



Chapter 16

Aquatic ecology

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Chapter 16 Aquatic ecology

The Secretary's environmental assessment requirements for the Narrabri Gas Project include a requirement to assess potential impacts on biodiversity. An aquatic ecological impact assessment is provided as an attachment to Appendix G1. This chapter draws on the assessment and describes aquatic and riparian (situated on a watercourse) flora and fauna and their habitats and the presence and likelihood of occurrence of threatened and migratory species, populations and ecological communities in the vicinity of Bohena Creek and the Namoi River / Narrabri Creek. Impacts on aquatic and riparian ecology associated with the managed release of treated water to Bohena Creek are assessed and mitigation measures identified to reduce potential impacts. Risk associated with depressurisation as it may impact surface water quality and flows were discussed in Chapters 12 (Surface water quality) and 13 (Hydrology and geomorphology), respectively. The key findings from the impact assessment in relation to aquatic ecology were:

- The aquatic ecological communities of Bohena Creek and the Namoi River / Narrabri Creek are generally in reduced ecological condition.
- The project would employ a range of planning and development controls to minimise risk on aquatic ecology, including the use of a Field Development Protocol.
- Hydrological and water quality modelling has shown there is a low risk of impacts occurring from the managed release of treated water to Bohena Creek. The managed release would occur during periods of flow of equal to, or greater than, 100 megalitres per day. As a result, the relatively small quantity of treated water being released would have a negligible impact on the hydrological regime and is therefore unlikely to result in significant change in water chemistry.
- There is a low risk to stygofauna from the project as a result of the implementation of mitigation measures, including the installation of linear infrastructure across ephemeral watercourses when the creek is not flowing at that point.
- A Water Monitoring Plan would be implemented to monitor for impacts from the managed release, including upstream and downstream water quality, toxicity assessments and groundwater. The Water Monitoring Plan is included as Appendix G3.

A desktop assessment was undertaken that considered the results of previous ecological assessments and scientific publications to determine the likely presence of aquatic flora and fauna species and their habitats in the study area. Aquatic and riparian flora and fauna field surveys were then conducted to validate the baseline ecological conditions in Bohena Creek and the Namoi River / Narrabri Creek to inform the assessment of ecological impacts associated with the release of treated water to Bohena Creek.

The surveys included a riparian habitat assessment and vegetation survey, an aquatic habitat assessment, a water quality assessment, a macroinvertebrate community survey, a fish survey and a stygofauna survey. Seven-part tests were prepared for two fauna species (one invertebrate and one fish) and one threatened population considered potentially or likely to occur in the study area, with an assessment of significance being completed under the EPBC Act for one fauna species (one fish). The assessment found that:

- Exotic fish and plant species are present in both Bohena Creek and the Namoi River / Narrabri Creek.
- Two threatened species (one invertebrate and one fish) and one threatened fish population listed under State legislation potentially occur in the vicinity of Bohena Creek and / or the Namoi River / Narrabri Creek.
- One threatened fish species listed under federal legislation potentially occurs in the vicinity of Bohena Creek and / or the Namoi River / Narrabri Creek.

- No stygofauna were found in 19 samples collected over three sample periods from the production bores in the Permian strata of the Black Jack Group and Maules Creek Formation, or from monitoring bores in the colluvium at Leewood, or from monitoring bores and pits in the Bohena Creek Alluvium. Extensive stygofauna communities were not expected in the Bohena Creek Alluvium due to the poor development of the aquifer, the frequency with which the aquifer dries out and that a release will occur when the aquifer is saturated.

The following management and mitigation measures would be undertaken for the project:

- Treated water would be released to Bohena Creek at the release point during periods when the flow in Bohena Creek is equal to, or greater than, 100 megalitres per day, as measured at the Newell Highway gauging station.
- A Water Monitoring Plan would be implemented; including monitoring of Bohena Creek flow rates and water quality up and downstream of the managed release point. The Water Monitoring Plan is included as Appendix G3.
- Watercourse crossings would use existing tracks where practicable and would be installed during periods of no flow.

With the implementation of the management and mitigation measures listed above, the residual risk from the project to aquatic and riparian flora and fauna and stygofauna is considered to be low to very low.

16.1 Methodology

Potential impacts to aquatic ecosystems include the construction and operation of gas field infrastructure and the managed release of treated water to Bohena Creek. To assess these potential impacts, the aquatic ecology assessment included a desktop review of databases and relevant literature, and field surveys, as described below.

16.1.1 Desktop review

A desktop assessment was undertaken to identify State and Commonwealth-listed threatened and migratory species, populations and ecological communities that may be affected by the project. Biodiversity databases pertaining to the study area were reviewed and included:

- Office of Environment and Heritage (OEH) NSW BioNet (Atlas of NSW Wildlife) for records of threatened species, populations and endangered ecological communities listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) that have been recorded within the locality (OEH 2014a).
- Department of Primary Industries (DPI) Fishing and Aquaculture Threatened and Protected Species Records Viewer for records of threatened aquatic species listed under the NSW *Fisheries Management Act 1994* (FM Act) that have been recorded within the locality.
- Commonwealth Department of the Environment and Energy Protected Matters Search Tool for Matters of National Environmental Significance listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) that have been recorded in the locality (DotE 2013b).

The search for the aquatic database review for threatened flora species was limited to a 10 kilometre radius from both the proposed release point on Bohena Creek, and from the junction of Bohena Creek and the Namoi River. The search area for threatened fauna, populations and endangered ecological communities was expanded to the Namoi River Catchment.

The results of previous ecological assessments and scientific publications were reviewed to determine the likely presence of aquatic flora and fauna species and their habitats within the region. A list of the literature that was reviewed is provided in Appendix C of Appendix G1.

16.1.2 Field survey

The extent of the aquatic ecology field survey is shown on Figure 16-1. For the purposes of this assessment, the survey was conducted as two integrated components. The first component concentrated on the reach of Bohena Creek where the managed release would occur. This included sites immediately upstream of the proposed release site, waterholes downstream of the release site, and three sites on the Namoi River / Narrabri Creek on either side of the Bohena Creek confluence. These surveys are referred to as the Bohena Creek Study and also included a stygofauna assessment. The purpose of the stygofauna assessment was to determine the likelihood of groundwater invertebrates being impacted by the managed release.

