ARCADIS Design & Consultancy for natural and built assets

Moorebank Precinct East - Stage 2

B106 – Baseline Aquatic Ecological Monitoring Report and Biodiversity Monitoring Strategy

(SSD 7628)

SIMTA SYDNEY INTERMODAL TERMINAL ALLIANCE

June 2018

Moorebank Precinct East Stage 2: Baseline Aquatic Ecological Monitoring Report and Biodiversity Monitoring Strategy Autumn 2018

FINAL REPORT

Prepared for Arcadis

8 June 2018

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Document information

Report to: Arcadis

Prepared by:

Biosis project no.: 26648

File name: 26648.BaselineAquaticEcologicalMonitoring.Autumn2018.FIN02.20180608

Citation: Biosis 2018. Baseline Aquatic Ecological Monitoring- Autumn 2018. Report for Arcadis Authors: [redacted] Biosis Pty Ltd, Sydney. Project no. 26648.

Document control

Version	Internal reviewer	Date issued
Draft version 01		19/02/2018
Draft version 02		03/05/2018
Final version 01		17/05/2018
Final version 02		08/06/2018

Acknowledgements

Biosis acknowledges the contribution of the following people and organisations in undertaking this study:

- Arcadis:

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1 Introduction

1.1 Project background

The Sydney Intermodal Terminal Alliance (SIMTA) received approval for the construction and operation of Stage 2 (the Project) of the Moorebank Precinct East (MPE) Project, which comprises the second stage of development under the MPE Concept Approval (MP10_0193) and approved under Development Approval SSD 7628.

The MPE site, including the Project site, is located approximately 27 km south-west of the Sydney Central Business District (CBD) and approximately 26 km west of Port Botany and includes the former Defence National Storage and Distribution Centre (DNSDC) site. The MPE site is situated within the Liverpool Local Government Area (LGA), in Sydney's South West subregion, approximately 2.5 km from the Liverpool City Centre.

The MPE Project involves the development of an intermodal facility including warehouse and distribution facilities, freight village (ancillary site and operational services), stormwater, landscaping, servicing and associated works on the eastern side of Moorebank Avenue,

Stage 2 of the MPE Project involves the construction and operation of warehousing and distribution facilities on the MPE site and upgrades to approximately 1.5 kilometres of Moorebank Avenue from approximately 35 metres south of the northern boundary of the MPE site to approximately 185 metres south of the southern MPE site boundary.

Key components of the Project include:

- Earthworks including the importation of 600,000 m^3 of fill and vegetation clearing
- Approximately 300,000 m^2 gross floor area (GFA) of warehousing and ancillary offices
- Warehouse fit-out
- Freight village, 8,000 m^2 GFA of ancillary retail, commercial and light industrial land uses
- Internal road network and hardstand across the site
- Ancillary supporting infrastructure within the site, including:
  - Stormwater, drainage and flooding infrastructure
  - Utilities relocation/installation
  - Fencing, signage, lighting, remediation and landscaping
- Moorebank Avenue upgrade including:
  - Raising by about two metres and some widening
  - Embankments and tie-ins to existing Moorebank Avenue road levels
  - Signalling and intersection works
- Intersection upgrades along Moorebank Avenue including:
  - Moorebank Avenue/MPE Stage 2 access
  - Moorebank Avenue/MPE Stage 1 northern access

- Moorebank Avenue/MPE Stage 2 central access
- Moorebank Precinct West (MPW) Southern Access/MPE Stage 2 southern emergency access.

The following general construction activities will be undertaken across the construction area for the Project:

- Vegetation clearance.
- Remediation works.
- Demolition of existing buildings and infrastructure.
- Earthworks and levelling of the Project site, including within the terminal hardstand.
- Drainage and utilities installation.
- Establishment of hardstand.
- Construction of a temporary diversion road (the Moorebank Avenue Diversion Road) to allow for traffic management along Moorebank Avenue during construction (including temporary signalised intersections adjacent to the existing intersections).
- Construction of warehouses and distribution facilities, ancillary offices and the ancillary freight village.
- Construction works associated with signage, landscaping, stormwater and drainage works.

The MPE Stage 2 Project has been assessed by the Department of Planning and Environment (DP&E) under Part 4 Division 4.1 (now Division 4.7 as of 1 March 2018) of the *Environmental Planning and Assessment Act 1979* (EP&A Act) as State Significant Development (SSD). The Planning Assessment Commission (PAC) granted Approval for the MPE Stage 2 Project on 31 January 2018 and is subject to the Minister's Conditions of Consent (CoC) (ref SSD 7628). The Project, including its potential impacts, consultation and proposed mitigation and management, is documented in the following suite of documents:

- State significant development approval SSD 7628.
- Moorebank Precinct East – Stage 2 – Environmental Impact Statement (Arcadis Australia Pacific Pty Limited, December 2016).
- Moorebank Precinct East – Stage 2 – Response to Submissions (Arcadis Australia Pacific Pty Limited, July 2017).
- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) Approval (No. 2011/6229) granted on March 2014
- Consolidated assessment clarification responses issued on 10 November 2017 (Arcadis 2017).

1.2 Purpose

Biosis Pty Ltd was commissioned by Arcadis to prepare a Baseline Aquatic Ecological Monitoring Program (BAEMP) for the Project (Biosis 2018), to ensure compliance with the Condition of Consent (CoC) B106 as detailed in Table 1. The BAEMP was prepared in March 2018 in consultation with Office of Environment and Heritage (OEH) and Department of Primary Industries (DPI) and was submitted to the Secretary for information in May 2018.

The purpose of this Aquatic Ecological Monitoring Report is to report on the monitoring undertaken as part of the BAEMP to determine the stream health conditions of Anzac Creek prior to any Stage 2 project works, and to use the monitoring results to establish a Baseline Monitoring Strategy.

Table 1 Condition of Consent Requirements

Condition Number	Requirement	Where addressed
B106	Prior to early works, a baseline monitoring program must be prepared in consultation with OEH and DPI to define pre-development conditions for water quality, invertebrates and fish assemblages. The results of this monitoring program are to be used to:	BAEMP (Biosis 2018)
B106(a)	Develop a **Biodiversity Monitoring Strategy** to identify any changes between upstream and downstream sites as a result of the construction and operation of the development;	This report
B106(b)	Set the stormwater water quality and quantity performance criteria referred to in condition B40.	Stormwater quality criteria during construction is in accordance with the CSWMP. Operational stormwater quality and quantity performance criteria will be developed upon completion of the water quality monitoring undertaken in accordance with this Baseline Monitoring Strategy.
B107	Any unavoidable indirect impacts as identified through the Biodiversity Monitoring Strategy required under condition B106, e.g. impacts of change hydrology on vegetation in boot land/ biobank site must be identified and measures to address this must be developed in consultation with OEH and implemented to the satisfaction of the Secretary. Measures may include additional offsetting.	To be developed if unavoidable indirect impacts are identified through ongoing monitoring. These will be identified throughout the life of monitoring.

The purpose of the BAEMP was to define a program to establish the baseline stream health and water quality conditions of waterways within, or in proximity to, the Moorebank Precinct East – Stage 2 site (study area). The BAEMP forms the basis for an ongoing Baseline Monitoring Strategy (Section 5) to assess stream health, in accordance with CoC B106, to determine any change in stream health or water quality throughout the life of the project and ascertain whether these changes can be attributed to the project works.

The BAEMP was submitted to the NSW Office of Environment and Heritage (OEH) and Department of Primary Industries (DPI) for consultation, prior to the first round of fieldwork being conducted and provided to the Secretary for information.

