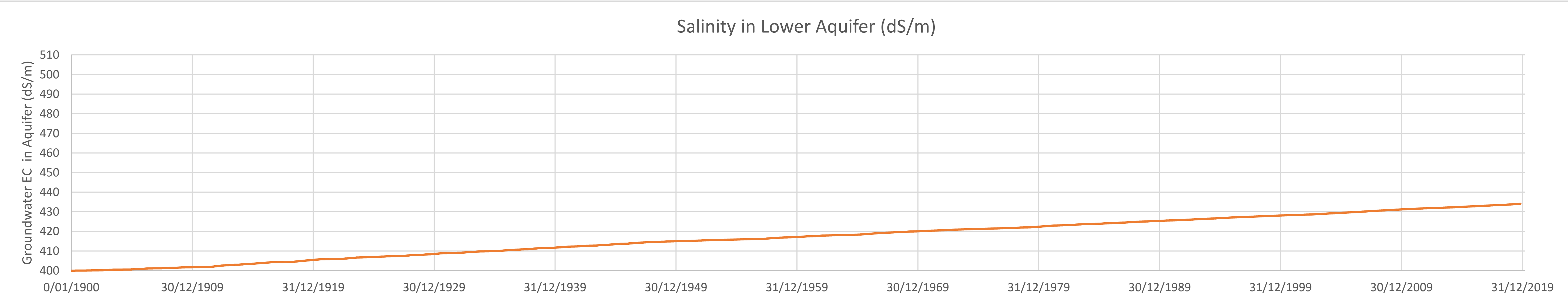
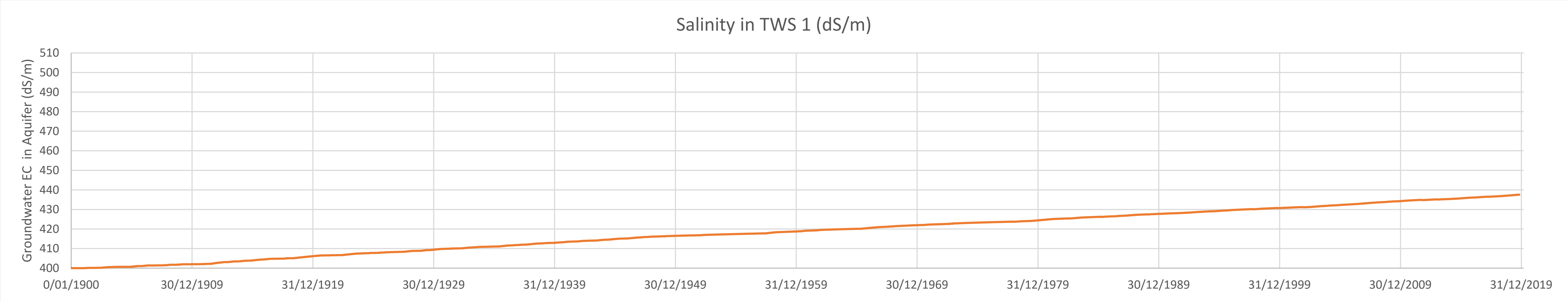
30/12/2009
31/12/2019

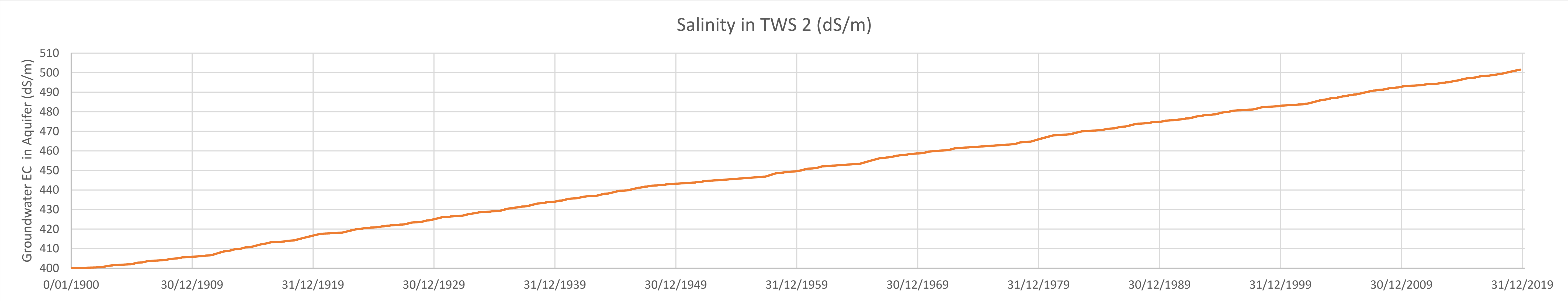

Head in Lower Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

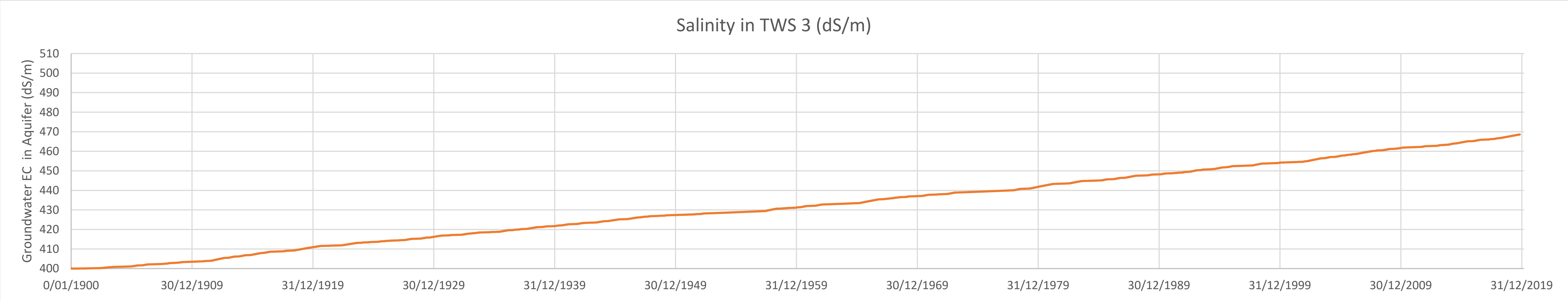

Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
550
540
530
520
510
500
490
480
470
460
450
440
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Lower Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