Aquatic and riparian field surveys were conducted to assess the baseline ecological conditions along Bohena Creek and Namoi River / Narrabri Creek, and ten other ephemeral watercourse sites. Bohena Creek survey sites were selected upstream and downstream of the proposed release location. The Namoi River / Narrabri Creek survey sites were located upstream and downstream of the confluence with Bohena Creek. To get a broader, regional perspective of aquatic ecological condition, nineteen sites were sampled in permanent and ephemeral watercourses of the Namoi River catchment

The Bohena Creek Study consisted of four surveys undertaken in accordance with the Australian River Assessment System (AUSRIVAS) (Turak and Waddell 2002). Surveys occurred during AUSRIVAS defined autumn (15 March to 15 June) and spring (15 September to 15 December) sampling periods (Turack and Waddell 2002). Survey dates for the four sampling periods were:

- 11 to 15 March 2013 – autumn 2013
- 2 to 4 December 2013 - spring 2013
- 3 to 6 June 2014 – autumn 2014
- 20 to 21 October 2014 - spring 2014.

The surveys included:

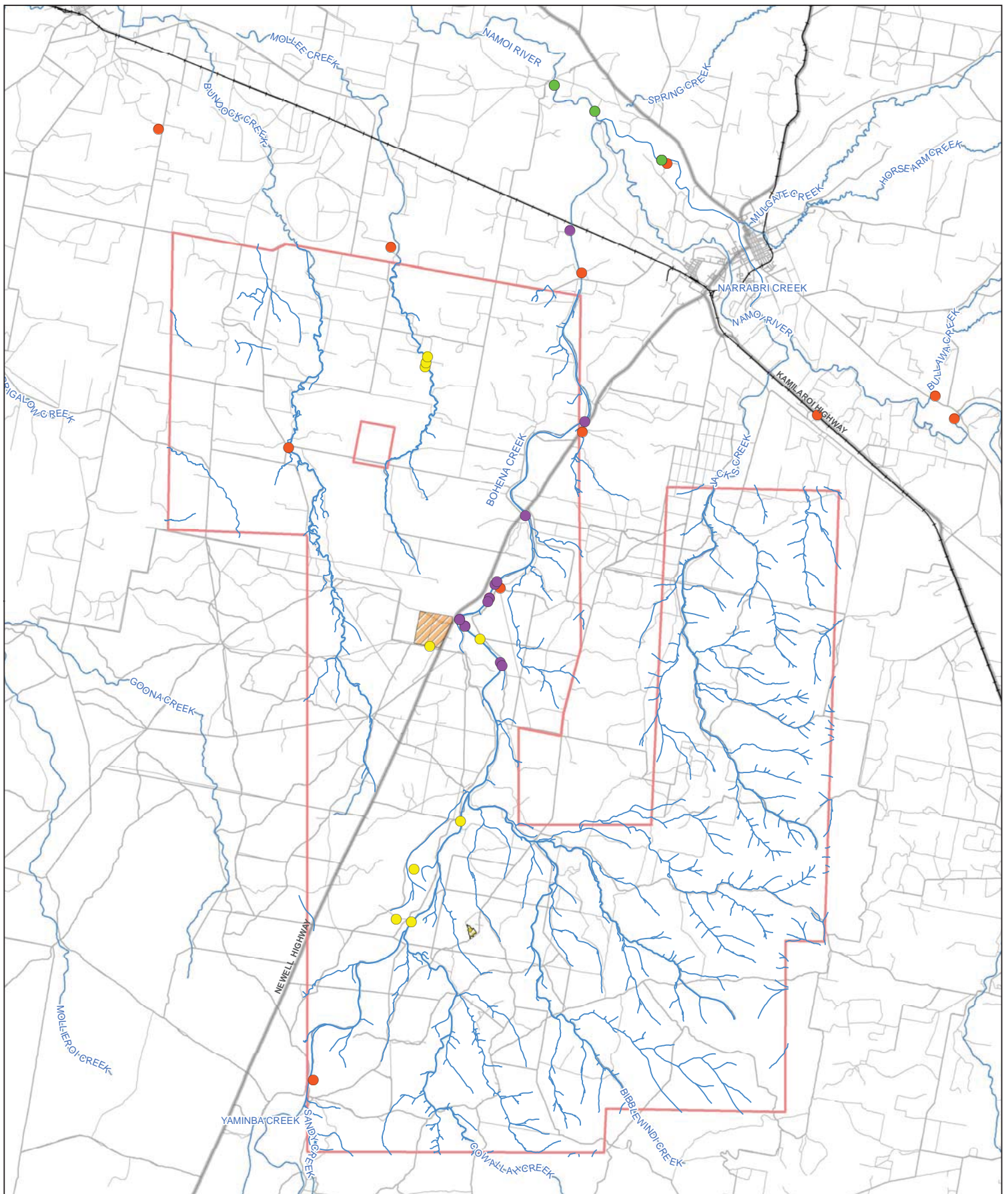
- Riparian habitat assessment. A riparian condition assessment was undertaken using a version of the Riparian, Channel and Environmental (RCE) Inventory (Peterson 1992) that was modified for Australian conditions (Chessman *et al.* 1997). The modified RCE inventory has 13 descriptors, each with a score from one to four. Descriptors included width and condition of the riparian zone, surrounding land use, extent of bank erosion, stream width, water depth, occurrence of pools, riffles and runs, sub-stratum type, presence of snags and woody debris, in stream and emergent macrophytes, algae and barriers to fish passage. The total score for each site was then derived by summing the score for each descriptor and calculating the result as a percentage of the highest possible score. Sites with a high RCE score indicate that the riparian zone is unmodified by human activity, while those with a low score have undergone substantial modification.
- Riparian vegetation survey (for autumn 2013 period). A biometric plot survey was conducted at each survey site using the *BioBanking Assessment Methodology* (OEH 2014e). Plots were located as close to the water's edge as possible to record riparian vegetation.