1.3 Scope of assessment

The objective of the BAEMP was to develop a comprehensive and repeatable stream assessment methodology to establish the baseline stream health within Anzac Creek which will enable ongoing periodic monitoring during construction and operation in accordance with the requirements of CoCs B43, B44 and B106.

Urbanisation degrades the ecological function of waterways, with an increase in effective imperviousness of only 10 % resulting in the loss of ecosystem function through alterations of the physical and biological characteristics of waterways (Booth and Jackson 1997). Therefore, the focus of monitoring within Anzac Creek aims to assess both physical and biological characteristics.

Two mapped waterways flow within, or adjacent to the study area. The main waterway is Anzac Creek, a first order (within the study area), non-perennial stream that flows into Lake Moore before entering the Georges River. While predominantly ephemeral, Anzac Creek has been noted to hold permanent water in isolated pools and is classified as representing Class 3 (minimal) fish habitat (Arcadis 2016). Extensive macrophyte cover has been recorded within Anzac Creek, with Eastern Gambusia *Gambusia holbrooki* and Long-finned Eel *Anguilla reinhardtii* the only aquatic fauna species recorded within the waterway by Arcadis (2016). The second waterway is an unnamed, non-perennial first order tributary of Anzac Creek. Flow from this tributary to Anzac Creek is interrupted by a dam, directly upstream of the confluence of these two waterways. This dam is located within Commonwealth Department of Defence Lands. Water from the dam passes through the dam wall, beneath the footpath and into Anzac Creek via a culvert.

The results presented within this report assesses Anzac Creek, the unnamed tributary of Anzac Creek and any other unmapped waterways identified during the field assessment. The assessment is focussed on Anzac Creek being the larger waterway and being most likely to hold water during any field assessment.

1.4 Construction and Operational Impacts

The Project is considered to only result in indirect impacts to Anzac Creek, as no instream or riparian works are being undertaken as part of the Project. Indirect impacts are generally associated with increased stormwater inputs from both the stormwater network and surface water flows from increases in non-permeable surfaces. Water Sensitive Urban Design (WSUD) measures such as onsite detention basins and rainwater gardens are incorporated into designs for the Project to mitigate impacts associated with increased stormwater runoff and nutrient/pollutants, therefore a key outcome of this monitoring program will be to determine that these measures are functioning as intended.

The increases in stormwater inputs to Anzac Creek could result in the following changes:

- Bed and bank scour as a result of increases in volume and velocity of water during rainfall events.
- Increases, or introduction, of pollutants via stormwater, with common pollutants including nitrogen, phosphorous, copper, aluminium and zinc.
- Alterations in vegetation structure as a result of altered hydrological regime.

The monitoring undertaken (refer Section 3) provides a baseline from which to assess these attributes within Anzac Creek to identify if these predicted indirect impacts are occurring, with the intent of guiding future management or mitigation of these impacts.

ALS (2011) assessed two sites within the project area, one on Anzac Creek and a second on the Georges River, which formed the aquatic ecological assessment component of the EIS prepared by Hyder (2011). The Anzac Creek site assessed by ALS corresponds to Site AQ2 in this monitoring plan. The sites were identified as being in a generally poor condition associated with water security, with macroinvertebrate surveys in 2011 indicating that the actual water quality in Anzac Creek was moderate-good. The fish survey results are unable to be used as a baseline, as they are not considered a sufficient means of assessing the status of resident fish communities in waterways. ALS identify that Anzac Creek is potentially subject to a more detectable degree of impact associated with the project, as the riparian and instream condition is confined and considered more representative of a natural waterway.

2 Baseline monitoring program methodology

The following section provides a summary methods applied in the BAEMP. Given the largely ephemeral status of Anzac Creek, the protocols below allowed for comprehensive assessment of aquatic ecological habitat whether the site was dry or holding water.

2.1 Monitoring sites

2.1.1 Site location

The monitoring sites were defined during the initial baseline monitoring program field survey, following an initial walk over of the length of the waterways within the site.

2.1.2 Assessment frequency

Monitoring will be conducted at least four times annually during construction, twice during both spring and autumn. The monitoring frequency will be reduced to twice-annually during the operational phase of the project. The NSW AUSRIVAS sampling and processing manual recommends sampling during autumn, 15 March to 15 June and spring, 15 September to 15 December, in order for the predictive models to be accurate. It is recommended that samples be collected as close as possible to the start and end of each monitoring season to effectively identify changes over time.

2.2 Stream health assessment

The four following types of assessment have been used, which together provide a comprehensive indication of the physical and biological function of Anzac Creek:

- Visual stream assessments.
- Surface water quality and sediment monitoring.
- Aquatic macroinvertebrate assessment.
- Fish assemblage assessment.

The assessment protocols, and condition of assessment (whether the waterway is dry or wet) is provided in Table 2. Full descriptions of the methodologies for each assessment protocol are provided in the sections below. Visual assessments were undertaken during the monitoring field survey regardless of whether the sites were dry or holding water, given the ephemeral status of the majority of Anzac Creek within the study area and ability for each visual assessment process to focus on different stream characteristics or processes.

Table 2 Baseline monitoring program assessment protocols

Type of assessment	Assessment protocol	Dry	Wet
Visual	DPI waterway classification and key fish habitat assessment	✓	✓
	NSW AUSRIVAS recording form	✓	✓
	HABSCORE assessment	✓	✓
	Ephemeral stream assessment	✓	
Surface water and sediment quality	In situ water quality monitoring		✓
	Water chemical sampling		✓

Type of assessment	Assessment protocol	Dry	Wet
	Sediment sampling	✓	✓
Aquatic macroinvertebrate	NSW AUSRIVAS and Signal2 sampling		✓
Fish community	Fish community/habitat suitability		✓

2.3 Site walkover

The assessment included a walkover of the length of Anzac Creek where accessible. Access to the associated canal drain tributary and dam was not possible due to Commonwealth Department of Defence fencing. However, the location of inputs to Anzac Creek from this tributary were identified and assessed. The walkover recorded:

- Location and condition of refuge pools
- Presence of aquatic macrophytes
- Changes in riparian and instream vegetation structure, condition and extent
- Key physical processes operating within the waterways and
- Identification of the optimal monitoring site selection

It is not proposed that this walkover will be completed during each monitoring event. However, a photo log of geotagged incidental photos has been collected to inform and compare against any subsequent monitoring activities where relevant.

2.4 Visual stream assessments

Multiple visual stream assessments were undertaken at each site, regardless of water presence and flow status. The purpose of the visual assessments were to characterise observable indicators of stream health and identify natural processes operating at each site, as well as grade the sites on the availability and condition of aquatic habitat and disturbance so that their condition may be compared and tracked over time.

A photo record, recording upstream and downstream views of each monitoring site, was collected and will also be collected during each future monitoring event.

2.4.1 DPI waterway classification and key fish habitat assessment

All sites are defined in accordance with the DPI *Fisheries Policy and Guidelines for Fish Habitat Conservation and Management* (DPI 2013). Key fish habitats are not defined under the *Fisheries Management Act, 1994*, however they underpin the approach applied by NSW DPI to ensure effort and resources are focused on habitats that are of a high priority to the conservation of fisheries.

Key fish habitat TYPE classifies the sensitivity and general value of the habitat present, while the CLASS classifies the flow status and connectivity of waterways in relation to fish habitat. The required information for NSW DPI to determine if the project will have a detrimental impact on the environment is specified in Section 3 of the *Fisheries Policy and Guidelines for Fish Habitat Conservation and Management* (DPI 2013).