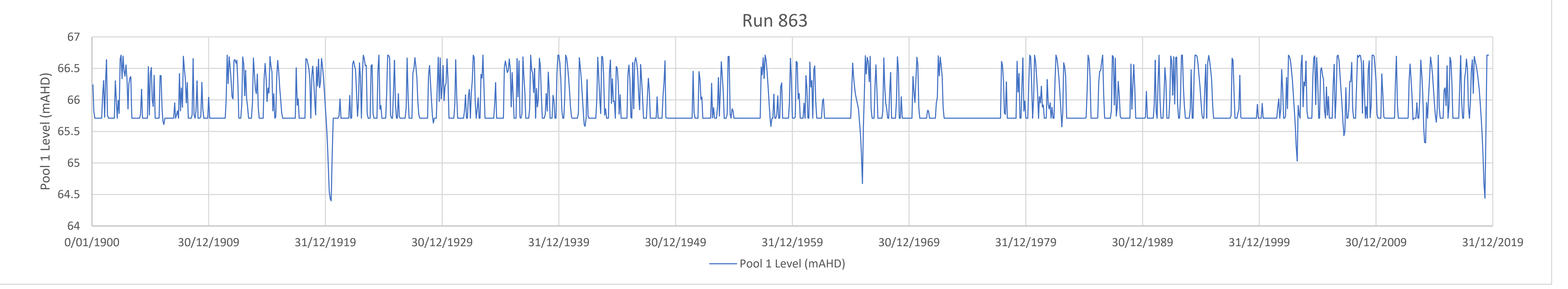

Salinity in TWS 1 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

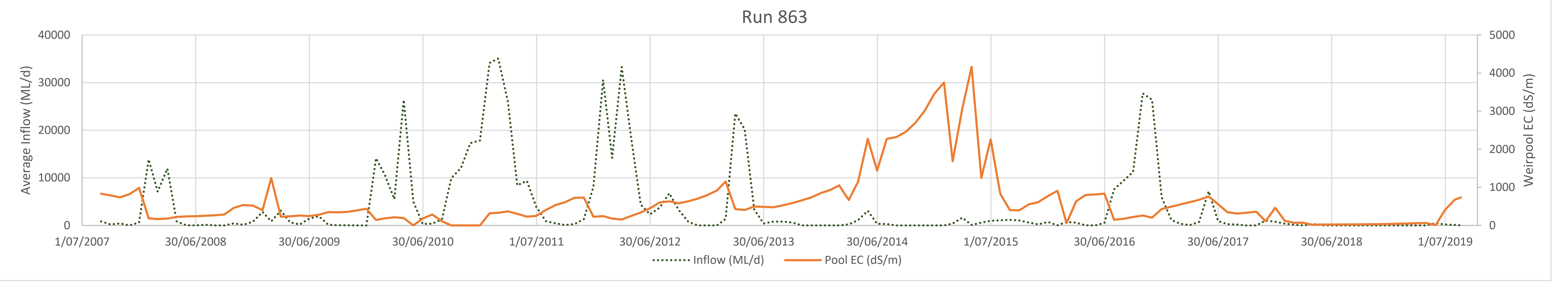

Salinity in TWS 2 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

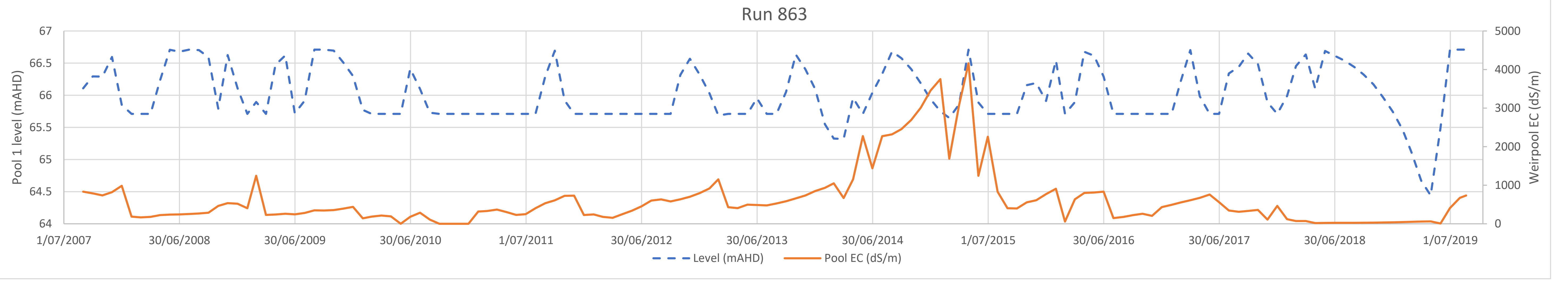

Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

MODFLOW future scenarios – WNSW Run 863

Input

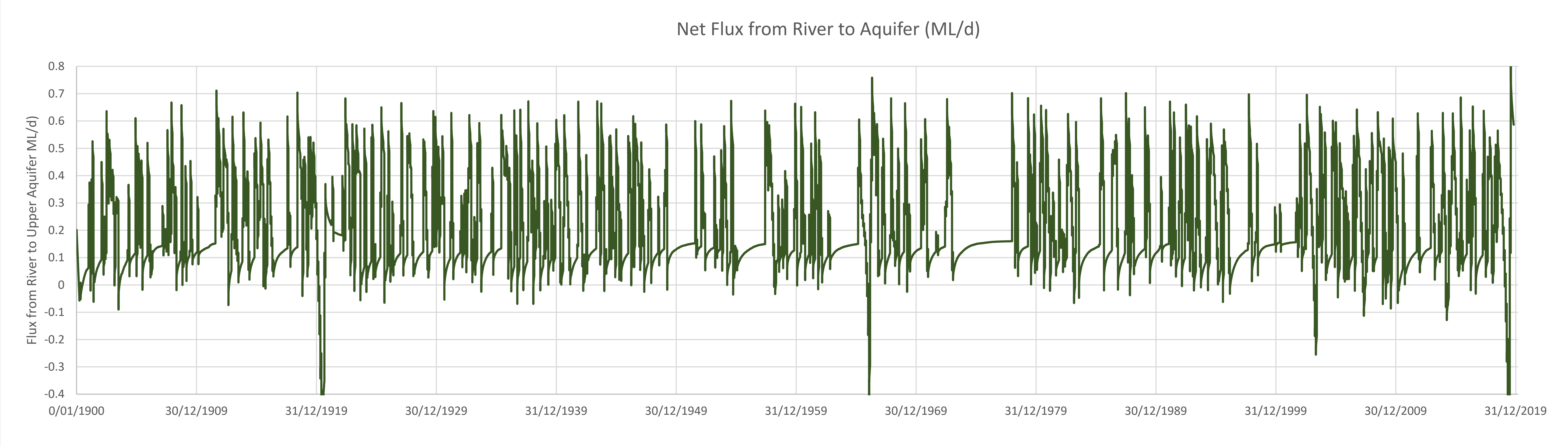


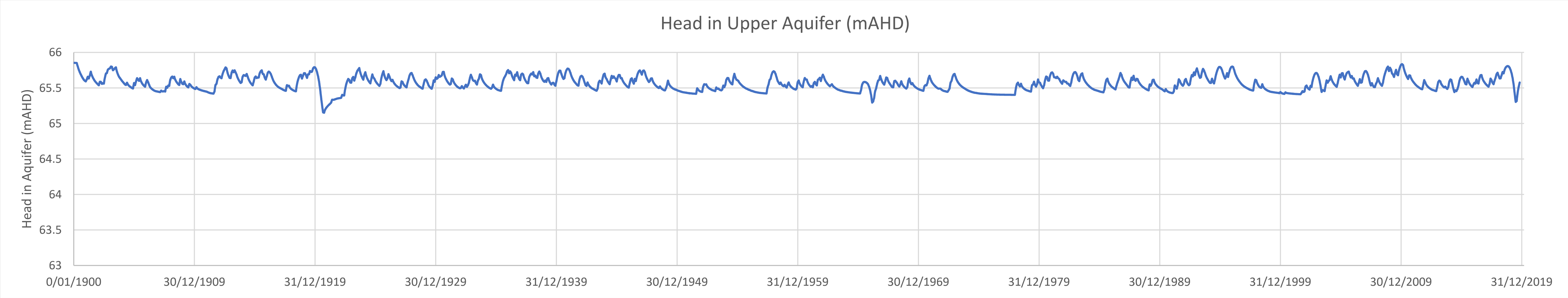


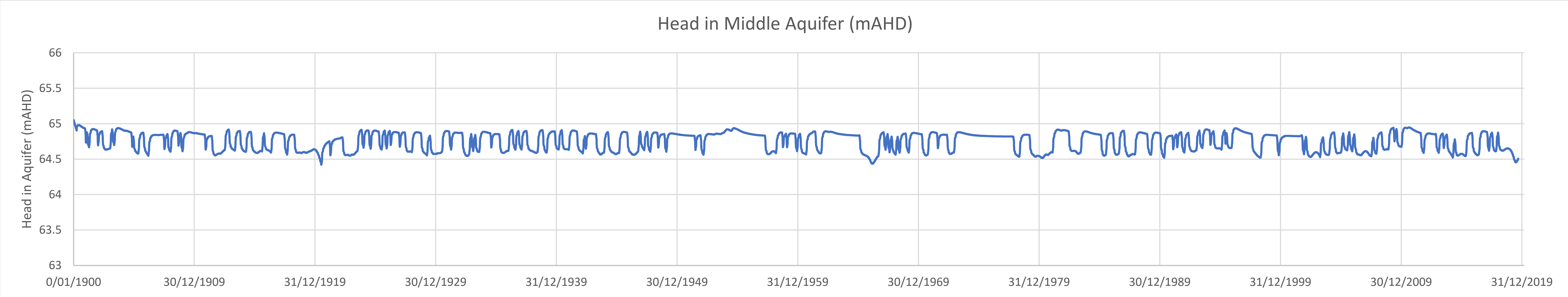


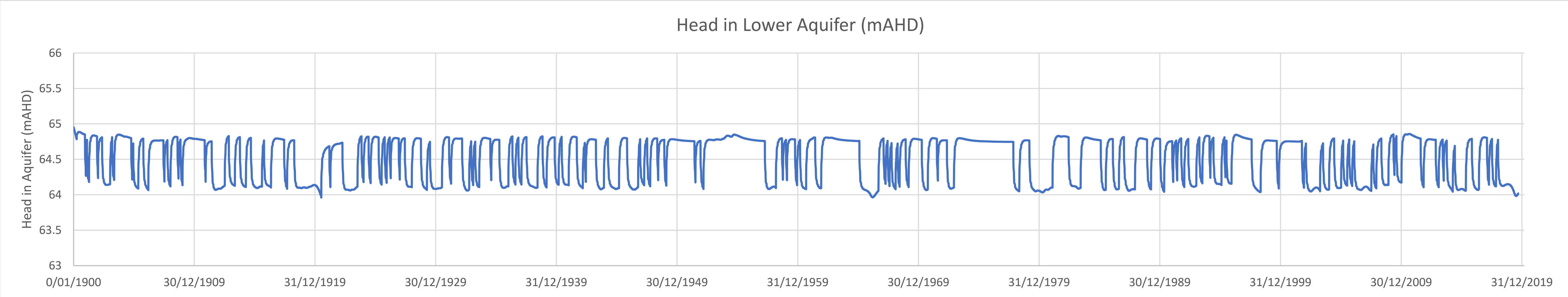
MODFLOW future scenarios – WNSW Run 863

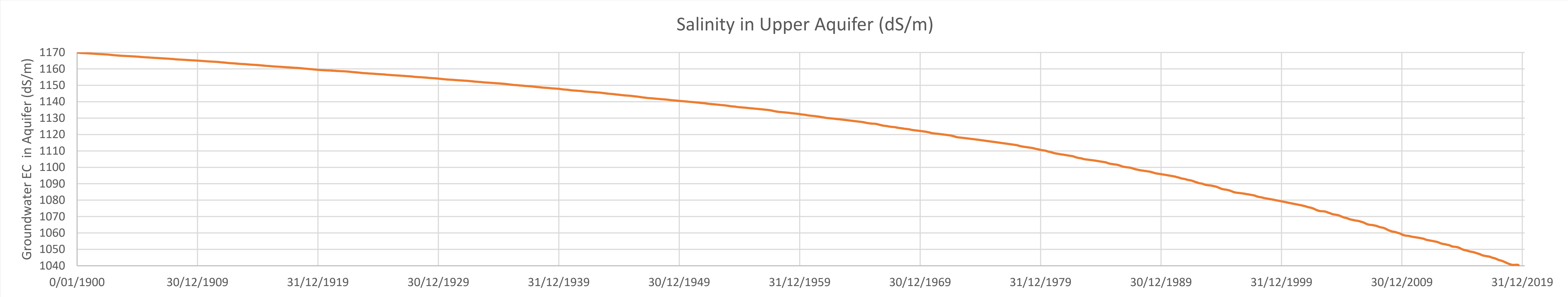
Output

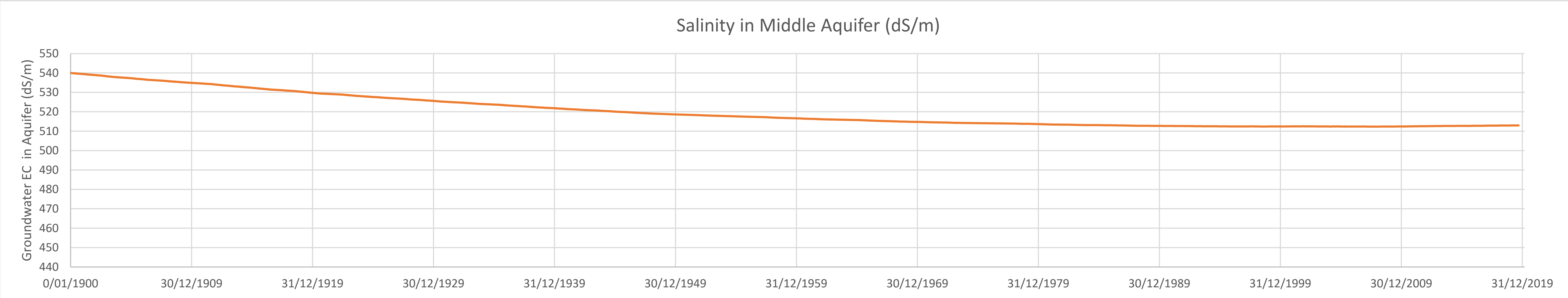


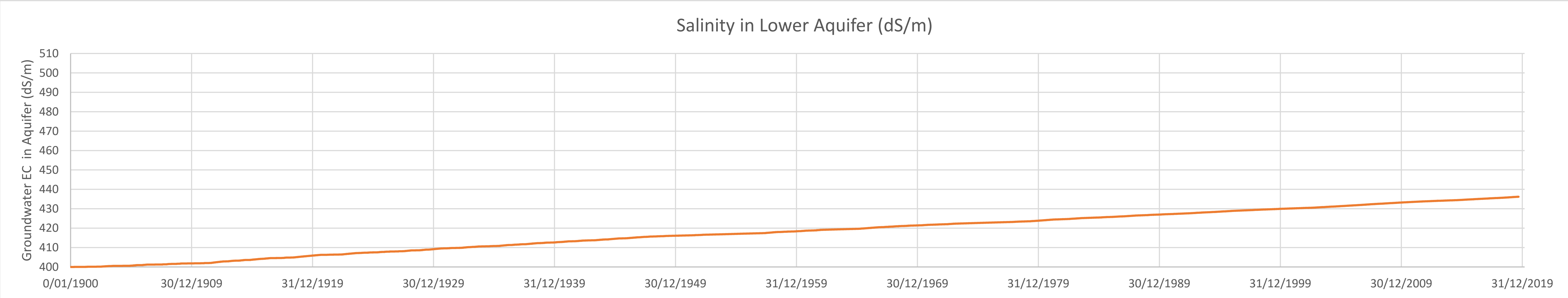

Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

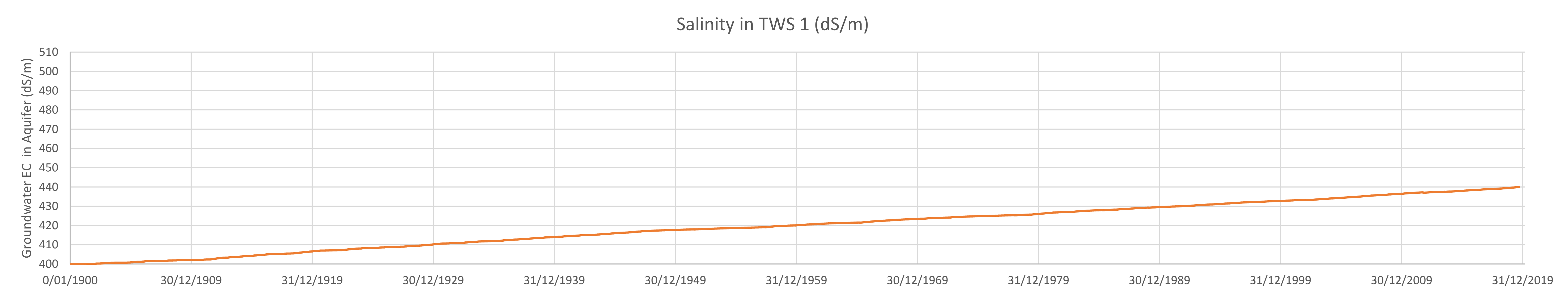

Head in Middle Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

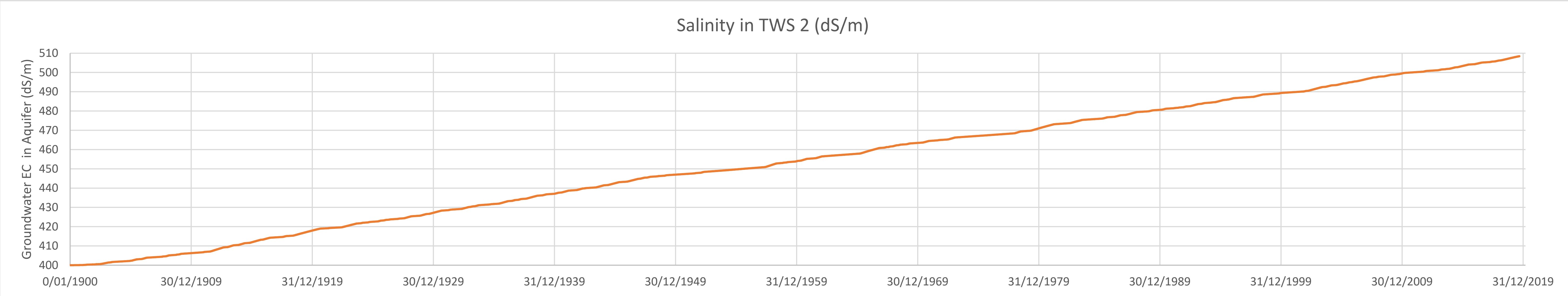

Head in Lower Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

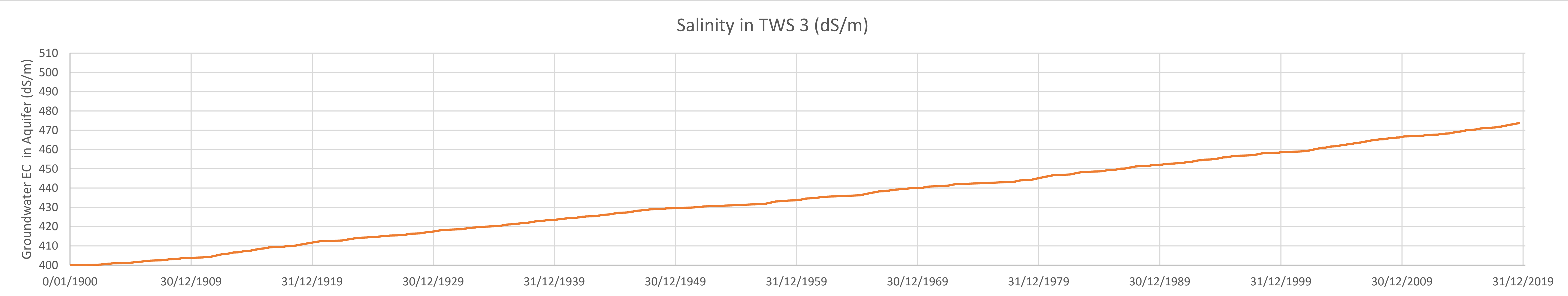

Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
550
540
530
520
510
500
490
480
470
460
450
440
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Lower Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