- Aquatic habitat assessment. The following data were recorded at each survey site: general signs of disturbance; habitat type; channel topography; water level; bank and bed slope; degree of river shading; amount of detritus; macrophyte type and extent; riparian zone width; snags and large woody debris coverage; stream width and depth; substrate; extent of bank overhang; amount of trailing bank vegetation; and surrounding land use.
- Water quality assessment. Water quality parameters were measured at each survey site including dissolved oxygen, pH, electrical conductivity, temperature and turbidity. Water quality was compared to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000).
- Macroinvertebrate community survey. Macroinvertebrates were collected from edge habitats at each survey site. Macroinvertebrate samples were live-sorted in the field (for a minimum of 40 minutes and maximum of 60 minutes). Macroinvertebrates were then preserved and transferred to a laboratory for identification. The results were used to assess whether the invertebrate communities at Bohena Creek resembled those within the Namoi River / Narrabri Creek. The results were also used to assess the biological condition or impairment at each survey site. Impairment was calculated using both AUSRIVAS Observed to Expected Ratio (O/E50) and Stream Invertebrate Grade Number – Average Level (SIGNAL) scores (defined in Appendix C of Appendix G1).
- Fish survey. Fish were surveyed at each survey site using traps (baited and unbaited) and / or nets (fyke, sweep and seine). Native fish were identified, counted and released. Pest species were counted and humanely euthanised.
- Stygofauna survey (spring 2013 and autumn 2014). Three different methods were used to sample for stygofauna. To sample monitoring bores, a weighted net with 50 micrometre mesh was used. This was lowered to the bottom of each bore and raised through the entire water column six times to collect fauna. For production bores, 60 litres of water were extracted through a bleed valve into buckets and then poured through a 50 micrometre mesh sieve. For sites on Bohena Creek where no bores were available, pits were dug down to the water table and 10 to 50 litres of water was filtered through a 50 micrometre mesh sieve. In all cases, net or sieve contents were preserved in a jar of 100 per cent ethanol. Samples were analysed under a microscope and stygofauna present were identified to a taxonomic level as far as possible using currently available taxonomic keys and expertise.

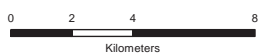
The second component of the aquatic ecology field assessment aimed at understanding the regional condition of aquatic ecosystems in the mid-Namoi River Catchment. This survey program included 19 sites on the Namoi River and its tributaries, in an area extending from upstream of Boggabri to 25 kilometres west of Wee Waa. These surveys are referred to as the Mid-Namoi Catchment Assessment. The mid-Namoi River Catchment Assessment also used AUSRIVAS protocol and the methods outlined above, although no fish or stygofauna sampling occurred and no riparian vegetation surveys were undertaken. These surveys occurred on the following dates:

- 28 October to 1 November 2013 - spring 2013
- 5 to 8 May 2014 – autumn 2014
- 18 to 21 October 2014 - spring 2014.

Further details on the aquatic, riparian and stygofauna field survey methodology are provided in Appendix C of Appendix G1.



- LEGEND**
- | | | | |
|--------------|--------------|---|------------------|
| Project area | Watercourses | Aquatic survey site locations (groups) | Stygofauna sites |
| Leewood | Roads | Bohema Creek | Mid-Namoi sites |
| Bibblewindi | Train line | Narrabri Creek / Namoi River | |



Narrabri Gas Project
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Aquatic ecology sample locations **Figure 16-1**

16.1.3 Likelihood of occurrence

Following the collation of database records and the results of previous ecological assessments in the study area and vicinity, a 'likelihood of occurrence' assessment was prepared with reference to the habitats within the study area. This was further refined following field surveys and the identification and assessment of the habitats present.

16.1.4 Assessment of significance of impacts

Section 5A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) lists seven factors that must be taken into account in the determination of the significance of potential impacts of an activity on 'threatened species, populations or ecological communities (or their habitats)' listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act). The '7 part test' is used to determine whether an activity is 'likely' to impose 'a significant effect' on threatened biota. Tests were prepared for two fauna species (one invertebrate and one fish) and one threatened population considered to potentially occur.

Under the Commonwealth EPBC Act, an action will require approval from the Minister if the action has, will have, or is likely to have, a significant impact on matters of national environmental significance. The Department of the Environment and Energy administers a series of guidelines to assist proponents to determine whether their proposed action is likely to have a significant impact on a matter of national environmental significance under the EPBC Act. An assessment of significance was prepared for one fish species considered to potentially occur in accordance with the Commonwealth's *Significant Impact Guidelines 1.1 - Matters of National Environmental Significance* (DotE 2013a).

The assessments of significance under the EP&A Act and the EPBC Act are summarised in Section 16.3.6. and presented in detail in Appendix G1

16.1.5 Independent Expert Scientific Committee

The Independent Expert Scientific Committee are a body established by the Commonwealth Government to provide advice to regulators on the impact of coal seam gas and large coal mining development on water resources. Water resources in this sense include water dependant assets such as surface water or groundwater dependant flora, fauna and ecosystems.

The Independent Expert Scientific Committee have developed the *Information Guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (IESC 2015). The guidelines set out the information required by the committee to provide robust scientific advice to regulators.

The requirements are provided in Appendix A along with cross-references to the relevant parts of the EIS where the requirements are addressed.

16.2 Existing environment

16.2.1 Watercourses

Watercourses within the project area are discussed in greater detail in Chapter 13 (Hydrology and geomorphology) including a description of hydrology and geomorphology. Hydrology refers to the movement, volume and distribution of surface water. Geomorphology refers to landforms and topography and in this assessment focuses on watercourse and drainage patterns. Detail on water quality is provided in Chapter 12. A brief description of some key watercourses is provided as relevant to this assessment in this section.

Bohena Creek is a sand-bed ephemeral watercourse that flows north through the eastern Pilliga (refer to Figure 12-6 and Figure 12-7 in Chapter 12 – Surface water quality), and is the major watercourse within the project area. Bohena Creek is dry for extended periods of time although there are deeper intermittent pools that contain permanent water (refer to Figure 16-2).