2.4.2 NSW AUSRIVAS recording form

A NSW AUSRIVAS recording form (Turak et al. 2004) was completed at each site to record qualitative descriptions of the aquatic habitat within each site. Qualitative descriptions are particularly useful for understanding changes in site conditions over time and when comparing sites to one another. The attributes described include:

- Surrounding landforms
- Instream habitat features
- Presence, extent and type of aquatic vegetation
- Stream substratum
- Potential areas of refuge during low flow periods
- Presence of fish habitat
- Presence of barriers to fish movement.
- Indicators of point source and diffuse pollution.

2.4.3 HABSCORE assessment

HABSCORE assessments were completed at each site, to provide a direct visual measure of the relative condition and availability of aquatic habitat. HABSCORE assessments are especially useful when the site is dry and no AUSRIVAS assessment can be completed. Barbour et al. (1999) describe HABSCORE as a *'visually based habitat assessment that evaluates the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community'.*

HABSCORE assessments are based on the presence and condition of the following habitat characteristics:

- Pool substrate characterisation
- Pool variability
- Channel flow status
- Bank vegetation (score for each bank)
- Bank stability (score for each bank)
- Width of riparian zone (score for each bank)
- Epifaunal substrate / available cover

These characteristics provide an indicator of the quality of the waterway even when there is insufficient water for AusRivAs and SIGNAL2 assessments. HABSCORE categories are derived from the sum of scores divided by the maximum possible score for the characters assessed and range from 'Poor' to 'Optimal' condition. Descriptions for condition grades are provided in Table 3 below.

Table 3 HABSCORE condition descriptions

HABSCORE	Description
Optimal	Watercourses that contain numerous large, permanent pools and generally have flow connectivity except during prolonged drought. They provide extensive and diverse aquatic habitat for aquatic flora and fauna.
Suboptimal	Watercourses that contain some larger permanent and semi-permanent refuge pools, which would persist through prolonged drought although, become greatly reduced in extent. These watercourses should support a relatively diverse array of aquatic biota including some fish, freshwater crayfish and aquatic macroinvertebrates. There may also be some aquatic plant species present.
Marginal	Watercourses that contain some small semi-permanent refuge pools which are unlikely to persist through prolonged drought. Flow connectivity would only occur during and following significant rainfall.

	These pools may provide habitat for some aquatic species including aquatic macroinvertebrates and freshwater crayfish.
Poor	Watercourses or drainages that only flow during and immediately after significant rainfall. Permanent or semi-permanent pools that could provide refuge for aquatic biota during prolonged dry weather are absent.

2.4.4 Ephemeral stream assessment

The *CSIRO Ephemeral Stream Assessment* guidelines was used to undertake rapid assessment of the geomorphic integrity of each site and identify the processes operating within each site. The *CSIRO Ephemeral Stream Assessment* guidelines provide an assessment of the following four indicators of stream bed condition:

- Type and condition of vegetation within the drainage line
- Shape of the drainage line and type of material on the channel floor
- Nature of drainage line wall material
- Nature of bank edge and lateral flow regulation

The outputs of the ephemeral stream assessment provide a rating of drainage line activity from very stable to very actively eroding, allows identification of the issues causing erosion, and prioritising where additional monitoring and remedial actions may be required.

Table 4 Ephemeral stream assessment score classifications

Activity rating	Classification	Discussion of classification
81-100	Very Stable	Drainage line is very stable and likely to be in original form. It is able to withstand all flow velocities that have previously occurred in this area and only minimal monitoring is required, predominantly after high flow events, to ensure condition does not deteriorate
61-80	Stable	Drainage line is stable. It is important to assess this zone in relation to the other classifications and define whether this zone is moving from potentially stabilising to a more stable form or if it is deteriorating from a very stable form. The nature of his relationship will identify the type of monitoring required
41-60	Potentially stabilising	Drainage line is potentially stabilising. Ongoing monitoring is required while rehabilitation works are not needed in the immediate future
21-40	Active	Drainage line is actively eroding and remedial actions are required. It is important to classify if erosion is caused primarily by upstream flows, lateral flows or unstable wall materials so that appropriate rehabilitation can be carried out.
0-20	Very active	Drainage line is very actively eroding and immediate remedial actions are required. It is important to classify if erosion is caused primarily by upstream flows, lateral flows or unstable wall materials so that appropriate rehabilitation can be carried out.

2.5 Surface water quality and sediment monitoring

Where sites held suitable amounts of water, *in situ* water quality sampling and chemical water quality sampling was conducted. The recorded values are compared to the ANZECC (2000) water quality values for lowland streams and 90% protection criteria for freshwater systems and NSW OEH *Water Quality and River Flow Objectives* for the Georges River catchment.

Sediment sampling was proposed to be undertaken only at the baseline monitoring phase (this report), to determine the presence of any legacy issues associated with the occurrence of contaminants.

2.5.1 Surface water quality monitoring

Surface water quality monitoring was conducted for a standard suite of relevant water quality parameters using a Horiba U-52 multiparameter water quality probe, including:

- Dissolved oxygen
- Electrical conductivity
- pH
- Water temperature
- Turbidity

Alkalinity was measured by field titration using a Hach alkalinity kit.

2.5.2 Water chemical and sediment sampling

Water chemical sampling was undertaken for a range of nutrients, metals and hydrocarbons relevant to stream health and aquatic assessment, listed below:

- Total phosphorus (surface water only)
- Total nitrogen (surface water only)
- Kjeldahl nitrogen (surface water only)
- Dissolved metals (standard 19 relevant to aquatic assessment) (surface water only)
- Total metals (standard 19 relevant to aquatic assessment) (sediment only)
- Total petroleum hydrocarbons, BTEX (benzene, toluene, ethylbenzene, trimethylbenzenes and three xylene isomers) hydrocarbons
- PFAS: Poly-fluoroalkyl substances (Including Perfluorohexane sulfonate PFHxS)

2.6 Macroinvertebrate assessment

2.6.1 Field sampling

Macroinvertebrate samples were undertaken one site during autumn 2018, where available water levels permitted sampling, using the NSW AUSRIVAS sampling and processing manual (Turak et al. 2004). AUSRIVAS assessments are proposed to be undertaken twice during each spring and autumn season (four times annually), with one samples collected at each site, where suitable habitat permits two samples (one edge and one riffle sample).

Aquatic macroinvertebrates were "live picked" at the site. Following (Turak et al. 2004), samples were searched for a minimum of 40 person minutes. If new taxa were found in the last 10 person minutes of searching, the sample was searched for a further 10 person minutes, up to 60 person minutes in total. The collected macroinvertebrates were preserved in 70% ethanol and transferred to a laboratory for identification to the family level. Taxonomic resolution of the macroinvertebrate identification is predominantly to the family level, however modifications have been prescribed for Oligochaeta (class), Acarina (order) and Chironomidae (sub-family).

2.6.2 Data analysis

The key outputs that were used to measure stream health and water quality were the Signal2 score, number of taxa recorded, AUSRIVAS band and OE50 score. Interpretation of these outputs together builds a comprehensive indication of stream health and long term water quality.