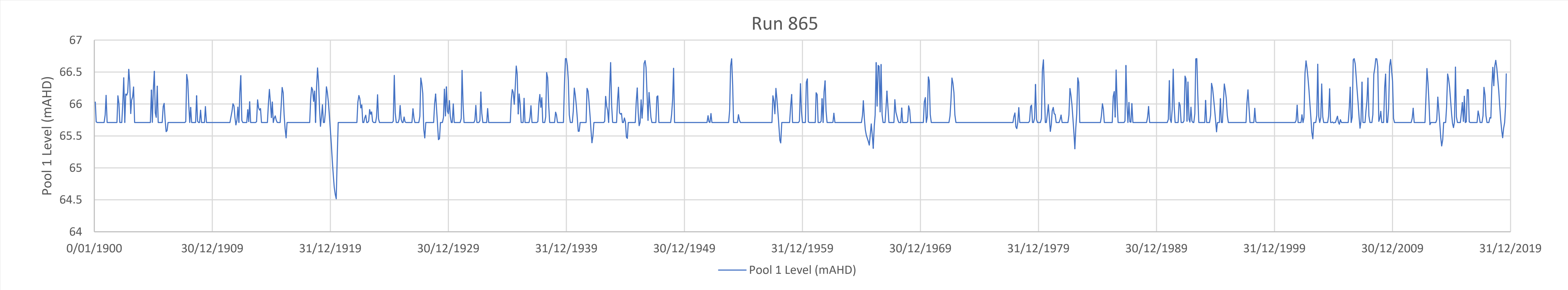

Salinity in TWS 1 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

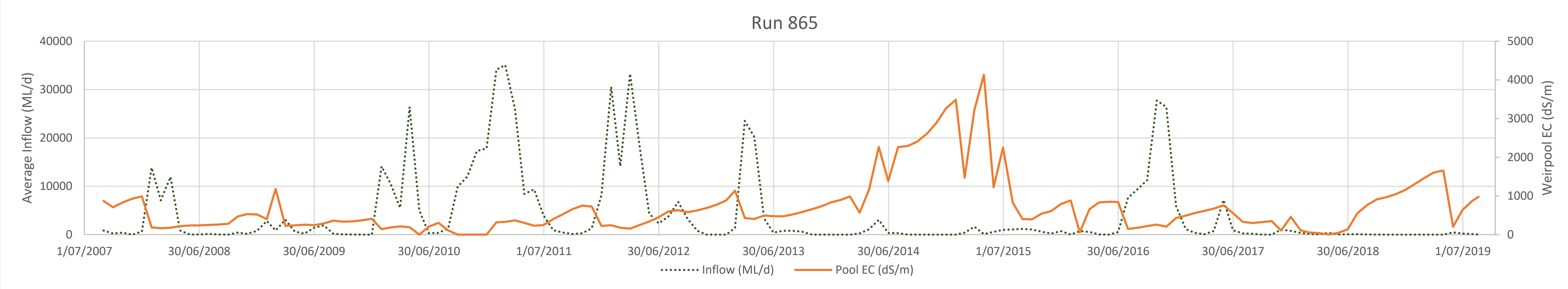

Salinity in TWS 2 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

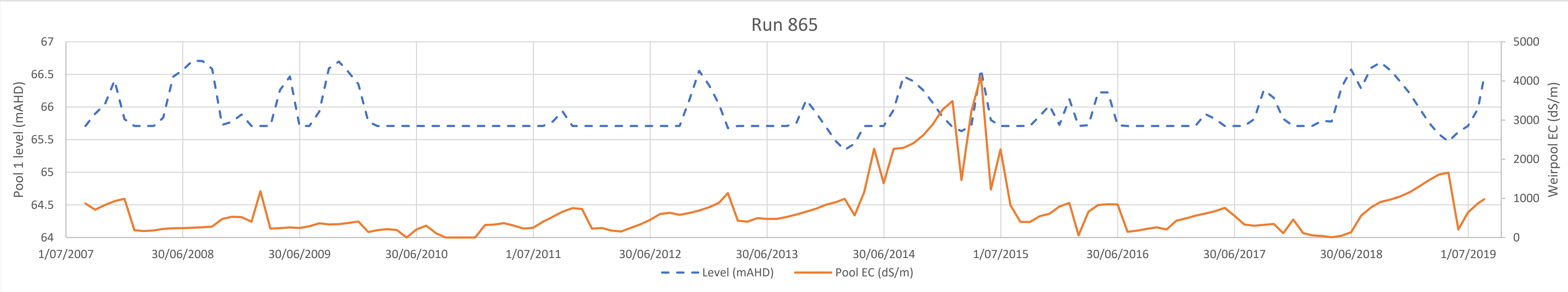

Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
490
480
470
460
450
440
430
420
410
400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019