Figure 16-2 Bohena Creek downstream of the proposed release site – view looking downstream in autumn

Bohena Creek experiences surface flow approximately 15 per cent of the time—generally if rainfall in the local catchment exceeds approximately 100 to 110 millimetres in a given month. During dry periods, the water table is an estimated two metres below the creek bed. Bohena Creek joins the Namoi River at Mollee Weir, just upstream of the Narrabri Creek confluence. Historic data from 1995 to 2005 shows that Bohena Creek flows exceed 100 megalitres per day at the Newell Highway gauging station around 12 per cent of the time (refer to Appendix G1).

The Namoi River is a perennial river and a major tributary of the Murray-Darling River system. It flows west from the foothills of the Great Dividing Range near Tamworth to join the Barwon River at Walgett. The river splits into two anabranches before reaching Narrabri, with Narrabri Creek as the northern channel receiving a greater proportion of flow than the Namoi River anabranch to the south. The two channels converge again upstream of Mollee Weir approximately 20 kilometres west of Narrabri. The weir is approximately five metres high and 60 metres wide, and has storage capacity for about 3,300 megalitres.

The Namoi River and Narrabri Creek were once likely ephemeral and experienced periods of no flow. However, both now flow permanently due to regulated water releases from Keepit Dam located upstream (refer to Figure 16-3). Major tributaries in the study area include Bohena Creek, Bullawa Creek, Nuable Creek, Illaroo Creek, Pian Creek, Werah Creek, Brigalow Creek, Coxs Creek, Middle Creek, Sandy Creek, and Spring Creek. All of these are ephemeral watercourses that require significant rainfall to flow.



Figure 16-3 The Namoi River, downstream of Mollee Weir – view looking upstream in spring

The Strahler (after Strahler 1952) order of watercourses is described in Chapter 13. Most watercourses in the project area are a minor Strahler stream order (first to third order). The exceptions are:

- Bohena Creek – which is a sixth order streamline along its entire length through the project area
- Cowallah Creek and Sandy Creek – which are fifth order streamlines along their entire length through the project area
- Biblewindi Creek – which increases from a third to fourth to fifth order streamline along its length through the project area
- Spring Creek and Yellow Spring Creek – which are fourth order streams along their entire length through the project area
- Jacks Creek – which is a fifth order stream along its entire length through the project area.

Examples of first and third order watercourses in the project area are shown in Figure 16-4. Further details are provided in Chapter 13 and Appendix G1.



Figure 16-4 Examples of typical first (left) and third (right) order watercourses in the project area

16.2.2 Riparian habitat

Riparian and channel environment (RCE) scores varied little through time at each site. RCE scores were between 56 per cent in Cox's Creek and 83 per cent in Teds Hole over the three seasons surveyed.

Of the mid-Namoi sites surveyed, around 16 per cent had riparian habitat that was in good condition, while around 79 per cent were in very good condition. RCE scores generally increased with distance downstream in the Namoi River, indicating an improvement in riparian habitat. The sites that scored well were characterised by more intact and wider riparian zones, more stream detritus and vegetation within 10 metres of the channel, and less bank undercutting in comparison to sites with relatively low scores. The sites with the most degraded riparian zones and channels were Cox's Creek, site 7517 on the Namoi River, and sites 7529 and 7531 on Narrabri Creek (refer to Appendix C of Appendix G1). These sites were characterised by little or no riparian vegetation, undercut and / or eroding banks, and were all adjacent to agricultural land. There was little change in RCE scores between sampling periods, with slight fluctuations in scores attributed to parameters that have relatively rapid ecological responses such as ground cover, and macrophyte and algal cover.

The riparian habitat survey for Bohena Creek showed that every site had very good or excellent riparian habitat except for Bohena Creek downstream (refer to Appendix C of Appendix G1), which had RCE scores of between 56 and 62 per cent. For the other sites, scores changed little through time and ranged from 67 and 87 per cent. All Bohena Creek sites had a good cover of mixed native vegetation and continuous strips of woody riparian vegetation more than 30 m wide. *Salix babylonica* (Weeping Willow) lined the water at several sites, and in all cases the willows were surrounded by large, hollow-bearing native tree species dominated by *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus largiflorens* (Black Box). The willows at one site were removed before the spring 2014 survey period.

Banks at most sites were stabilised by a well-developed herb layer and woody vegetation that included trees and shrubs. Banks were undercut at some of the ephemeral sites, and at two of the Namoi River / Narrabri Creek sites. Some of the smaller ephemeral sites (e.g. Coxs Creek, 7518, Brigalow Creek) were impacted by surrounding agricultural activity or their proximity to roads. There was no significant undercutting along Bohena Creek.

Pool and riffle sequences were absent from all sites apart from the Namoi River downstream of Mollee Weir. At Bohena Creek, the absence of riffles was due to the low gradient sand bed and a lack of continuous surface flow between pools. The absence of continual linking surface flow is also the reason for the absence of riffles at the ephemeral sites. At the Namoi River / Narrabri Creek survey sites, the river was too deep and broad for riffles.

Occasional logs were present at most of the survey sites, but not in sufficient volume to have a significant damming or retention effect on flow. At the Namoi River site beneath Tulladunna Bridge west of Wee Waa, a large number of logs had been deposited against the footings of a rail bridge. This log jam may cause a barrier to the migration of large fish species during low flow, but would be beneficial habitat at high and moderate flows. Bars and beds of sand were common at all sites along Bohena Creek, and large mixed bars of cobble, sand and gravel occurred at the Namoi River / Narrabri Creek sites.

No aquatic vegetation was observed at the Namoi River / Narrabri Creek survey sites. Submerged vegetation may have been present but obscured by turbid water. At Bohena Creek, macrophytes occurred at all sites with communities dominated by *Phragmites australis* (Common Reed), *Juncus spp.* and *Cyperus spp.* Macrophytes were absent from most of the ephemeral sites, although these sites were often dry or in a state of contraction when sampled.

16.2.3 Riparian vegetation

Floristic surveys of four Bohena Creek and three Namoi River / Narrabri Creek sites identified 112 flora species in the riparian zone. Of these, 35 species were introduced. (A floristic species list is presented in Appendix C of Appendix G1). There were more introduced species at the Namoi River / Narrabri Creek sites than at Bohena Creek. No threatened plant species were recorded in the riparian zone at the survey sites.