Signal2

SIGNAL2 grades have been calculated for the macroinvertebrate samples and will be the primary output used to measure stream health and water quality as it does not rely on the use of reference sites as the AUSRIVAS approach does. Due to the levels of development and historic land use in the area, it can be assumed that while Anzac Creek functions as a waterway, it will not function exactly as an undisturbed reference waterway would. The Signal2 (Stream Invertebrate Grade Number Average Level) biotic index score (Chessman 2003) applies a revised sensitivity grade to macroinvertebrate families and, based upon the original Signal grade (Chessman 1995) is considered a more accurate grading than the original. The Signal2 biotic index describes the tolerance of macroinvertebrate taxonomic families to pollution. Signal2 grades range between 1 and 10, with pollution-tolerant taxa (such as freshwater worms) having scores close to 1 and pollution-sensitive taxa (such as certain mayflies) having scores closer to 10. The index is derived from the sum of scores divided by the sum of individual families collected and is calculated by the AUSRIVAS model, provided as the O0 Signal score.

Table 5 Signal2 grade biotic index descriptions

Signal2 score	Impairment	Water quality status
Greater than 7	Unimpaired & rich in sensitive taxa	Excellent water quality
6 - 7	Unimpaired	Good water quality
5 - 6	Mildly impaired	Fair quality, possible mild pollution
4 - 5	Moderately impaired	Poor quality
Less than 4	Severely impaired	Very poor water quality

The index provides a comprehensive ecological indicator that produces an average Signal2 score for each monitoring site as an indication of the macroinvertebrate community's overall tolerance to pollution or disturbance which provides a basis for interpreting the level of impairment and water quality status of the site.

NSW AUSRIVAS analysis

Macroinvertebrate community analysis also included the use of AUSRIVAS software package, which contains predictive models that assess the ecological health of a site by comparing its macroinvertebrate community with those of similar 'reference' sites within the model. The macroinvertebrates recorded at these reference sites are considered to be a strong representation of what macroinvertebrate communities would be expected to occur at a monitoring site if it is in a 'reference' or undisturbed condition. If a site does not contain the taxa expected by the model, then its condition is described as being 'lower than reference'.

Table 6 AUSRIVAS OE50 scores and Band ratings

Score	Explanation
Band rating	
X	The site is richer than reference condition
A	The site is equivalent to reference condition
B	The site is in significantly impaired condition
C	The site is in severely impaired condition
D	The site is in extremely impaired condition
OE50 score	
> 1	The observed macroinvertebrate community is richer than the predicted reference site
- 1	The observed macroinvertebrate community is similar to that of a reference or undisturbed stream
< 1	The observed macroinvertebrate community is impoverished when compared to a reference site

Number of taxa

The number of taxa recorded at each site are also calculated, providing a useful basic level of comparison among sites and within sites over time. The number of taxa may also be broken down into groups based on their Signal2 grade, with the relative abundance of 'pollution sensitive' and 'pollution tolerant' taxa compared. The number of environmentally sensitive (EPT) taxa are also calculated for each site. The Ephemeroptera, Plecoptera and Trichoptera (EPT) orders are considered to be very sensitive to stream pollution in comparison to other orders. Calculation and comparison of these taxa based scores provides a further indication of disturbance at each site to support interpretation of the Signal2 biotic index scores.

2.7 Fish community survey

CoC B106 specifies that fish assemblages are to be considered in the establishment of a pre-development condition of the waterbodies within the study area. During the EIS, two species of fish were recorded within Anzac Creek: Eastern Gambusia and Long-finned Eels. Fish community survey was undertaken in autumn 2018 to provide an assessment of the baseline condition of the waterways.

2.7.1 Field sampling

Fish surveys are undertaken using a modified Sustainable Rivers Audit (SRA) method (MDBC 2004). Fish sampling was undertaken using a Smith Root LR-24 backpack electrofishing unit. Backpack electrofishing consisted of electrofishing a 120 metre transect, targeting suitable habitat and cover, with 10 bait traps deployed to collect cryptic species not typically susceptible to capture by electrofishing. Bait traps were deployed for a minimum of 90 minutes and a maximum of 2.5 hours.

The number of nets of each type, the duration of net deployment and the number of electrofishing shots taken at each site were recorded. Data from each sampling technique was processed and recorded separately at each site. All fish collected were identified, with the first 30 individuals of a species caught using the same sampling technique being measured (total length) at each site. All individuals in the electrofishing shot or net containing the 30th caught individual were measured to reduce size selection bias, with any additional fish caught in separate shots or nets only being counted.

2.7.2 Data analysis

Length frequency distributions were derived for each species to allow a description of the respective modal distributions and relevant cohorts. This information was utilised in the description of the populations and allowed further explanation of patterns observed in the study area. Length modes may indicate age groups and are generally most pronounced in fish with a short spawning season and fast and uniform growth (Bagenal and Tesch, 1968).

3 Results – Autumn 2018

The results of the baseline ecological assessment, during autumn 2018, utilising the BAEMP methodology are provided below.

3.1 Survey dates and personnel

The autumn 2018 baseline aquatic ecological monitoring was conducted over two days on the 12 and 19 April 2018. Survey was undertaken by [redacted] (Senior Aquatic Ecologist), [redacted] (Field Aquatic Ecologist) and [redacted] (Field Ecologist).

During the site walkover, a total of 15 sites were identified as warranting individual characterisation. The location of these sites are shown in Figure 1. These sites were selected due to changes in channel geometry or in-stream features, riparian or in-stream vegetation, disturbance factors or land use. Aquatic habitat descriptions and observations concerning erosional processes are detailed below. Vegetation descriptions have been limited to structural form, given the focus of this component of the assessment is on erosion resistance and habitat provision.

3.2 Rainfall

Rainfall data was obtained from the Bankstown Airport AWS (station number: 66137). No rainfall was recorded during the two field survey dates or days in between. Mean average rainfall for the area is 98.7 mm for March and 86.0 mm for April. Rainfall was considered to be below average for the six week period preceding the field survey, being only 40.8 mm in total.

3.3 Bushfire

A large bushfire occurred within the Holsworthy area between the two field survey dates, burning across 3848 ha of south western Sydney, including a portion of the study area. Biosis understands that the bushfire entirely burnt a portion of the southern section of the study area, including all instream and riparian vegetation, extending through the "Boot Land" up to the power line easement at site AQ4. Access into burnt sections of Anzac Creek following bushfire was not possible due to the presence of *Hibbertia fumana* (Critically Endangered: BC Act) within the area and biosecurity protocols that had been put in place to protect this species. The visual assessments and descriptions of Anzac Creek were undertaken prior to impacts of bushfire. These assessments and descriptions are considered to remain relevant as they assess conditions and processes within Anzac Creek under nominal or baseline conditions. While impacts from bushfire, particularly to affected riparian vegetation may be detected in future monitoring surveys, natural regeneration will in time return Anzac Creek to conditions similar to the pre-bushfire state. As bushfires and subsequent regeneration are a natural process, re-assessment of Anzac Creek is not considered necessary.

Figure 1: Aquatic ecological assessment map

AQ1

Site AQ1 was dry at the time of survey. Soils beneath the instream root layer were dry to a depth of at least 30 centimetres, with scattered woody perennials establishing in the active channel zone. The active channel zone averages approximately four metres width at this section of Anzac Creek. This site featured a dense and continuous coverage of instream emergent macrophytes dominated by reed-like structural forms. The most common species were the Native Rush *Typha* sp., Marsh Club-rush *Bolboschoenus fluviatilis*, with the exotic understory species Alligator Weed *Alternanthera philoxeroides* also occurring in patches. Dieback of these macrophytes, presumably a result of dry conditions, was observed at the time of survey. The presence of these macrophytes indicates that a degree of water is periodically held within the channel zone. The riparian vegetation was relatively intact, save for a cluster of exotic Bamboo that has established on the right bank and the presence of access tracks.