MODFLOW future scenarios – WNSW Run 865

Input

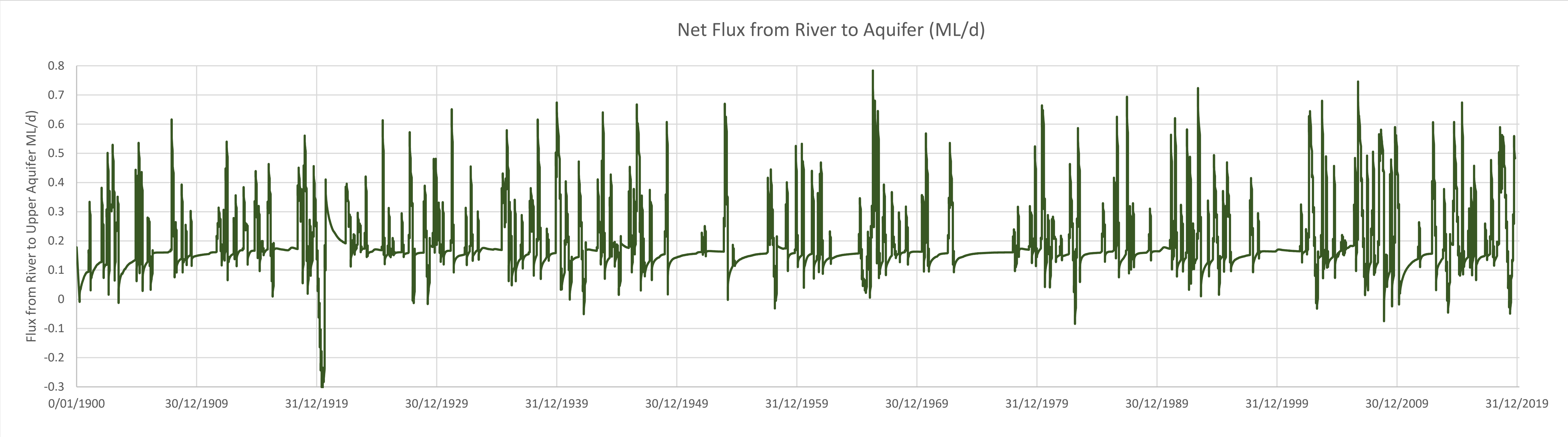


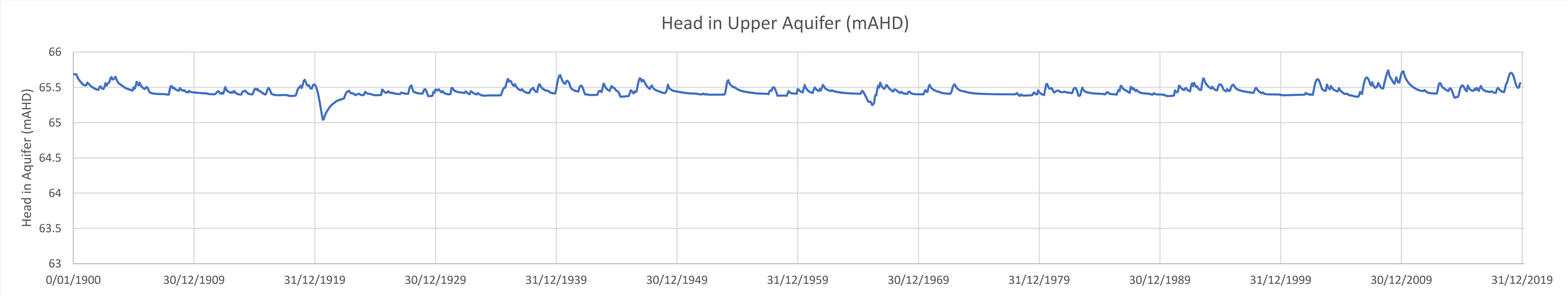


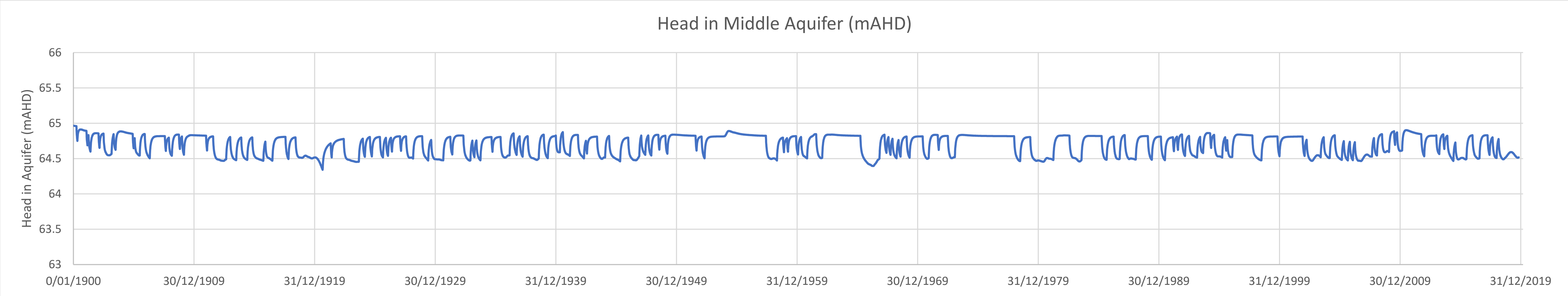


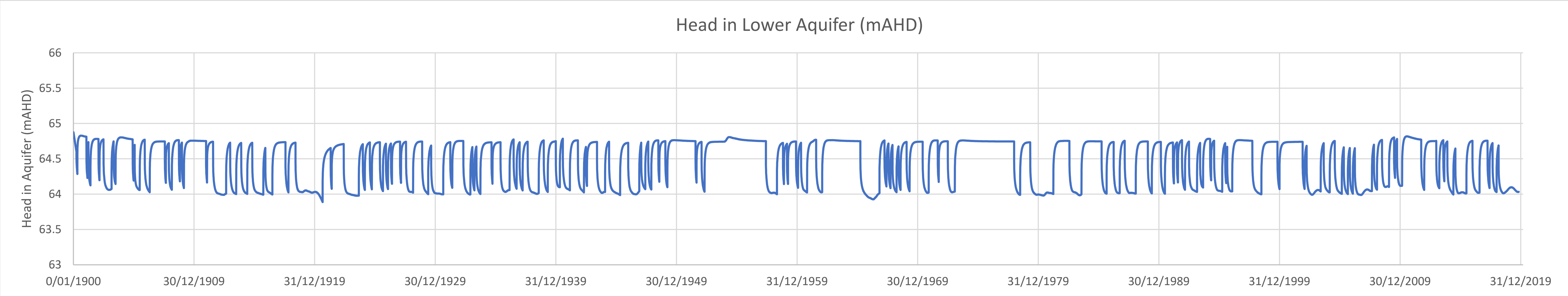
MODFLOW future scenarios – WNSW Run 865

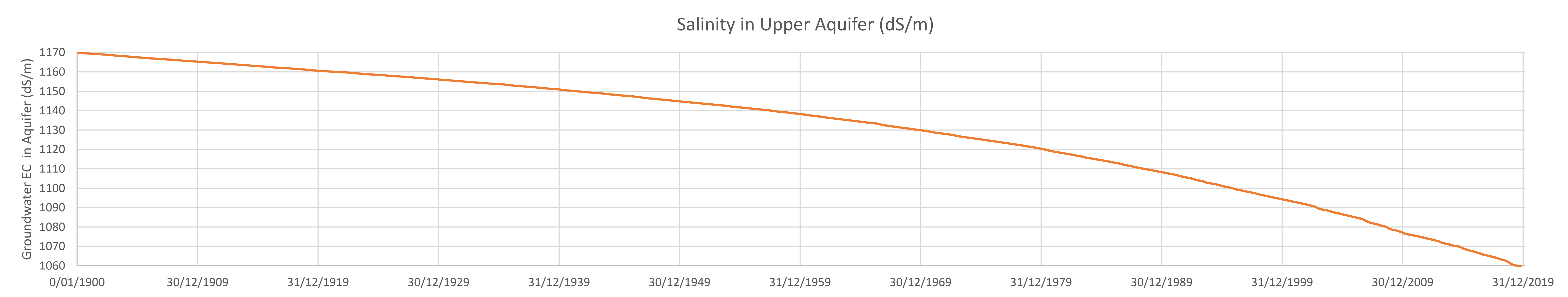
Output

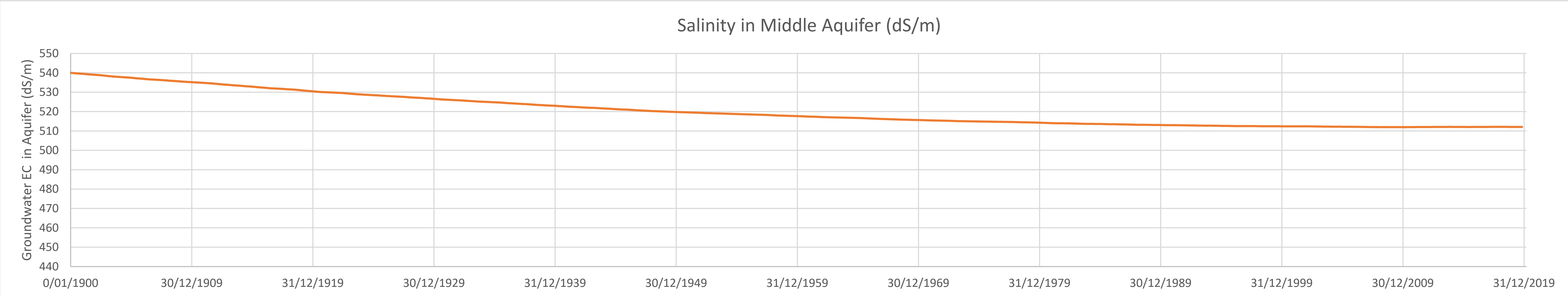


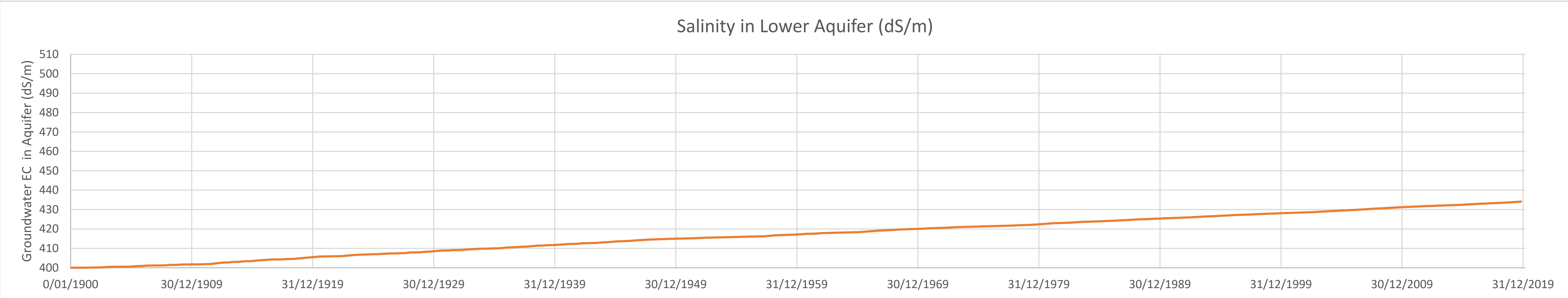

Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Head in Middle Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Head in Lower Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
550
540
530
520
510
500
490
480
470
460
450
440
0/01/1900
30/12/1909
31/12/1919
30/12/1929
31/12/1939
30/12/1949
31/12/1959
30/12/1969
31/12/1979
30/12/1989
31/12/1999
30/12/2009
31/12/2019


Salinity in Lower Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
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400
0/01/1900
30/12/1909
31/12/1919
30/12/1929
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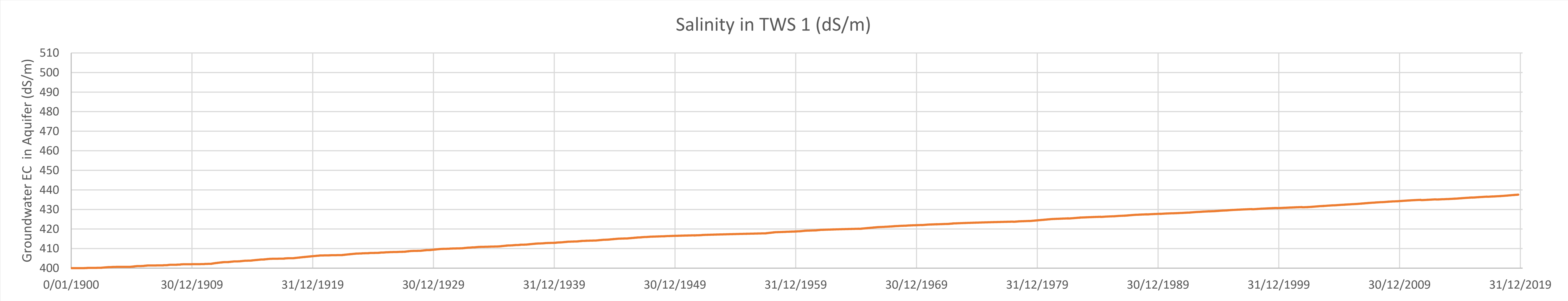
Salinity in TWS 1 (dS/m)
Groundwater EC in Aquifer (dS/m)
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500
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470
460
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410
400
0/01/1900
30/12/1909
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30/12/1929
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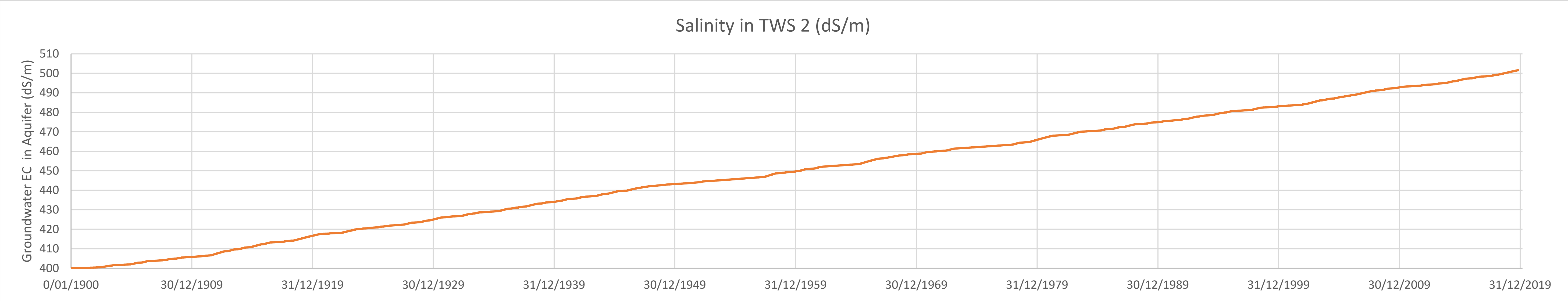
31/12/2019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Groundwater EC in Aquifer (dS/m)
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460
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0/01/1900
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30/12/1929
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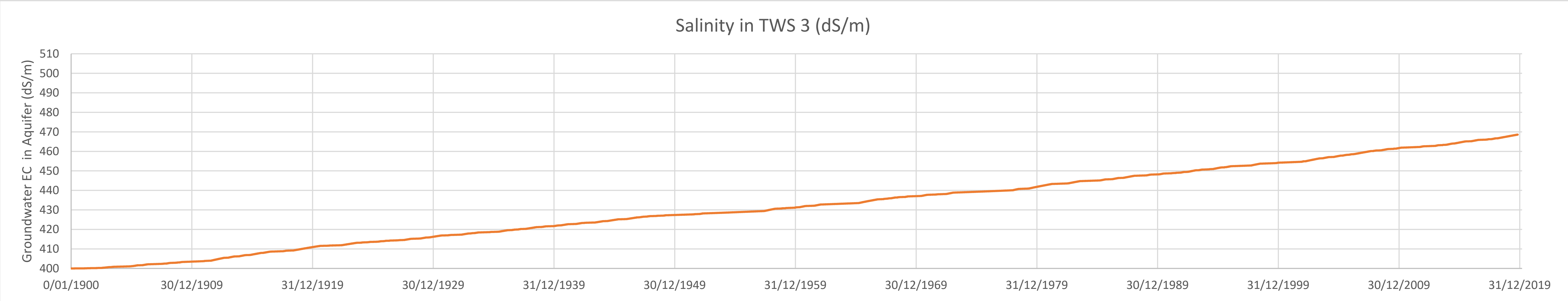
Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
500
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0/01/1900
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30/12/1929
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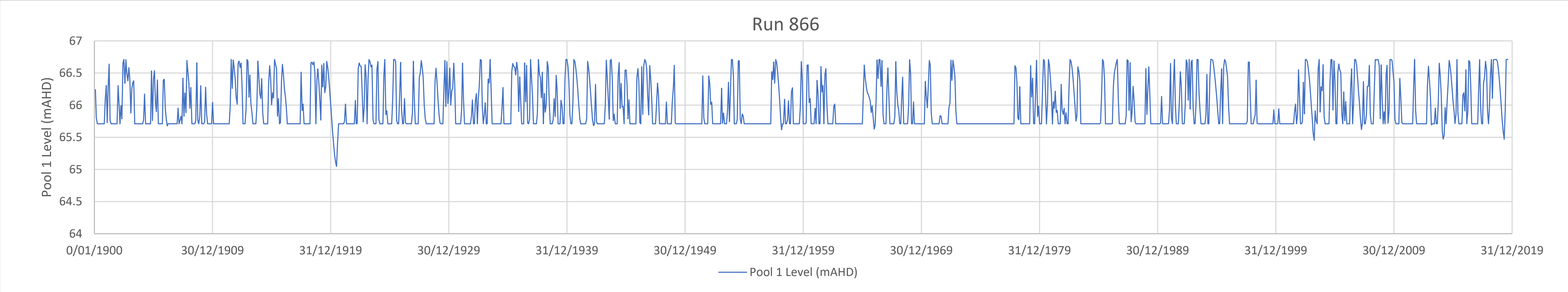
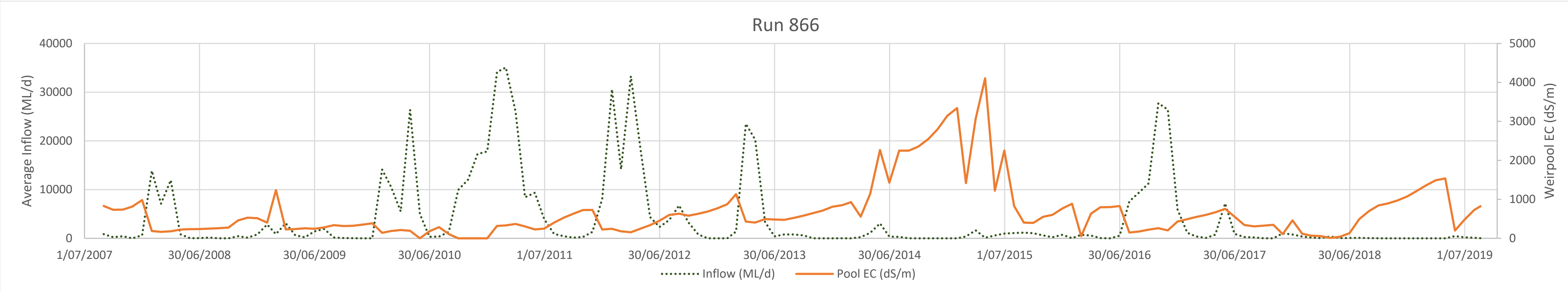
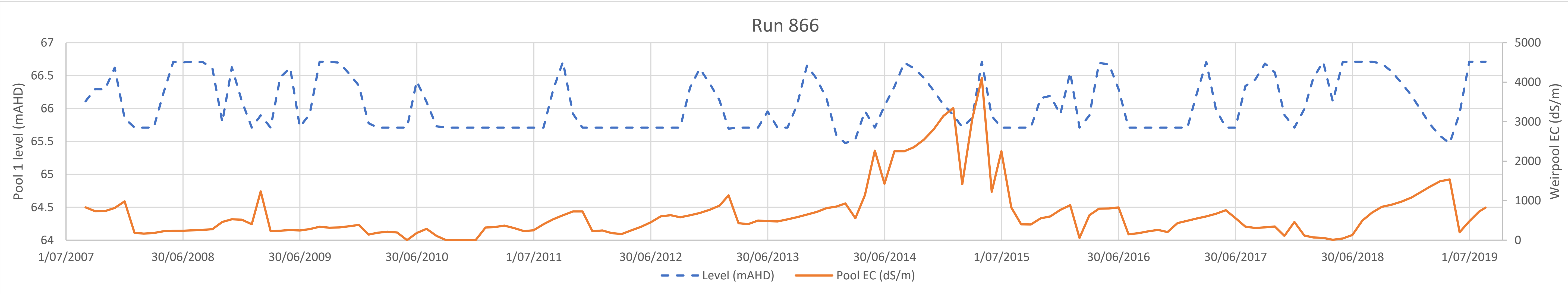
MODFLOW future scenarios – WNSW Run 866