Two biometric vegetation types were present in the study area:

- Rough-barked Apple riparian forb / grass open forest of the Nandewar Bioregion recorded at the Bohena Creek survey sites.
- River Red Gum riverine woodlands and forests in the Nandewar and Brigalow Belt South Bioregions recorded at the Namoi River / Narrabri Creek survey sites.

Vegetation on the banks and floodplains of Bohena Creek is less disturbed than the Namoi River / Narrabri Creek and is also contiguous with large areas of relatively intact woodland of the Pilliga Forest. This vegetation is generally dominated by native species, although exotic species are also present in high densities at some areas. The major disturbance regimes of this vegetation are likely to be fire, flood and weed invasion.

Vegetation on the banks and floodplains of the Namoi River / Narrabri Creek has been affected by clearing for agriculture, water infrastructure, flow regulation, roads and tracks, grazing and by disturbance events such as fires, flooding, erosion, rabbits and hares and weed invasion. This has resulted in degraded woodlands, especially on the banks of the river, in which the shrub and ground layer are dominated by exotic plant species. During the spring 2014 survey, willows at the Namoi River site downstream of Mollee Weir had been removed from one bank, improving the quality of the riparian zone.

16.2.4 Aquatic habitat

For most of its length, the sandy bed of Bohena Creek has very little topographic variation, so remnant pools were shallow, relatively uniform, and lacked riffles. The latter two Bohena Creek Study surveys included four sites (Teds Hole, BCS02, BCS07, and BCS09) that were exceptions to this and were potentially permanent waterholes from which aquatic species could disperse during periods of flow. The main habitat feature at the Bohena Creek sites was fringing *Phragmites australis* (Common Reed), which grows in low to medium densities. Large woody debris, overhanging and trailing vegetation, and benthic leaf packs were also present at the permanent sites.

In the Namoi River / Narrabri Creek, the main habitat features were deep pools and large woody debris. The site downstream of Mollee Weir had greater habitat complexity than the two other sites. At this site, there was a well-developed riffle that ran beside a gently sloping gravel bar into a deep pool. The Tulladunna Bridge site, in the Namoi River west of Wee Waa, had a large amount of woody debris against the pylons of a rail bridge.

All of the ephemeral watercourse sites had large woody debris that would provide fish and macroinvertebrate habitat during flow periods. Most of them also had good fringing vegetation, providing habitat for emerging macroinvertebrates. Coxs Creek was heavily degraded, with cattle accessing the creek bed. At this site, the water was in a pool beneath a bridge that contained large amounts of woody debris. Brigalow Creek, Middle Creek, and Spring Creek had the largest pools of the ephemeral sites visited (apart from Bohena Creek), and all of these had water for the duration of the survey period.

16.2.5 Water quality

Dissolved oxygen concentrations at most sites were outside of ANZECC/ARMCANZ (2000) guideline values for more than one survey period. Most often concentrations were low, although at some ephemeral sites (e.g. site BCUSD in spring 2013 – refer to Appendix C of Appendix G1), concentrations were high, probably due to increased algal photosynthesis. Turbidity exceeded the target value at several sites. This was likely due to the shallow depth of the pools, their small size and silt-disturbance from large, benthic-feeding fish.

Turbidity in the Namoi River / Narrabri Creek was almost twice the upper ANZECC/ARMCANZ (2000) target value for most survey periods. The high turbidity probably contributes to the low dissolved oxygen concentrations, which were below the target value on most sampling occasions. One reason for the high turbidity was the large volume of sediment suspended in the water column. The high sediment load is likely to be caused by the re-suspension of silt washed into the river channel over the past decade or more from catchment-wide erosion and bank slump. The respiration of bacteria attached to suspended sediments can consume large amounts of oxygen in turbid water, driving down oxygen concentrations. Coupled with this, very little sunlight is able to penetrate the turbid water, reducing photosynthetic contributions to oxygen levels. Turbidity in most of the ephemeral sites was also above the ANZECC/ARMCANZ (2000) target value, except for at Coxs Creek, which was consistently within the specified range.

All other parameters measured (temperature, electrical conductivity and pH values) were generally within ANZECC/ARMCANZ (2000) target values. Electrical conductivity was notably lower in Bohena Creek than in the Namoi River / Narrabri Creek, consistent with historical datasets reported in Chapter 12 (Surface water quality), and was also low in the Bohena Creek alluvial aquifer.

Surface water quality in the project area is discussed further in Chapter 12 (Surface water quality).

16.2.6 Macroinvertebrates

Macroinvertebrates were collected from 16 sites in the mid-Namoi assessment, although not on every occasion because some sites were dry. Invertebrate diversity was poor at all sites, with between four and 22 families collected during each survey period. Diversity was highest in autumn 2014 at 11 sites. Diversity at Namoi River and Narrabri Creek sites was low—between four and 13. Illaroo and Cox's Creek had the highest diversity in autumn 2014, with 21 and 22 taxa respectively. Middle Creek had 21 taxa in spring 2013, but that fell on subsequent survey periods. The Namoi River / Narrabri Creek sites had SIGNAL scores between 2.7 and 5.2, indicating moderate to mild disturbance and were in AUSRIVAS Bands B or C. This indicates that the sites were in poor condition and either significantly or severely impaired, with fewer of the expected invertebrate taxa and lower water quality than modelled reference sites.

All sites were dominated by pollution-tolerant invertebrate taxa, with average SIGNAL scores for the sites being low. The highest score was downstream of Mollee Weir in the Namoi River.

In the Bohena Creek Study, 38 invertebrate families were collected, with 27 were collected from Namoi River / Narrabri Creek. Invertebrate diversity was generally higher in spring than in autumn for all sites. There were also distinct differences in the invertebrate communities between Bohena Creek and Namoi River / Narrabri Creek, although both systems were dominated by tolerant taxa. The macroinvertebrates collected at each survey site are listed in Appendix C of Appendix G1. SIGNAL scores for the survey sites in Bohena Creek were between 2.0 and 4.6, indicating severe to moderate levels of disturbance. Generally, ephemeral sites exhibited fewer and fewer taxa as pools dried up.