The dense coverage of instream emergent macrophytes in addition to the relatively intact woody riparian vegetation has resulted in a stable watercourse, with a wide and shallow channel geometry.

Upstream	Downstream
	

Plate 1 Views upstream and downstream of site AQ1

AQ2

Site AQ2 was dry at the time of survey, with soils beneath the instream root layer dry to a depth of at least 30 centimetres. Anzac Creek is intersected at this site by a large culvert supporting rail tracks. The Creek widens slightly at this site, with the active channel zone averaging approximately five metres width. This site featured a dense and continuous coverage of instream emergent macrophytes. The instream vegetation within site AQ2 was consistent with site AQ1, dominated by tall reed-like structural forms. Dieback of these macrophytes, presumably a result of dry conditions, was observed to increase slightly at this site, in comparison to upstream. The presence of these macrophytes indicates that a degree of water is periodically held within the channel zone. The riparian vegetation was relatively intact, except for a gap on both banks where rail tracks intersect Anzac Creek.

The dense coverage of instream emergent macrophytes in addition to the relatively intact woody riparian vegetation has resulted in a stable watercourse, with a wide and shallow channel geometry.

Upstream	Downstream
	

Plate 2 Views upstream and downstream of site AQ2

AQ3

Site AQ3 was dry at the time of survey, with an increase in scattered woody perennials observed establishing in the active channel zone in comparison to upstream sections. A greater degree of the channel bed surface was exposed at the time of survey. The channel width narrows slightly at this point, to approximately three metres. The riparian and instream vegetation composition was generally consistent with sites AQ1 and AQ2, although the increase in bare stream substrate and instream occurrence of woody perennials indicate reduced water availability at this site.

The dense coverage of instream emergent macrophytes in addition to the relatively intact woody riparian vegetation has resulted in a stable watercourse, with a wide and shallow channel geometry.

Upstream	Downstream
	

Plate 3 Views upstream and downstream of site AQ3

AQ4

Site AQ4 was dry at the time of survey. Anzac Creek narrows at this site to a width of approximately three metres flowing through a culvert along a power line easement. The width depth ratio of Anzac Creek also decreases at this site. *Casuarina* species become the dominant riparian canopy species. Instream vegetation was almost entirely absent at the time of survey, however a dense coverage of dried leaf litter (coarse particulate organic matter) and dried macrophytes was observed within the channel zone. A small number Spike Rush (*Eleocharis* sp.) macrophytes, were observed within the channel. Indicating that water is periodically held within the channel zone, supporting dense plant growth.

The lack of instream vegetation, decrease in width depth ratio and exposure of some bank material indicates that this section of Anzac Creek is more susceptible to erosion than the upstream reaches. However no indicators of significant erosional impacts were observed, indicating that Anzac Creek remains relatively stable at this site.

Upstream	Downstream
	

Plate 4 Views upstream and downstream of site AQ4

AQ5

Site AQ5 was dry at the time of survey. However the presence of a variety of lush emergent macrophytes and terrestrial groundcover species within the channel indicate a greater availability of sub-surface water. Grass, tussock, branched and unbranched structural forms were all recorded within the active channel zone. The channel narrows significantly at this point, to approximately one and a half metres width. Channel shading also increases at this site, with *Casuarina* species decreasing in abundance. Riparian vegetation is almost entirely intact at this site, with native woody canopy species dominating. Scattered deposits of coarse woody debris were observed within the channel zone.

The presence of dense woody riparian vegetation, continuous instream macrophyte cover and coarse woody debris provide erosion resistance. No significant erosional processes were observed at this section of Anzac Creek.

Upstream	Downstream
	

Plate 5 Views upstream and downstream of site AQ5

AQ5.1

Site AQ5.1 is a small unmapped tributary of Anzac Creek and was dry at the time of survey. Given the straight planform of this tributary, it is likely to have been constructed to facilitate drainage into Anzac Creek. The majority of the stream substrate is covered by leaf litter, with scattered Spike Rush occurring within the stream bed.

The presence of dense woody riparian vegetation and intact vegetated banks suggest that this is a stable channel and is not subject to significant erosional processes.

Plate 6 Views upstream and downstream of site AQ5.1

AQ6

Anzac Creek becomes discontinuous at site AQ6, with the vegetation transitioning to a swamp-like understory species composition. The vegetation is characterised by tussocks of rush and sedge species, with an open canopy. The riparian vegetation surrounding site AQ6 remains intact and is dominated by native woody species. The site was dry at the time of survey.

The discontinuous nature of Anzac Creek at this site and presence of dense riparian vegetation suggest Anzac Creek is highly stable at this point.

Plate 7 Views upstream and downstream of site AQ6

AQ7

Site AQ7 consists of an access track depression, potentially directing flow into Anzac Creek during heavy rainfall events. The depression has been colonised by aquatic vegetation in the form of emergent macrophytes in numerous sections, with beds of Spike Rush macrophytes occurring in the deepest pools.

Upstream

Downstream

Plate 8 Views upstream and downstream of site AQ7

AQ8

Site AQ8 along Anzac Creek marks a return to the wide shallow channel geometries recorded upstream of site AQ4, from the more discontinuous form observed at AQ6. Instream vegetation in the upstream section of AQ8 is comprised of low growing rush species. With the downstream section being dominated by the Reed like structural forms, predominantly the Common Reed. *Casuarina* species also become the more dominant riparian species as the Common Reed increases in abundance downstream. A large access track has been cut and maintained at this section of Anzac Creek disturbing riparian vegetation on the left bank.

Upstream

Downstream

Plate 9 Views upstream and downstream of site AQ8

AQ9

Site AQ9 is a small drainage channel facilitating runoff from residential areas to the east into Anzac Creek. The site is subject to edge effects and weed ingress due to its proximity to housing. Instream vegetation within the channel is dominated by exotic terrestrial species, with woody exotic species, such as large leaf privet *Ligustrum lucidum* also present.

Upstream

Downstream

Plate 10 Views upstream and downstream of site AQ9

AQ10

Site AQ10 was dry at the time of survey. This section of Anzac Creek displays a high degree of modification. The riparian vegetation on the right bank is displaced by residential housing, with a stormwater drain draining from the residential area also occurring on the right bank. Anzac Creek passes through a culvert at this section, with cobble sized rocks placed on the bed and banks as an erosion protection measure. Site AQ10 is highly edge affected with exotic terrestrial species dominating the channel and right bank. The dominance of terrestrial species indicates that water is held infrequently at this site. Downstream of the culvert Anzac Creek exhibits the same morphology and bed armouring measures. The riparian vegetation continues to decline in extent downstream, with dense beds of Common Reed occurring within the channel zone.

The reduction in instream and riparian vegetation, combined with the proximity to increased impervious surface areas and storm water inputs also suggests that AQ10 is subject to a greater degree of erosion than the upstream sections of Anzac Creek. The erosion protection measure of bed and bank armouring with rocks indicates that AQ10 is somewhat susceptible to erosional processes. Despite this, no significant indicators of erosion were observed at AQ10.

Upstream

Downstream

Plate 11 Views upstream and downstream of site AQ10

AQ11

Site AQ11 occurs just upstream of the large refuge pool at AQ12 and held a small amount of water at the time of survey. Dense beds of Native Rush and Common Reed occur within the active channel zone, with riparian vegetation decreasing significantly in extent and condition in comparison to that of the “Boot land”.