Input







MODFLOW future scenarios – WNSW Run 866

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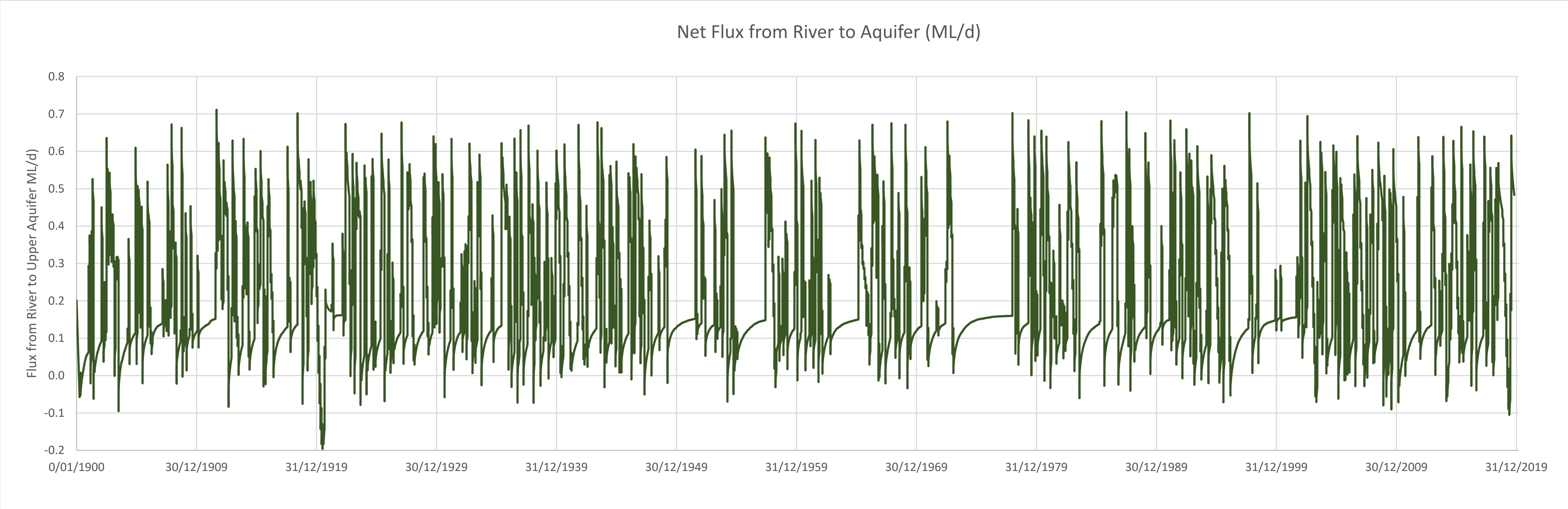

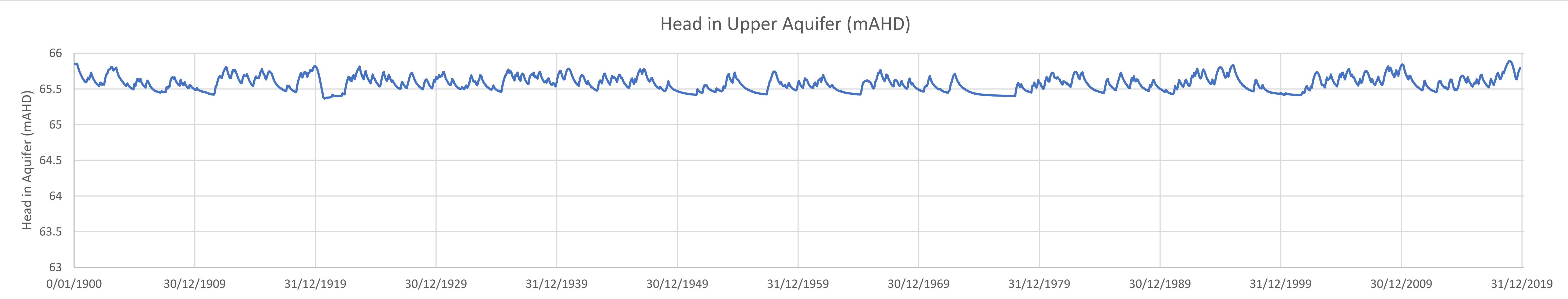
Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
65
64.5
64
63.5
63
0/01/1900
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31/12/1919
30/12/1929
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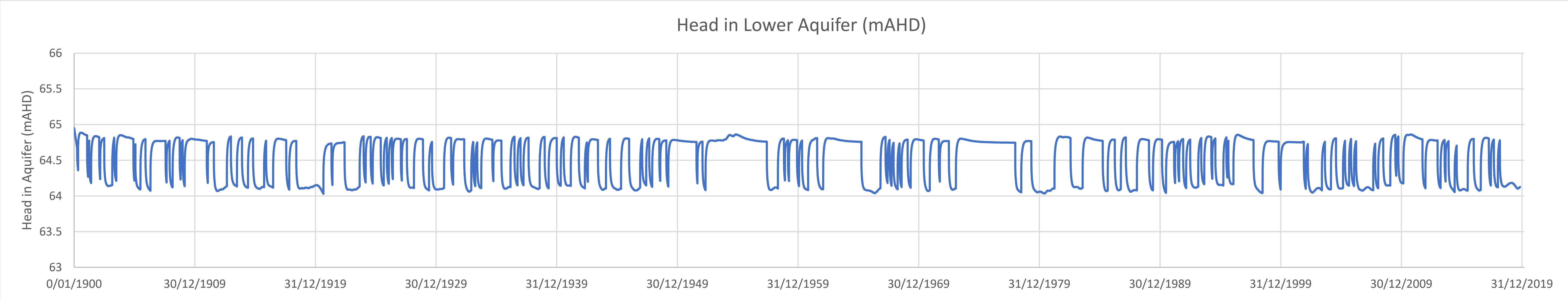
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Head in Aquifer (mAHD)
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64.5
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63.5
63
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31/12/1919
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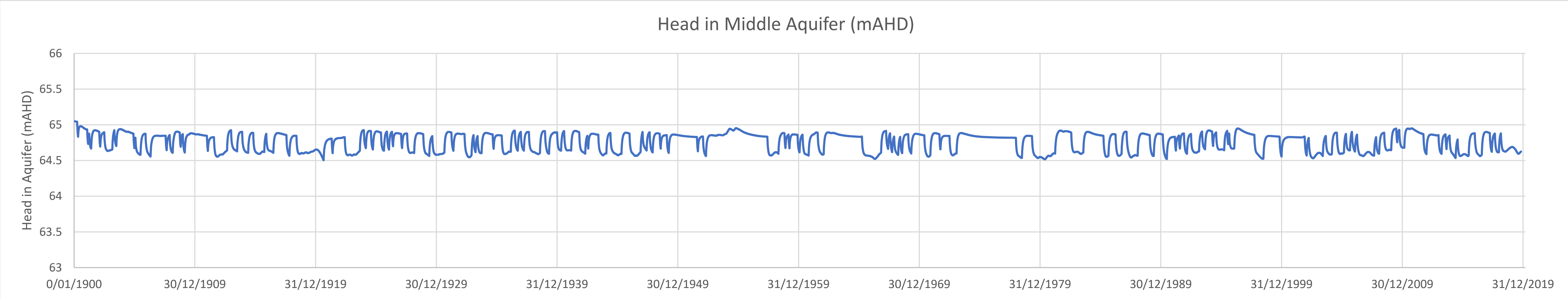
31/12/2019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Head in Aquifer (mAHD)
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65.5
65
64.5
64
63.5
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0/01/1900
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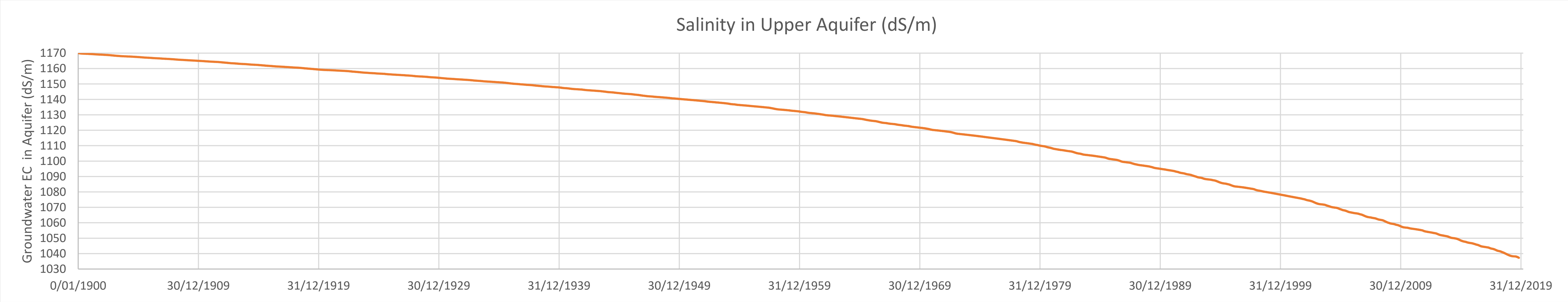
Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
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1080
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1060
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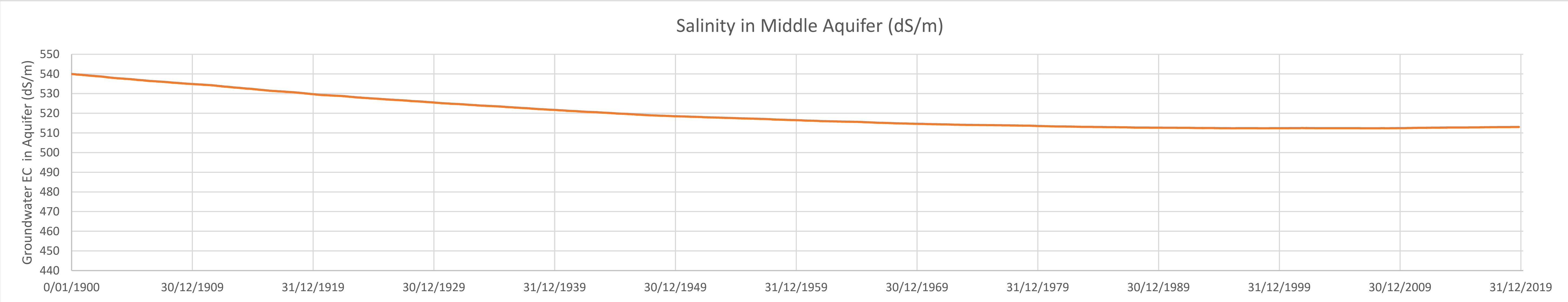
Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
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530
520
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500
490
480
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0/01/1900
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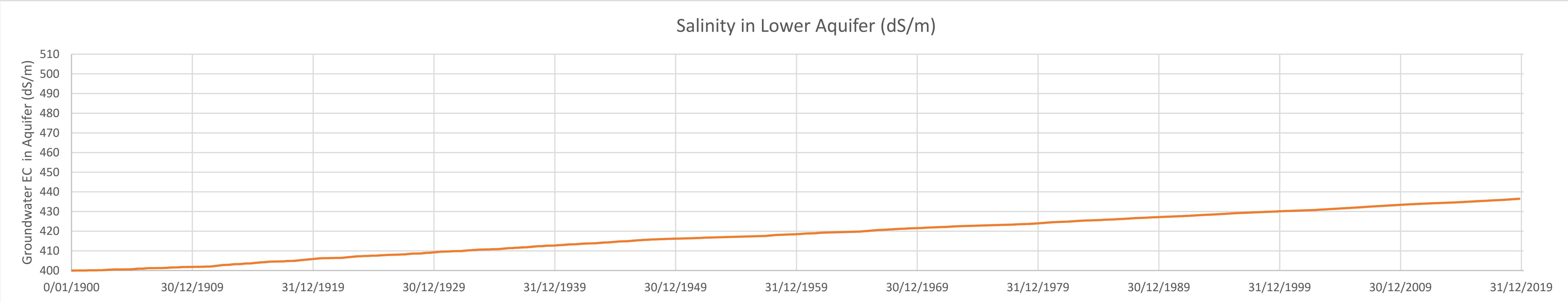
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Groundwater EC in Aquifer (dS/m)
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500
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0/01/1900
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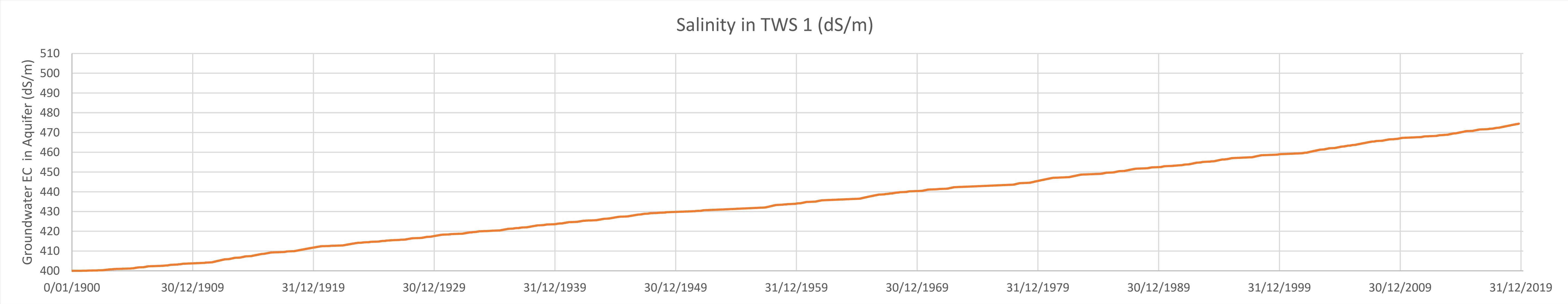
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Groundwater EC in Aquifer (dS/m)
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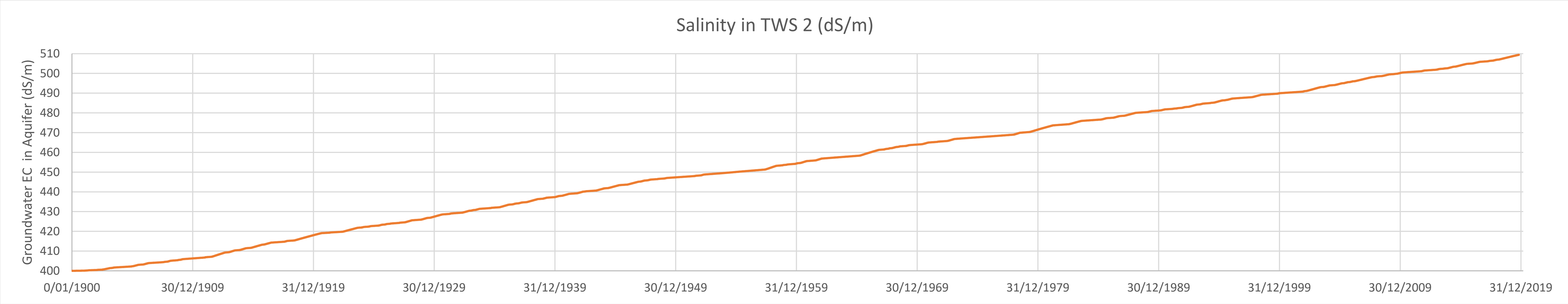
Salinity in TWS 2 (dS/m)
Groundwater EC in Aquifer (dS/m)
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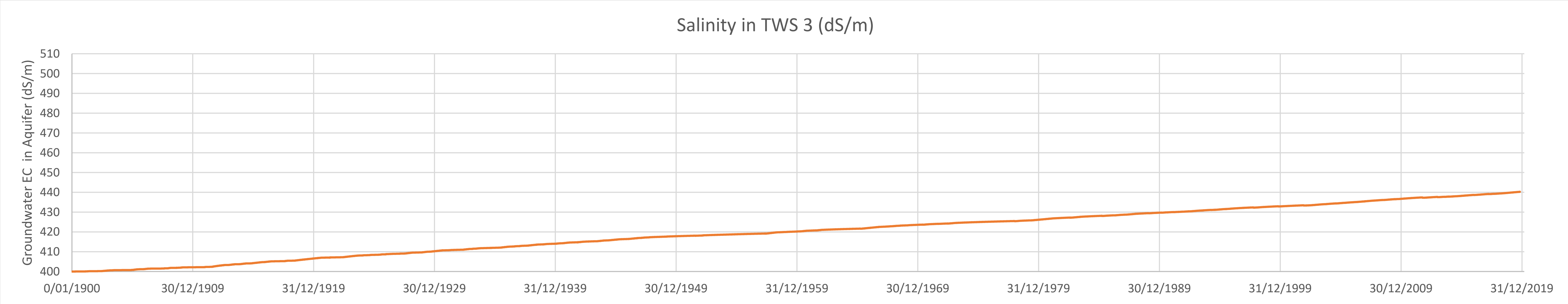
Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
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500
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31/12/1919
30/12/1929
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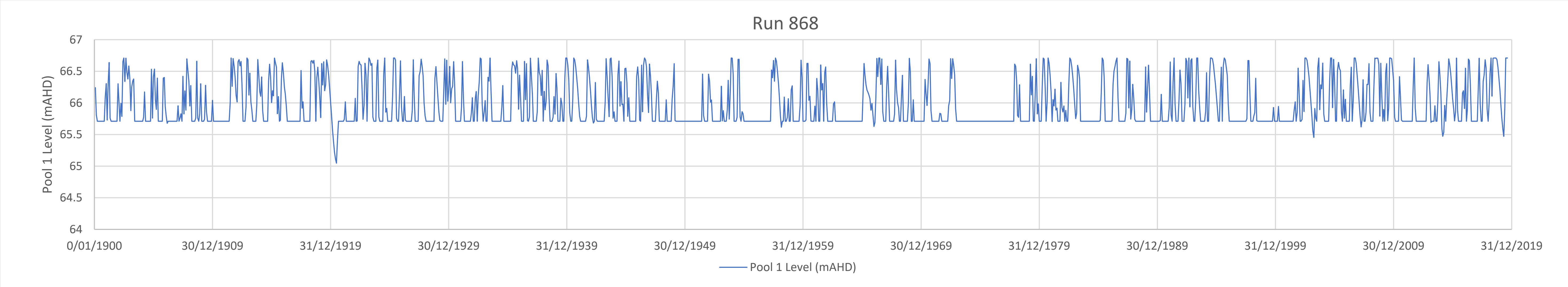
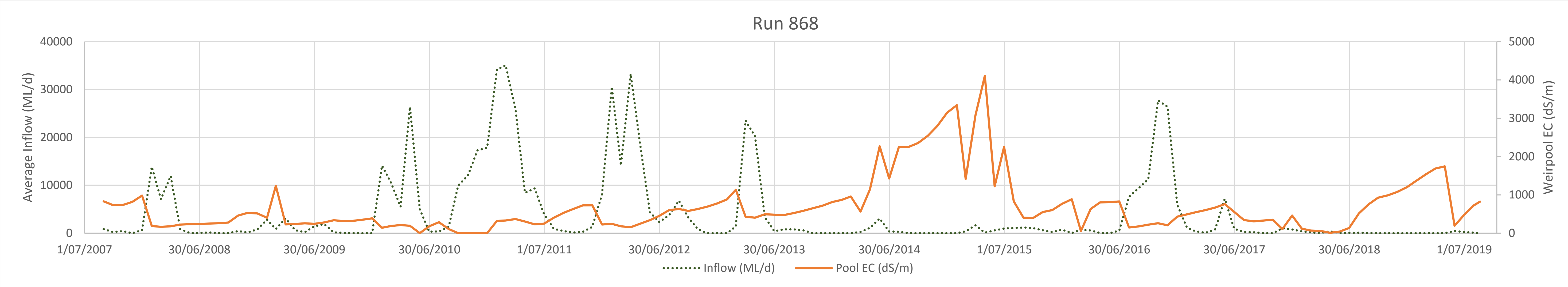
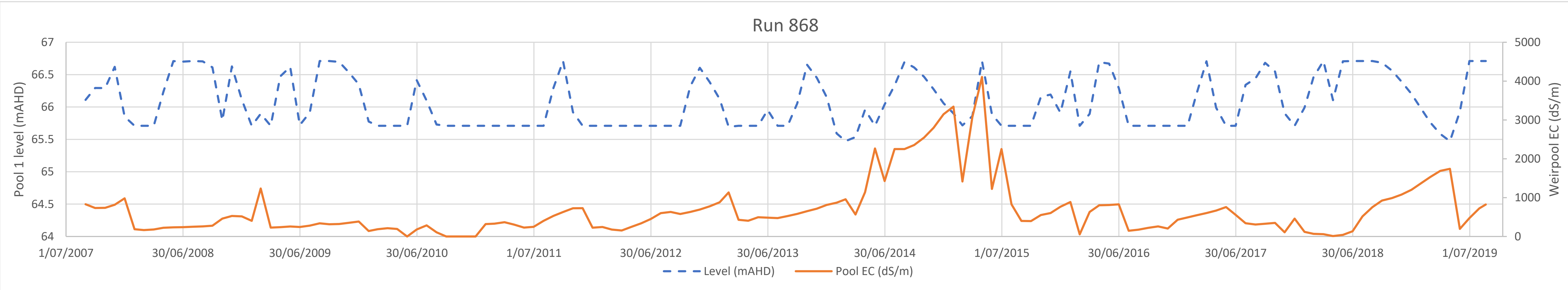
31/12/2019