The main determinant of the current ecological condition of the Namoi River / Narrabri Creek appears to be flow regulation and impacts from catchment-scale land management. Many ephemeral sites also display evidence of impacts from agricultural practices in the catchment, with the invertebrate community also largely determined by regular drying periods and consequent contraction of pool size at many sites. The Bohena Creek sites were generally in forested areas, so were less vulnerable to historical and ongoing agricultural activities. Here, the invertebrate community was determined by the drying hydrological phase extant during the surveys.

The lack of diversity for invertebrate fauna at the Mollee Weir and Narrabri Creek upstream sites is due to a combination of factors. Both sites were in a reach of river that experiences daily fluctuations in water level due to the backing-up effect from Mollee Weir. This resulted in the edges, where samples were collected from, being relatively featureless, and apart from a few pieces of large woody debris, were essentially bare mud. Regular fluctuations of up to 30 centimetres, coupled with rapid drop-off into the water and high turbidity, have made the edge unsuitable for submerged macrophytes as invertebrate habitat.

16.2.7 Fish

Eleven fish species (eight native and three introduced) were collected from Bohena Creek and Namoi River / Narrabri Creek. Bohena Creek had seven species while the Namoi River / Narrabri Creek had ten. *Macquaria ambigua ambigua* (Golden Perch), *Hypseleotris* sp. (Carp Gudgeon), *Retropinna semoni* (Australian Smelt), *Cyprinus carpio* (Common Carp) *Leiopotherapon unicolor* (Spangled Perch), and *Gambusia holbrooki* (Plague Minnow) were common to both systems, while *Craterocephalus stercusmuscarum fulvus* (Unspeckled Hardhead) was collected only from Bohena Creek.

Carassius auratus (Goldfish), *Melanotaenia fluviatilis* (Murray-Darling Rainbowfish), *Nematalosa erebi* (Bony Bream), and *Tandanus tandanus* (Eel-tailed Catfish) were collected in only the Namoi River / Narrabri Creek. Carp Gudgeon was the only species to occur at all sites and was collected in both autumn and spring sampling trips.

Eel-tailed Catfish is listed as a threatened population in the Murray-Darling Basin under the FM Act. The two specimens collected during the surveys both came from the Namoi River / Narrabri Creek upstream of Mollee Weir. There is no suitable habitat for this species identified along Bohena Creek.

16.2.8 Stygofauna

Stygofauna samples were collected over three sample periods between March 2013 and July 2014. Nineteen samples were collected from two monitoring bores in the colluvium at Leewood, four production bores, three monitoring bores and five hand dug pits in the Bohena Creek alluvium. Attempts were made to collect ten other samples from five more monitoring bores at Leewood, however these were dry when visited. None of the samples were observed to contain stygofauna. The production bores were too deep and isolated from surface sources of organic matter, and had water with an electrical conductivity considered generally too high for most stygofauna.

Water chemistry in the colluvium at Leewood and in the alluvial aquifer at Bohena Creek was potentially suitable for stygofauna, but no stygofauna were located. This is likely because these aquifers are thin and have no permanent hydrological connection to a larger aquifer. The hand dug pits produced five terrestrial invertebrate taxa and six aquatic invertebrate taxa, emphasising the importance of the Bohena Creek sediments as a refuge for both aquatic and terrestrial invertebrates during periods of no flow, rather than as a critical habitat for stygofauna (refer to Appendix C of Appendix G1).

16.2.9 Threatened species, populations and ecological communities

Searches of online databases and literature identified twenty-two threatened plant species listed under the TSC Act and / or EPBC Act had been previously recorded, or are predicted to occur, within a 10 kilometre radius of the Bohena Creek and Namoi River / Narrabri Creek (refer to Appendix C of Appendix G1). None of these terrestrial species are considered likely to occur in the study area and, therefore, would not be impacted by the project (refer to Appendix C of Appendix G1). A search of the NPWS Wildlife Online database and review of the species risk assessment found that no aquatic plant species of conservation significance were previously known within the study area.

On the basis of regional records, a literature review and the presence of suitable habitat, nine threatened fauna species listed under the TSC Act, NSW *Fisheries Management Act 1994* (FM Act) and / or EPBC Act had been previously recorded, or are predicted to occur, in the study area. The predicted presence is based on the known geographical distribution, preferred habitats for each species and the corresponding habitats in the study area. These include one invertebrate, three fish, three amphibians, one reptile and one endangered amphibian population. These species are described in Appendix C of Appendix G1 and terrestrial fauna species are discussed further in Chapter 15. Of these, the following are considered to be present or may occur in the study area (refer Table 16-1):

- Two species listed under the FM Act (one invertebrate and one fish).
- One species listed under the EPBC Act (one fish).

The remaining species are considered unlikely to occur in the study area and, therefore, would not be impacted by the project.

Two endangered populations have been previously recorded or are predicted to occur in the Namoi River Catchment. These are:

- Murray-Darling Basin population of Eel-tailed Catfish (*Tandanus tandanus*) listed as endangered under the FM Act. This population occurs in the study area at Mollee Weir and upstream of Mollee Weir. Bohena Creek is unlikely to have suitable habitat for catfish, as it is ephemeral and has a sand dominated bed which is not the preferred habitat for catfish.
- Tusked Frog *Adelotus brevis* population in the Nandewar and New England Tableland Bioregions listed as endangered under the TSC Act. This population is unlikely to occur in the study area based on a lack of suitable habitat and because the study area is outside of the predicted and known distribution of the species in the region.

A database and literature search identified that fifteen endangered ecological plant communities listed under the TSC Act and / or EPBC Act had been recorded, or are predicted to occur, in the Namoi River Catchment. None of these communities are considered likely to occur in the study area, however, some are likely to occur in adjoining areas such as floodplains.

Table 16-1 Threatened fauna known or predicted to occur in the study area (aquatic)

Scientific name	Common name	Conservation status ^a			Comments
		TSC Act	FM Act	EPBC Act	
Invertebrates					
<i>Notopala sublineata</i>	River Snail	-	E	-	Potential to occur based on the presence of suitable habitat (known from the Namoi River near Mollee Weir).
Fish					
<i>Bidyanus bidyanus</i>	Silver Perch	-	V	CE	Potential to occur based on the presence of suitable habitat (known from the Namoi River downstream and upstream of Mollee Weir).
<i>Maccullochella peelii peelii</i>	Murray Cod	-	-	V	Potential to occur based on the presence of suitable habitat (known from the Namoi River downstream and upstream of Mollee Weir).