The channel geometry at this section is relatively wide and shallow, with vegetated and cohesive banks. As such this section of Anzac Creek is considered stable.

Upstream | Downstream

Plate 12 Views upstream and downstream of site AQ11

AQ12

Site AQ12 features a large refuge pool approximately ten metres wide with an average depth of at least one metre. It is considered likely that this refuge pool holds water year round. Submerged macrophytes were observed throughout the pool, with floating and emergent macrophytes also present in large amounts around the pool margins. The upstream and downstream edges of the pool are covered by dense beds of Common Reed. These macrophytes provide significant epifaunal cover. The riparian vegetation continues to decline in extent and condition at site AQ12.

The amount of tall instream vegetation upstream of site AQ12, submerged vegetation within the refuge pool and vegetation root binding along the banks suggest Anzac Creek is stable at site AQ12. This is despite the reduction in woody riparian vegetation present at this site.

Upstream | Downstream

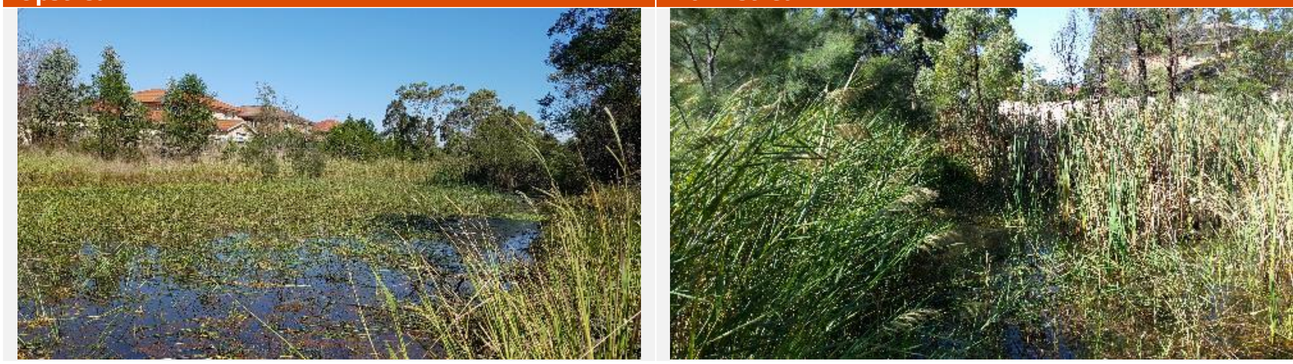

Plate 13 Views upstream and downstream of site AQ12

AQ13

Site AQ13 is located along Anzac Creek immediately upstream of the culvert entrance from the canal drain that links the dam within Commonwealth Department of Defence Lands to Anzac Creek. An overflow channel from Wattle Grove Lake enters Anzac Creek, approximately 150 metres upstream of site AQ13. This overflow channel is covered by maintained terrestrial lawn grass with scattered trees. Suggesting that water flows through this channel infrequently.

Anzac Creek between AQ13 and the overflow channel exhibits a wide shallow channel geometry, with dense low growing emergent macrophytes covering all instream surfaces. A very minor amount of standing water was observed at this section of Anzac Creek. Riparian vegetation increased in terms of condition and extent at this section, with *Casuarina* species established along both banks to a greater degree, compared to the upstream and downstream sections.

Upstream	Downstream
	

Plate 14 Views upstream and downstream, between the overflow channel and site AQ13

Site AQ13 site was completely dry at time of survey. Woody riparian vegetation is highly reduced along the left bank at AQ13, with terrestrial shrubs becoming more common. A thin strip of *Casuarina* species occur along the right bank. The riparian vegetation along the left bank and within the culvert entrance is highly edge affected, being dominated by exotic terrestrial grasses and understory species. Native species dominate within the active channel zone with dense beds of Native Rush present.

Culvert	Entrance to Anzac Creek
	

Plate 15 Plates of the culvert and entrance to Anzac Creek at site AQ13

This section of Anzac Creek is potentially more susceptible to erosion due to the presence of additional inputs from both the overflow channel and culvert. However, both site AQ13 and the section of Anzac creek between AQ13 and the overflow channel exhibit a considerable degree of channel stability. This is due to the dense coverage of instream vegetation, as well as the wide and shallow channel morphology.

AQ14

Site AQ14 is the most downstream site assessed. The site was dry at the time of survey. Dense beds of Native Rush occur within the active channel zone, with the extent and condition of riparian vegetation being consistent with sites AQ12 and AQ13.

The channel geometry at this section is relatively wide and shallow, with dense instream vegetation and vegetated banks. As such this section of Anzac Creek is considered stable.

Upstream	Downstream
	

Plate 16 Views upstream and downstream at site AQ14

3.4 Visual stream assessments

A number of visual stream assessments were undertaken at each site in order to provide a comprehensive assessment of stream condition and processes, including during dry periods. The results of these assessments are detailed below.

3.4.1 DPI waterway classification

The DPI waterway classification, following DPI (2013), for each site is presented in Table 7. The majority of sites recorded TYPE 1 scores, indicating highly sensitive key fish habitat. This was generally due to the presence of aquatic vegetation within Anzac Creek at these sites. The majority of sites recorded CLASS 2 scores, indicating moderate key fish habitat, both due to the presence of aquatic vegetation and the defined nature of the bed and banks along Anzac Creek. Site AQ10 recorded TYPE and CLASS scores of three, meaning the site is considered to represent minimal and minimally sensitive key fish habitat due to the lack of channel definition and absence of aquatic vegetation. Site AQ12 recorded both TYPE 1 and CLASS 1 scores, meaning the site is considered highly sensitive key fish habitat classed as both highly sensitive key fish habitat and major key fish habitat.

Sites AQ6, AQ7 and AQ9 were not considered appropriate for classification due to the lack of bed and bank definition. It should be noted that the discontinuous section of Anzac Creek at AQ6 is still considered part of the Anzac Creek.

Table 7 DPI waterway classification by site

Site	TYPE	CLASS	Notes
AQ1	1	2	Aquatic vegetation present.
AQ2	1	2	Aquatic vegetation present.
AQ3	1	2	Aquatic vegetation present.
AQ4	1	2	Aquatic vegetation present.
AQ5	1	2	Aquatic vegetation present.
AQ5.1	1	2	Drainage channel into Anzac Creek. Aquatic vegetation present.
AQ6	N/A	N/A	Discontinuous section of Anzac Creek, waterway classification not appropriate.
AQ7	N/A	N/A	Aquatic vegetation present in access track depression, not considered a waterway.
AQ8	1	2	Aquatic vegetation present.
AQ9	N/A	N/A	Drainage line receiving runoff, not considered a waterway.

Site	TYPE	CLASS	Notes
AQ10	3	3	Aquatic vegetation present.
AQ11	1	2	Aquatic vegetation present.
AQ12	1	1	Permanent refuge pool, diverse fish community recorded, aquatic vegetation present.
AQ13	1	2	Aquatic vegetation present.
AQ14	1	2	Aquatic vegetation present.

3.4.2 Ephemeral stream assessment

Ephemeral stream assessments were undertaken across the upstream sections of Anzac Creek, following the *CSIRO Ephemeral Stream Assessment* guidelines. Downstream sites along Anzac Creek were not deemed suitable for this assessment due to the high degree of modification along these reaches. The riparian vegetation of these downstream reaches is reduced in both condition and extent. Additionally these reaches receive additional flow inputs from the overflow channel and culvert linking the dam within Commonwealth Department of Defence Lands to Anzac Creek. Field observations suggest that channel modification measures (such as bed armouring with cobbles) along the downstream reaches, along with the presence of dense beds of emergent macrophytes within the channel zone, indicate a considerable degree of stability along these reaches.