MODFLOW future scenarios – WNSW Run 868

Input







MODFLOW future scenarios – WNSW Run 868

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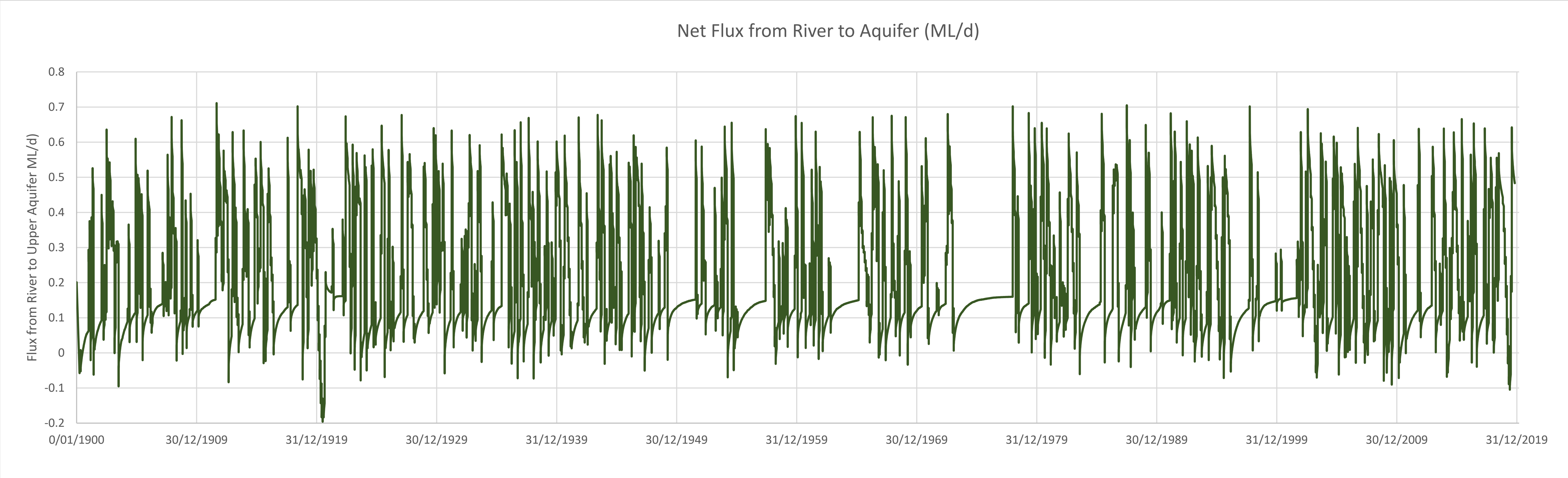