^a CE = Critically Endangered E = Endangered V = Vulnerable (TSC, FM Act and EPBC Act).

16.3 Potential impacts

This section presents the potential impacts on aquatic and riparian flora and fauna (including threatened and migratory species, populations and ecological communities) of the managed release of treated water to Bohena Creek. Other potential impacts, such as those from watercourse crossings and infrastructure development, are also considered.

16.3.1 Impacts due to increased water volume

As noted above, managed release of treated water would occur during operation of the project when Bohena Creek is flowing at greater than, or equal to, 100 megalitres per day as measured at the Newell Highway gauging station. The managed release of treated water to Bohena Creek under these flow conditions would result in negligible variation to the current hydrological regime of Bohena Creek. Consequently, there would be negligible impact to aquatic and riparian flora and fauna.

No additional pools would be created by the discharge as Bohena Creek would be under event flow conditions. The release of treated water would also not increase the frequency of links between waterholes, nor increase the impact of flooding. Further, the proposed release of treated water would not affect the frequency, duration or intensity of natural periods of drying.

16.3.2 Impacts due to changed water quality

The water treatment process, outlined in Chapter 7 (Produced water management), as well as the managed release approach and diffuser design, ensures that the water to be released would generally be of similar quality to the background water quality in Bohena Creek. As outlined in Table 12-5 of Chapter 12 the mean treated water quality is not expected to exceed the Bohena Creek baseline water quality nor the relevant assessment guideline values. Comparative water quality data of the treated water, the Bohena Creek baseline and the ANZECC / ARMCANZ (2000) guideline values are provided in Table 12-4 of Chapter 12.

A mixing zone study was undertaken on the managed release to Bohena Creek (refer Appendix E of Appendix G1). Modelling for the study found that with the proposed baseline flow conditions of at least 100 megalitres per day, releases would be subject to rapid dilution and would not change the natural chemistry of the water significantly. The impact assessment also found that under these release conditions there is likely to be very little change to the natural pattern of wetting and drying. As such, the assessment indicated that managed release to Bohena Creek would not result in significant changes to its ecological properties.

The project would seek to operate the managed release under a toxicity based licence approach within the Environment Protection Licence. This approach is consistent with the Environment Protection Authority Licensing Fact Sheet *Using Environment Protection Licensing to Control Water Pollution* (NSW EPA 2013).

A water quality monitoring program would be implemented to ensure that the treated water meets the required specifications, including both continuous monitoring and regular analysis of water quality samples by a NATA accredited laboratory.

In addition, regular monitoring of the Bohena Creek for morphological change (erosion and sedimentation) immediately upstream and downstream of the release point would be undertaken.

Based on the water quality modelling and the implementation of the management, mitigation and monitoring strategies listed above, the release of treated water to Bohena Creek would be unlikely to significantly change the chemistry of the water in Bohena Creek. Therefore, there would be low risks to aquatic and riparian flora and fauna in Bohena Creek from the release of treated water.

16.3.3 Impacts from watercourse crossings

Road, gathering line and pipe crossings of Bohena Creek and other ephemeral watercourses have the potential to obstruct fish passage, damage riparian vegetation, and cause compaction or erosion of the bank and bed. Where practical, existing road crossings would be used to prevent the need for further vegetation removal.

Gathering lines and pipes would be buried and would therefore not create an obstruction to fish passage. They would be installed when no surface flow at the site was evident. This will minimise potential impacts to aquatic fauna seeking refuge in the wet Bohena Alluvium. No stygofauna were located in the Bohena Alluvium (refer Appendix C of Appendix G1).

The *Guidelines for Riparian Corridors on Waterfront Land* (DPI 2012) provide procedures for conducting controlled activities adjacent to rivers, including providing minimum riparian zone widths based on

Strahler Stream Order. Under the Strahler system of determining stream order, Bohena Creek is listed as a sixth order stream (refer to Chapter 13). Under these guidelines, roads, pipelines or powerlines running alongside Bohena Creek need to be set back at least 40 metres (DPI 2012). Other infrastructure, such as wells and buildings should also be separated by at least 40 metres. The Field Development Protocol (Appendix C) defines the riparian corridor widths that will be adopted for the project (see Table 16-2). The Field Development Protocol complies with *Guidelines for Riparian Corridors on Waterfront Land* (DPI 2012a)—refer to Table 16-2.

Table 16-2 Riparian corridor widths adopted in the Field Development Protocol

Strahler Order	Riparian corridor width (on each side)
1st order	10 m plus channel width
2nd order	20 m plus channel width
3rd order	30 m plus channel width
4th order and greater	40 m plus channel width

Standard operating procedures would be used during construction to minimise the potential for impacts, including the implementation of an erosion and sediment control plan. Refer to Chapter 12 (Surface water quality) for an assessment of potential turbidity impacts as they relate to water quality, and therefore, secondary risk to aquatic ecology and the management and mitigation measures proposed to manage and mitigate that risk.

16.3.4 Impacts to riparian vegetation communities

Potential impacts from the managed release to riparian vegetation communities along Bohena Creek are considered to be negligible. This is because the release will occur when Bohena Creek is already flowing with a volume of at least 100 megalitres per day. Weed species with propagules spread by water will have already been distributed by natural flows.

Other impacts may occur where pipes or roads need to cross drainage lines. While existing crossings will be used where practical, the constraints approach outlined in the Field Development Protocol would be adopted when planning the location of future crossings to minimise impacts.

16.3.5 Impacts to stygofauna

The following potential risks to stygofauna have been identified:

- impacting suitable habitat during drilling
- impacts to groundwater levels or water quality associated with trans-boundary flow between aquifers due to improper drilling and/or completion techniques
- depressurisation of underlying aquifers that alters the physical structure of stygofauna habitat and subsequently changes groundwater levels or quality.