Results of the ephemeral stream assessment are provided in Table 8. The classifications ranged from stable to very stable. Key factors contributing to these high scores are the degree of vegetation along both the channel banks and channel floor, gently sloping channel geometry and the condition and extent of riparian vegetation which provides lateral flow regulation.

Table 8 Ephemeral stream assessment results: autumn 2018

Site	Score (%)	Category
AQ1	88	Very stable
AQ3	88	Very stable
AQ4	78	Stable
AQ5	78	Stable
AQ6	91	Very stable
AQ8	91	Very stable

3.4.3 HABSCORE assessments

The results of the HABSCORE assessments along Anzac Creek, following Barbour et al. (1999), are provided in Table 9. All sites upstream of site AQ12 recorded marginal grades, despite the dry conditions at the time of survey. While site AQ10 recorded a marginal grade, actual aquatic habitat condition and availability at this site is considered very poor due to the degree of channel modification, absence of aquatic vegetation, reduced structural heterogeneity and extensive terrestrial weed ingress. The extent and condition of "Boot land" vegetation along the left bank significantly increases the score for AQ10 despite the lack of aquatic habitat. The downstream sites AQ12, AQ13 and AQ14 recorded the lowest scores, due mainly to the decline in riparian condition and extent.

Table 9 HABSCORE assessment results by site

Site	Score	Category
AQ1	37	Marginal

Site	Score	Category
AQ2	36	Marginal
AQ3	36	Marginal
AQ4	28	Marginal
AQ5	41	Marginal
AQ8	41	Marginal
AQ10	26	Marginal
AQ11	41	Marginal
AQ12	55	Suboptimal
AQ13	21	Poor
AQ14	22	Poor

3.5 Surface water and sediment testing

The results of the surface water quality monitoring and sediment testing are provided below.

3.5.1 Surface water quality monitoring

Surface water quality data was collected at AQ11 and AQ12 during the autumn 2018 survey, with results displayed in Table 10. The dissolved oxygen values recorded were below guideline values, however these readings are considered to be within the range of values typical of urbanised systems. Turbidity readings exceeded guideline values, however the readings recorded are considered to be typical of refuge pools with substrates dominated by fine sediment. Both total Phosphorus and total Nitrogen exceeded guideline values to a considerable degree. Kjeldahl nitrogen is the combination of organically bound nitrogen and ammonia. As the values for Total Nitrogen and Total Kjeldahl Nitrogen are equal, this suggests that the high nitrogen values recorded at AQ11 can be attributed to natural processes such as the breakdown of organic matter, rather than inorganic inputs such as stormwater or fertilizer. This is not considered unusual, given the amount of instream vegetation present along Anzac Creek upstream of AQ12. Given the lack of opportunities for runoff from residential areas observed along Anzac Creek at this section, it is assumed that the high phosphorus value can also be attributed to natural processes.

Table 10 Water quality monitoring results: autumn 2018

Physicochemical parameter	NSW water quality and river flow objectives: Freshwater (Georges River Catchment)	AQ11	AQ12
Field measurements			
pH (pH units)	**6.5-8.5**	6.61	7.01
Dissolved Oxygen (% Saturation)	**85-110**	38	62
Electrical Conductivity (µS/cm)	**125-2200**	287	354
Temperature (°C)	**-**	26.72	18.49
Turbidity (NTU)	**6-50**	68	91
Nutrients (µg/L)			
Total Phosphorous	**25**	580	-
Total Nitrogen	**350**	8200	-
Total Kjeldahl Nitrogen	**-**	8200	-

The dissolved metal and hydrocarbon sampling results are provided in Table 18. Samples were collected from AQ11, being the only site other than AQ12 to hold sufficient water for sampling. Site AQ12 was not also selected for dissolved metal and hydrocarbon sampling due to its proximity to AQ11, which provides a more effective location due to its upstream position. The results are compared to the ANZECC (2000) guideline 90% criteria for freshwater systems. The 90% criteria have been adopted for Anzac Creek within the study area, based upon the relatively intact nature of the upstream reaches of Anzac Creek and relatively diverse fish community recorded from AQ12. Aluminium exceeded the 90% protection criteria by over three times. Aluminium was the only parameter recorded above guideline values recorded, exceeding the criteria. No other dissolved metal or hydrocarbon parameters exceeded guideline values.

3.5.2 Sediment metal testing

The results of the sediment testing for total metals are provided in Table 19. Lead was found to exceed guideline values at site AQ1. The source of Lead cannot be confirmed in the available data. However lead does not appear to be washed downstream through Anzac Creek. The proximity of AQ1 to Moorebank Avenue, a major roadway may explain the elevated Lead levels at this site. Lead was the only parameter recorded above guideline values.

3.5.3 Sediment and water PFAS sampling

The results of the sediment PFAS sampling are provided in Table 20. The sediment PFAS (PFOS and PFOA) parameters were below both the "Urban residential/public open spaces" as well as "National parks/areas with high ecological values" investigation levels.

The results of water PFAS sampling are provided in Table 21. The PFAS (PFOS and PFOA) values were below the 95% species protection (slightly to moderately disturbed systems) exposure scenario. The PFOA value was also below the 99% species protection (high conservation value systems) exposure scenario.

3.6 Macroinvertebrate analysis

Macroinvertebrate sampling and analysis was undertaken at site AQ12, the only site holding suitable levels of water to permit AUSRIVAS sampling during the field assessment.

The results of the macroinvertebrate assessment are provided in Table 11. Site AQ12 recorded a Signal2 score of four, indicating moderately impaired stream health conditions, with poor water quality. The AUSRIVAS Band and OE50 scores indicate significantly impaired stream health conditions, with the macroinvertebrate community impoverished when compared to a reference sites.

Table 11 Macroinvertebrate analysis results: autumn 2018

Site	Signal2 (calculated)	Signal2 (O0Signal)	OE50	Band	Number of taxa	EPT taxa
AQ12	4.07	4.00	0.49	B	13	2

3.7 Fish community assessment

Fish community survey was undertaken at the single refuge pool (AQ12) identified during the field assessment. The catch results are presented in Table 12. The invasive species Eastern Gambusia *Gambusia holbrooki* was by far the most numerous species recorded from AQ12. All other species recorded from AQ12 are native with relatively high numbers of the native Striped Gudgeon *Gobiomorphus australis* and Empire Gudgeon *Hypseleotris compressa* recorded, considering the surrounding land use.

Table 12 Fish catch results: autumn 2018

Scientific name	Common name	Number caught	Number observed	Size range (mm)
Anguilla reinhardtii	**Long-finned Eel**	2	0	500-600
Gambusia holbrooki	**Eastern Gambusia**	328	>2000	15-40
Gobiomorphus australis	**Striped Gudgeon**	28	0	38-112
Hypseleotris compressa	**Empire Gudgeon**	13	0	37-88

Length frequency distribution graphs have been constructed for the Striped and Empire Gudgeon species, presented in Figure 2 below. Length frequency distributions provide a simple graphical representation of the population structure of each species collected during surveys. Providing an indication of recruitment events and population age structure, with assessments over time also providing an indication of the ongoing trajectory of fish populations. Length frequency graphs have not been constructed for Eastern Gambusia, due to its abundance, or for the Long-finned Eel *Anguilla reinhardtii*, due to its common occurrence in such systems as well as the mobile and robust nature of this species.