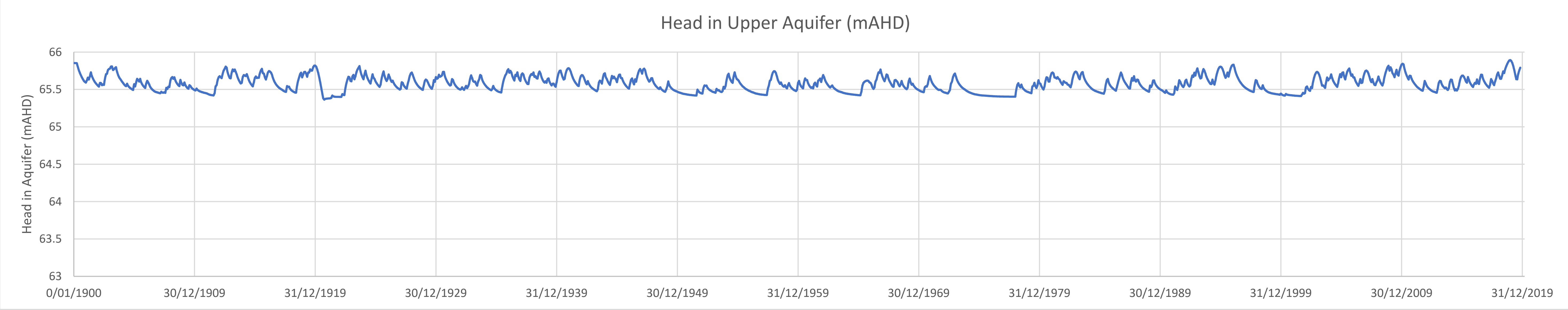
Head in Upper Aquifer (mAHD)
Head in Aquifer (mAHD)
66
65.5
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31/12/1919
30/12/1929
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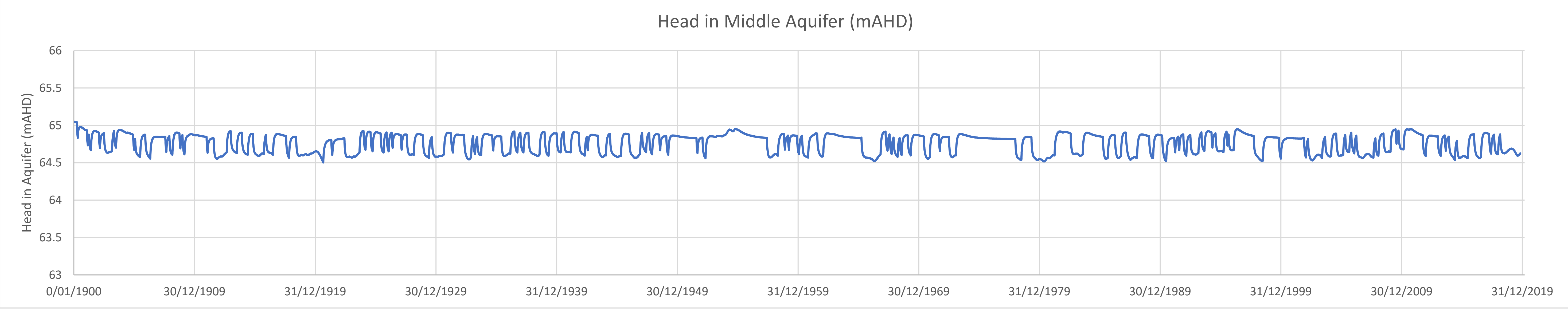
Head in Middle Aquifer (mAHD)
Head in Aquifer (mAHD)
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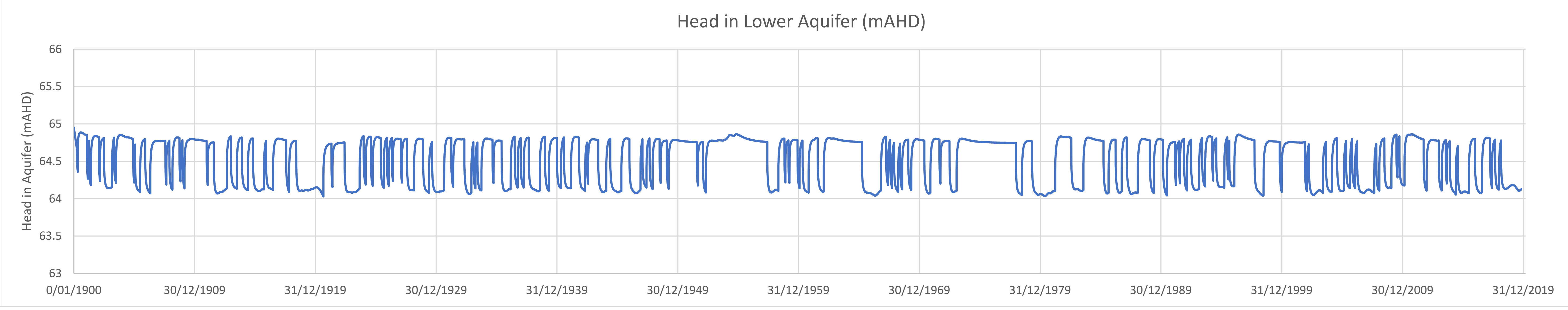
Head in Lower Aquifer (mAHD)
Head in Aquifer (mAHD)
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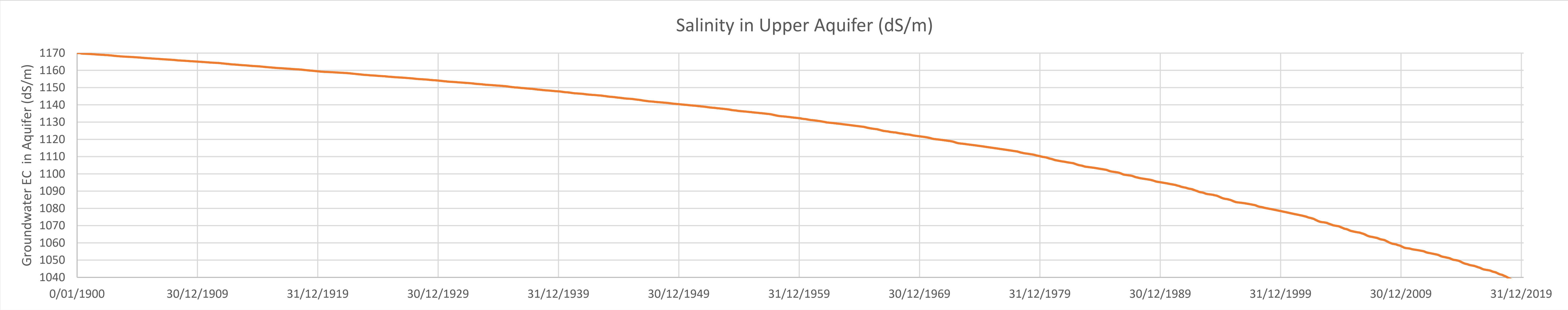
Salinity in Upper Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
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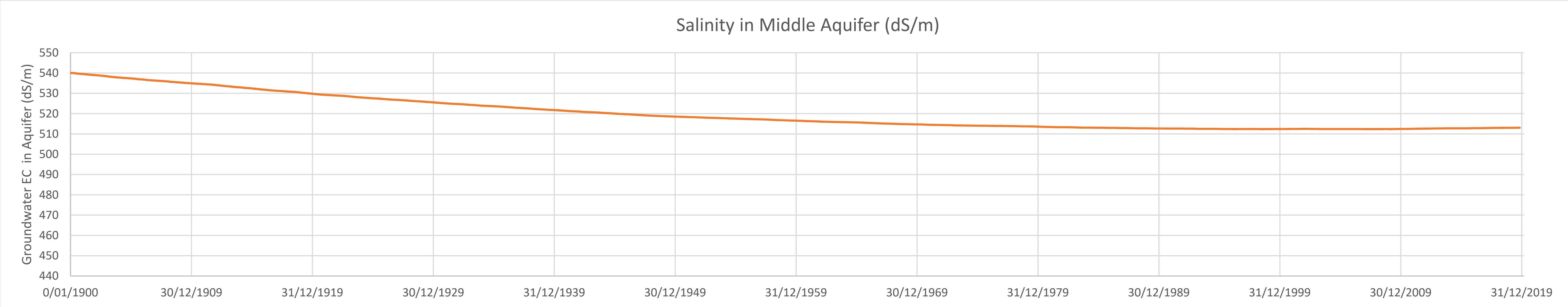
Salinity in Middle Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
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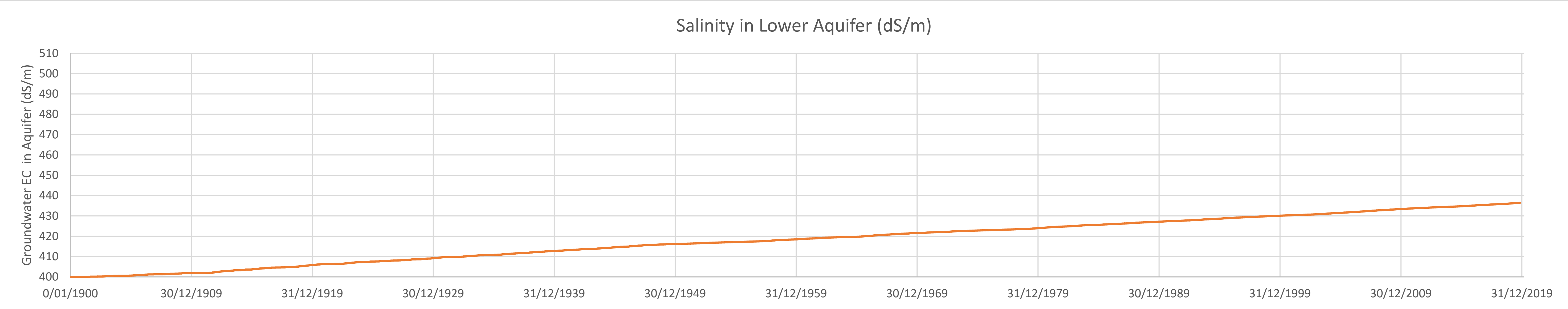
Salinity in Lower Aquifer (dS/m)
Groundwater EC in Aquifer (dS/m)
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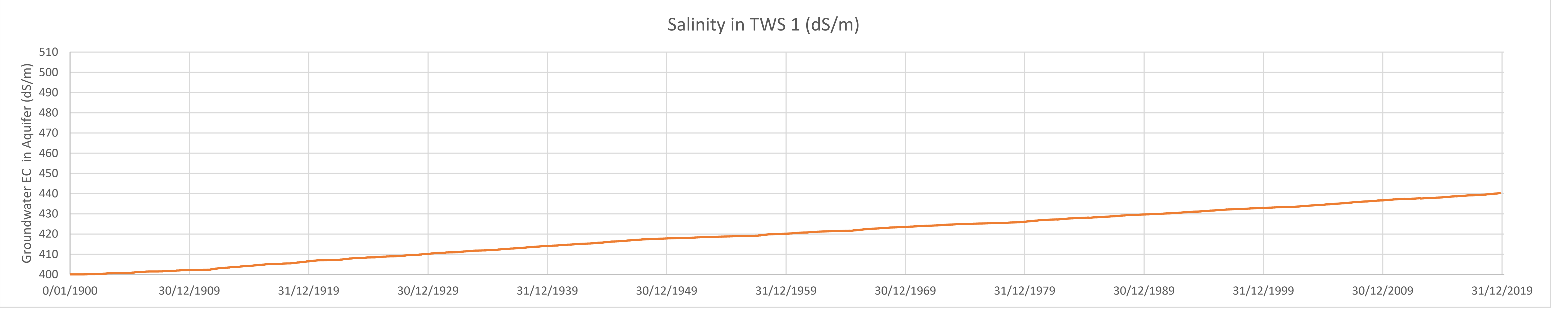
Salinity in TWS 1 (dS/m)
Groundwater EC in Aquifer (dS/m)
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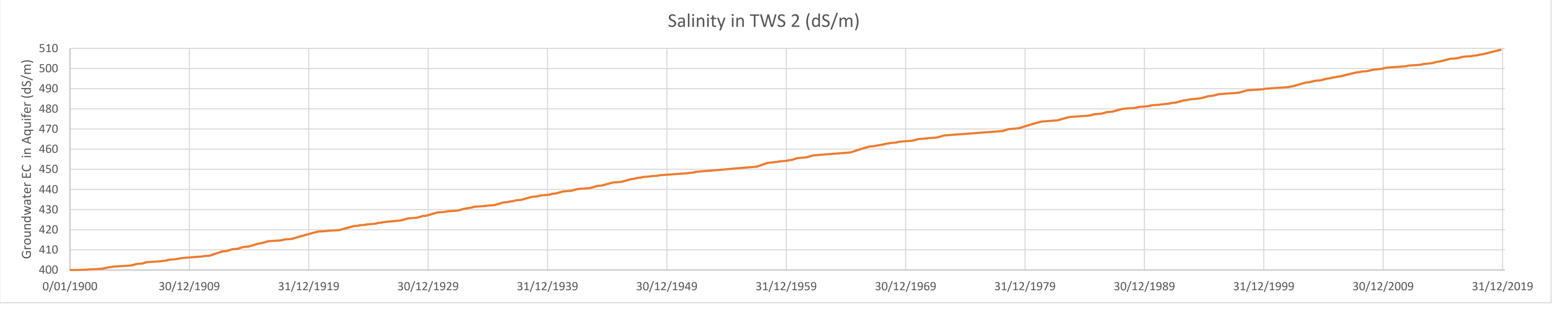
Salinity in TWS 2 (dS/m)
Groundwater EC in Aquifer (dS/m)
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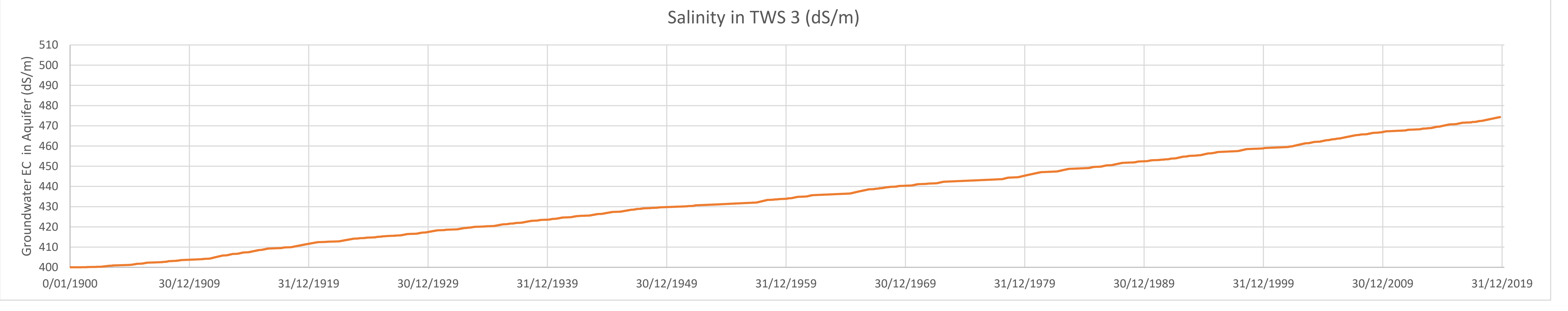
Salinity in TWS 3 (dS/m)
Groundwater EC in Aquifer (dS/m)
510
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31/12/1939
30/12/1949
31/12/1959
30/12/1969
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Appendix E. Visual survey

A visual survey of the Darling River (Baaka) from downstream of the new weir site to the upstream extent of the extended weir pool when the new weir is in drought security operation mode was carried out between 17 and 22 November 2020. The survey locations are shown in **Figure E-1.** Descriptions of the river at each survey location are provided in **Table E-1**.