No stygofauna were detected in samples collected from the Bohena Creek alluvial aquifer, nor are extensive stygofauna communities likely because of the poor development of the aquifer and frequency with which the aquifer dries. There remains a small chance that some species may occur in the deeper parts that are permanently saturated. The proposed release to Bohena Creek is unlikely to have a significant impact on stygofauna communities, because at the time of discharge, Bohena Creek will be flowing and the alluvial aquifer will be saturated. Also, the thorough and rapid mixing of treated water once released would ensure no change to groundwater chemistry in the alluvial aquifer.

The proposed project does not include wells that require drilling through the Namoi alluvial aquifer and this significantly reduces the potential for impact to stygofauna. A maximum drawdown of 0.5 metres has been predicted from numerical modelling for the Namoi River alluvial aquifer (refer to Chapter 11). This is unlikely to have an impact on stygofauna communities, which are likely to be resilient to such small fluctuations in the water table. Stygofauna living in alluvial aquifers have evolved under conditions where the water table fluctuates naturally, and are able to move up and down with the water table provided the change in water level is not too extreme.

Provided drilling, operation and closure activities are undertaken in accordance with the relevant guidelines and legislation, the proposed project activities are very unlikely to pose a significant threat to known or potential stygofauna habitat.

Pipe crossings will also pose no significant threat to stygofauna populations or habitat, as construction will occur during periods of no flow in the watercourse.

16.3.6 Assessments of significance (EP&A Act and EPBC Act)

Assessments of significance under the EP&A Act and EPBC Act were undertaken for the following threatened species:

- *Notopala sublineata* (River Snail) listed as endangered under the FM Act
- *Bidyanus bidyanus* (Silver Perch) listed as vulnerable under the FM Act and critically endangered under the EPBC Act
- *Maccullochella peelii peelii* (Murray Cod) listed as vulnerable under the EPBC Act
- Murray-Darling Basin population of Eel-tailed Catfish (*Tandanus tandanus*) listed as endangered under the FM Act.

The assessments of significance are presented in Appendix C of Appendix G1. The outcome of these assessments is that the project would have no or negligible impacts on these threatened species as they are unlikely to occur in Bohena Creek due to a lack of suitable habitat. Impacts to these species would also be unlikely in the Namoi River due to of the distance between the proposed release point and the confluence of the Namoi River.

16.4 Environmental risk assessment

Table 16-3 summarises the environmental risk assessment undertaken for the potential impacts of the project on aquatic ecology. For each potential impact, the assessment considered:

- the potential pre-mitigated impact, where the potential impacts are uncontrolled
- the mitigation measures that would be used to manage the potential impacts on aquatic ecology to reduce the likelihood of the potential impacts
- the residual risk of the potential impact after the implementation of mitigation measures. The residual risk takes into account the potential for impact that remains after the mitigation measures are applied.

The mitigation measures identified in Table 16-3 would be incorporated into a Biodiversity Management Plan.

Table 16-3 Environmental risk assessment

Potential Impact	Phase	Pre mitigated risk			Mitigation and management measure	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Managed release to Bohena Creek alters flow regime and disturbs stream channel and associated habitat	Construction	NA	NA	NA	Treated water will be released to Bohena Creek at the managed release point only during periods when the flow in Bohena Creek is equal to, or greater than, 100 ML/day as measured at the Newell Highway gauging station.	NA	NA	NA
	Operation	Possible	Minor	Low		Unlikely	Minor	Low
	Decommissioning	NA	NA	NA		NA	NA	NA
Managed release to Bohena Creek changes water quality	Construction	NA	NA	NA	The managed release to Bohena Creek will utilise a diffuser designed to promote mixing of water at the release point. The managed release activity will be undertaken in a manner that minimises erosion of the bed and banks at the release point and the build-up of sediment at that location. The Water Monitoring Plan (Appendix G3) will be implemented.	NA	NA	NA
	Operation	Possible	Minor	Low		Unlikely	Minor	Low
	Decommissioning	NA	NA	NA		NA	NA	NA
Managed release to Bohena Creek impacts stygofauna	Construction	NA	NA	NA	The Water Monitoring Plan (Appendix G3) will be implemented.	NA	NA	NA
	Operation	Unlikely	Negligible	Very low		Unlikely	Negligible	Very low
	Decommissioning	NA	NA	NA		NA	NA	NA
Linear infrastructure changes water quality and damages riparian zone	Construction	Unlikely	Negligible	Very low	Infrastructure will be sited in accordance with the Field Development Protocol to avoid or minimise potential impacts. Erosion and sediment control measures will be implemented during construction of watercourse crossings. Construction of watercourse crossings would occur during periods of no flow in the watercourse. Vehicular crossing will be designed and constructed to include appropriate stabilisation.	Unlikely	Negligible	Very low
	Operation	Unlikely	Negligible	Very low		Unlikely	Negligible	Very low
	Decommissioning	Unlikely	Negligible	Very low		Unlikely	Negligible	Very low

NA: Not applicable during this project phase.

16.5 Conclusion

The following mitigation and management measures would be incorporated into a Biodiversity Management Plan for the project to minimise potential impacts on aquatic and riparian flora and fauna. These measures include ensuring that treated water is released to Bohena Creek at the release point during periods when the flow in Bohena Creek is equal to, or greater than, 100 megalitres per day, as measured at a gauging station at the Newell Highway. A water monitoring plan would also be implemented, including monitoring of Bohena Creek flow rates and water quality up and downstream of the managed release point.

The implementation of these mitigation and management measures would be satisfactory to control and minimise the potential impacts of the project on aquatic and riparian ecology, including stygofauna. The residual risk for the construction, operation and decommissioning phases of the project are summarised in Table 16-4 and range from low to very low.

Table 16-4 Aquatic ecology residual risks

Potential Impact	Residual risk		
	Construction	Operations	Decommissioning
Managed release to Bohena Creek alters flow regime and disturbs stream channel and associated habitat	NA	Low	NA
Managed release to Bohena Creek changes water quality	NA	Low	NA
Managed release impacting stygofauna	Very low	Very low	Very low
Linear infrastructure changes water quality and damages riparian zone	Very low	Very low	Very low

NA: Not considered to be a risk at this stage of the project