Figure E-1 Visual survey of the Darling River (Baaka), new weir pool extent

Existing weir
Proposed new weir
Visual survey sites
Roads

Full supply level
New and existing weir pool
New permanent weir pool (the 'new town pool')
New temporary weir pool (drought security operation mode only)

0 0.5 1 km
N

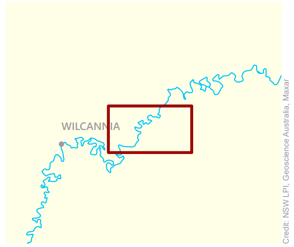

Figure E-1 Visual survey of the Darling River (Baaka), new weir pool extent

Figure E-1 Visual survey of the Darling River (Baaka), new weir pool extent

Table E-1 Visual survey findings

Visual survey site	Site location	Site photographs	Site description
A1-A	480 metres downstream of the proposed new weir	 Site A1-1 facing upstream  SiteA1-1 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 is located on a meander bend of the river, about 5.5 kilometres downstream of the existing Wilcannia Weir. The channel is about 30 metres wide at this location and the riverbanks are moderately steep. Immediately upstream and downstream of the site were two large, deep pools. There were also three bars present instream and connected to the riverbank. The substrate consists of a fine silt. There was no evidence of active erosion at this site.

Visual survey site	Site location	Site photographs	Site description
A1	Proposed new weir site	 Site A1 facing upstream  Site A-1 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 five kilometres downstream of the existing Wilcannia Weir. The channel is about 30 metres wide at this location and the riverbank slope is moderate on the western bank and steep on the eastern bank (near vertical on the eastern bank). 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. There is a small bar connected to the western riverbank. The substrate consisted of a fine silt which appeared to have been trampled. There was evidence of undercutting at the site.

Visual survey site	Site location	Site photographs	Site description
A2	About 160 metres upstream of the proposed new weir	 Site A2 facing upstream  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 is about 20 metres wide at this location and the riverbank slope is moderate on the western bank and steep on the eastern bank (near vertical on the eastern bank). 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 river bank were present on the western side of the river. 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.

Visual survey site	Site location	Site photographs	Site description
A3	About 450 metres upstream of the proposed new weir	 Site A3 facing upstream  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 about 4.5 kilometres downstream of the existing Wilcannia Weir. The channel is about 30 metres wide at this location and the riverbank slope is moderate on the western bank and steep on the eastern bank. A large pool was present on the eastern side of the river which connected two large pools immediately upstream and downstream of the site. On the western side of the river was a small bar connected to the river bank. The substrate consisted of a fine silt. There was evidence of undercutting at the site.

Visual survey site	Site location	Site photographs	Site description
A4	About 1.1 kilometres upstream of the proposed new weir	 Site A4 facing upstream  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 about four kilometres downstream of the existing Wilcannia Weir. The channel is about 50 metres wide at this location and the riverbanks were moderately steep on both sides of the river. Two large instream bars which were connected to the banks extended about 260 metres and were each about 20 metres wide, encompassing most of the river channel except for a 2-metre-wide flowing channel in the centre. 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.

Visual survey site	Site location	Site photographs	Site description
A5-A	About 1.75 kilometres upstream of the proposed new weir	 Site A5-A facing upstream  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 about 3.25 kilometres downstream of the existing Wilcannia Weir. The channel is about 30 metres wide at this location and both riverbanks are steep. Two large pools were present at the upstream and downstream extent. A small bar was connected to the eastern river bank. Another small bar was located on the western bank. The substrate consisted of a fine silt. There was evidence of past bank failure and gully erosion on the western bank.

Visual survey site	Site location	Site photographs	Site description
A5	About 2.45 kilometres upstream of the proposed new weir	 Site A5 facing upstream  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 about 1.75 kilometres downstream of the existing Wilcannia Weir. The river channel at this location is about 50 metres wide however there were two large bars connected to river banks on either side of the channel that span the length of the reach. The channel that had water was about three metres wide. Both banks of the river are moderately steep. 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.

Visual survey site	Site location	Site photographs	Site description
A6	About 3.45 kilometres upstream of the proposed new weir	 Site A6 facing upstream  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 about 1.55 kilometres downstream of the existing Wilcannia Weir. The channel is about 40 metres wide at this location and both riverbanks were moderately steep. A large pool was present at the upstream extent of the reach. A bar connected to the eastern riverbank. Another bar connected to the western riverbank. A small instream bar was present at the downstream extent of the site. The substrate consisted of a fine silt. There was no evidence of active erosion at this site.

Visual survey site	Site location	Site photographs	Site description
A7	About 4.25 kilometres upstream of the proposed new weir	 Site A7 facing upstream  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 about 750 metres downstream of the existing Wilcannia Weir and Wilcannia Bridge (Barrier Highway) with instream pylons is about 100 metres upstream. The channel is about 40 metres wide at this location and both riverbanks are moderately steep. A dry mud-bar connected to the northern riverbank. Another large bar was connected to the southern riverbank. The water channel was about three metres wide and flowed between the two bars. The substrate consisted of a fine silt. There was evidence of past bank failure and undercutting on the western bank.

Visual survey site	Site location	Site photographs	Site description
A8	The existing weir site	 Site A8 facing upstream  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 is rock armouring at the downstream side of the weir structure and there is an extraction pipe about 50 metres upstream of the weir wall on the northern side. The channel is about 40 metres wide at this location and both riverbanks are moderately steep. An instream bar is connected to the southern riverbank. Another bar is connected to the northern riverbank. The channel which had water was about 10 metres wide. The substrate consisted of a fine silt. There was evidence of past bank failure and undercutting on the western bank.

Visual survey site	Site location	Site photographs	Site description
A9	About 1.8 kilometres upstream of the existing weir	 Site A9 facing upstream  Site A9 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A9 had high water level (weir pool at full supply 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/blue colour and was mostly clear. The site is located on a meander bend of the river, and about 1.8 kilometres upstream of the existing Wilcannia Weir. The Warrawong camping ground and a large farm property are situated on the southern bank of the river. The channel is about 60 metres wide at this location and both riverbanks are moderately steep. 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.

Visual survey site	Site location	Site photographs	Site description
A10	About 4.6 kilometres upstream of the existing weir	 Site A10 facing upstream  Site A10 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A10 had high water level (weir pool at full supply level) 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 about 4.6 kilometres upstream of the existing Wilcannia Weir. The channel is about 35 metres wide at this location. The eastern bank slope is moderately steep. The western bank slope at the site is gently sloped (access track to the riverbank). A large bar is connected to the western riverbank and there are 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.

Visual survey site	Site location	Site photographs	Site description
A24	About 5.1 kilometres upstream of the existing weir	 Site A24 facing upstream  Site A24 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A24 had high water level (weir pool at full supply 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 highly turbid. Scum and some green filamentous algae were present on the surface of the water. The site is located about 5.1 kilometres upstream of the existing Wilcannia Weir and about 40 metres downstream of the confluence with Kallyanka Creek (which is ephemeral and dry most of the time). The channel is about 32 metres wide at this location. The northern bank slope was very steep (near vertical) and the southern bank slope was moderately steep. 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.

Visual survey site	Site location	Site photographs	Site description
A11	About 10.3 kilometres upstream of the existing weir	 Site A11 facing upstream  Site A11 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A11 had high water level (weir pool at full supply level) 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 about 10.3 kilometres upstream of the existing Wilcannia Weir. A rural residential property is situated about 150 metres to the west on the northern bank of the river. The channel is about 80 metres wide at this location. The southern bank slope is moderately steep and the northern bank at the site is gently sloped (forming an access track to the water's edge). 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.

Visual survey site	Site location	Site photographs	Site description
A12	About 26 kilometres upstream of the existing weir	 Site A12 facing upstream  Site A12 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A12 had high water level (weir pool at full supply 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 highly turbid. The site is located on a meander bend and about 26 kilometres upstream of the existing Wilcannia Weir. The channel is about 35 metres wide at this location. Both bank slopes are moderately steep. 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. 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.

Visual survey site	Site location	Site photographs	Site description
A13	About 30.1 kilometres upstream of the existing weir	 Site A13 facing upstream  Site 13 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A13 had high water level (weir pool at full supply 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 highly turbid. Patches of green filamentous algae were present on the surface of the water. The site is located on a meander bend and about 30.1 kilometres upstream of the existing Wilcannia Weir. The channel is about 50 metres wide at this location. Both bank slopes are moderately steep. 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. 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.

Visual survey site	Site location	Site photographs	Site description
A14	About 32 kilometres upstream of the existing weir	 Site A14 facing upstream  Site A14 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A14 had high water level (weir pool at full supply 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 highly turbid. The site is located on a meander bend and about 32 kilometres upstream of the existing Wilcannia Weir. The channel is about 45 metres wide at this location. Both bank slopes are moderately steep. 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 riverbank. 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.

Visual survey site	Site location	Site photographs	Site description
A15	About 38.5 kilometres upstream of the existing weir	 Site A15 facing upstream  Site A15 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A14 had high water level (weir pool at full supply 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 highly turbid. Small patches of green filamentous algae were present on the surface of the water. The site is located about 38.5 kilometres upstream of the existing Wilcannia Weir. The channel is about 45 metres wide at this location and there was a disconnected, dry oxbow channel situated on the western side of the river. Both riverbank slopes are moderately steep. 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.

Visual survey site	Site location	Site photographs	Site description
A25	About 47.5 kilometres upstream of the existing weir	 Site A25 facing upstream  Site A25 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A25 had high water level (weir pool at full supply 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 highly turbid. Some scum was present on the surface of the water. The site is located at a meander bend and about 47.5 kilometres upstream of the existing Wilcannia Weir. The channel is about 30 metres wide at this location. Both bank slopes are moderately steep. 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 riverbank. 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 riverbanks.

Visual survey site	Site location	Site photographs	Site description
A23	About 54.8 kilometres upstream of the existing weir	 Site A23 facing upstream  Site A23 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A23 had high water level (weir pool at full supply 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 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 is about 35 metres wide at this location. Both bank slopes are moderately steep. Most 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.

Visual survey site	Site location	Site photographs	Site description
A16	About 58.6 kilometres upstream of the existing weir	 Site A16 facing upstream  Site A16 facing downstream	At the time of inspection, the Darling River (Baaka) at Site A16 had high water level (weir pool at full supply 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. 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 is about 35 metres wide at this location. Both bank slopes are moderately steep. 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.

Visual survey site	Site location	Site photographs	Site description
A17	About 1.8 kilometres downstream of the existing weir pool extent	 Site A17 facing upstream  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 is about 35 metres wide at this location. Both bank slopes are moderately steep. 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.

Visual survey site	Site location	Site photographs	Site description
A18	About 5.8 kilometres upstream of the existing weir pool extent	 Site A18 facing upstream  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 is 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 an island between the backwater and the channel. The bank slopes are moderately steep. The channel on the southern side of the river reach is 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.

Visual survey site	Site location	Site photographs	Site description
A19/20	About 1.2 kilometres downstream of the proposed weir pool extent when the new weir is in drought security operation mode	 Site A19/20 facing upstream  Site A19/20 facing downstream	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 an island between the backwater and the channel. The bank slopes are moderately steep. The backwater formation was at a slightly higher elevation than the river channel. 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.

Visual survey site	Site location	Site photographs	Site description
A21	About 740 metres downstream of the proposed weir pool extent when the new weir is in drought security operation mode	 Site A21 facing upstream  Site A21 facing downstream	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 is 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 is about 30 metres wide at this location. The bank slopes are moderately steep. A flat, mud-rock platform is connected to the northern riverbank and is adjacent to the channel on the southern side of the river reach. The channel is 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 is about 30 metres wide and an island between the backwater and the channel. Evidence of active erosion at the site includes some past bank failure on the mud-rock platform, a number of large fallen trees on the bank slope and exposed roots.

Visual survey site	Site location	Site photographs	Site description
A22	About 130 metres downstream of the proposed weir pool extent when the new weir is in drought security operation mode	 Site A22 facing upstream  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 when the new weir is in drought security operation mode. The water channel is about 45 metres wide at this location. The western bank slope is very steep (near vertical) and the eastern slope is moderately steep. A large mud-rock bar and platform (upstream) was connected to the western riverbank. 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.