The length frequency distributions for the Striped and Empire Gudgeon species recorded from AQ12 are provided in Figure 2, below. The presence of individuals within the small size classes of both species, indicate populations of both species are breeding successfully within the refuge pool at site AQ12.

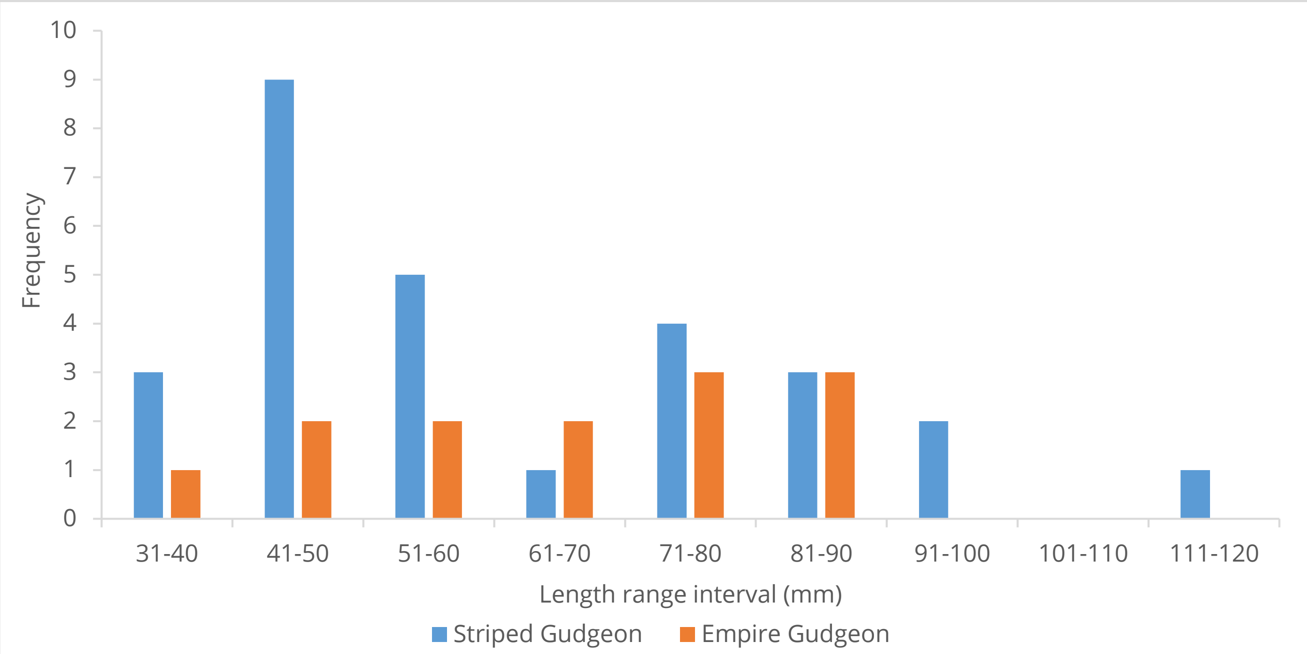

Figure 2 Fish community length frequency distributions (AQ12): autumn 2018

3.8 Limitations

3.8.1 Dry conditions

The largely ephemeral nature of Anzac Creek and limited rainfall during the survey period resulted in the majority of Anzac Creek being dry at the time of survey. Where no surface water was present within Anzac Creek, no assessment of water quality could be undertaken. The condition of Anzac Creek during the collection of baseline data is considered to be nominal, and as such the data collected is representative of "baseline" conditions. In response to this challenge, a number of visual assessments were undertaken providing a comprehensive assessment of the dominant physical processes operating within the creek, levels and types of disturbance, riparian condition, as well as the availability and condition of aquatic habitat. The HABSCORE assessment in particular allows for a direct comparison of site condition among sites and over time, even where sites may be completely dry, and is complemented by the qualitative descriptions made using the AUSRIVAS recording form.

Additionally, sediment sampling was undertaken at dry sites in order to identify potential legacy contamination issues. Sediment sampling involved a single grab sample at each sediment sampling site for a standard suite of metals and pollutants relevant to aquatic systems and PFAS.

Additional methods may be undertaken in an attempt to overcome the challenge of dry conditions, which are expected to continue at Anzac Creek. Wet weather *in-situ* and chemical sampling may be undertaken by SIMTA to determine the water quality and chemical status of water passing through the waterways during periods of flow in accordance with the Construction Soil and Water Management Plan and Biodiversity Monitoring Strategy outlined in Section 7 of this report. It is anticipated that changes to the amount of impervious surface area will occur as a result of the proposed works, resulting in increases to stormwater discharge into the waterways.

3.8.2 Access

No visual or physical assessment of the canal drain tributary of Anzac Creek or the dam located within Commonwealth Department of Defence lands was possible, due to access and visibility constraints. Inputs to Anzac Creek via this tributary will therefore be understood via assessment of Anzac Creek itself. This approach will use data collected at sites located upstream and downstream of inputs from this tributary, that enter Anzac Creek via a single culvert.

3.8.3 Surface water quality monitoring

The water quality parameters measured/analysed provide a snapshot of conditions at a given point in time. Some of these parameters typically exhibit a high degree of temporal variation and can change substantially over small periods of time (weeks, days and even hours), particularly in response to significant weather events.

3.8.4 Mapping

Mapping is conducted using hand-held (non-differential) GPS units and aerial photo interpretation. The accuracy of this mapping is therefore subject to the accuracy of the GPS units (generally +/- 7 metres) and dependent on the limitations of aerial photo rectification and registration.

4 Discussion and recommendations

4.1 Anzac Creek overview

The initial field survey during autumn 2018 identified Anzac Creek to be an ephemeral waterway with one large refuge pool (AQ12), considered likely to hold water year round. The upstream reaches (sites AQ1 to AQ4) featured minor to moderately disturbed riparian vegetation, instream vegetation dominated by native aquatic species and generally wide, shallow channel geometries. Reaches downstream of AQ4 within the “Boot land” became more confined before transitioning back to a wide shallow geometry after passing through a discontinuous flow section. Instream vegetation within these reaches continues to be predominantly native aquatic species. The riparian vegetation within this section of Anzac Creek is largely intact. Site AQ10 marks the change to the downstream reaches. Anzac Creek becomes a substantially modified waterway with the extent and condition of riparian considerably reduced. Channel bed armouring and substantial weed ingress of terrestrial exotic species become common throughout Anzac Creek at this point. Despite the general decline in riparian vegetation and aquatic habitat in the downstream reaches compared to upstream, a relatively diverse fish community was identified within the refuge pool at AQ12, also despite moderately impaired stream health conditions and poor water quality.

4.2 Ongoing monitoring sites

It is recommended that the following six sites (Table 13, Figure 1) be established as ongoing monitoring sites to allow for the identification of impacts to aquatic habitat and water quality within Anzac Creek. The spatial location of these sites has been established to identify the source of any impacts or changes to Anzac Creek. For example flows through the overflow channel associated with Wattle Grove Lake or increased traffic along the powerline easement at site AQ4. The purpose of the location of each monitoring site is detailed in Table 13. It is considered likely that runoff from the MPE Stage 2 construction area will be collected to some degree by the dam within the Commonwealth Department of Defence land. Therefore monitoring site AQ13 and AQ14 are recommended to be included to identify any changes associated with this and disentangle any impacts from flows through the overflow channel associated with Wattle Grove Lake.

Table 13 Monitoring site establishment

Site	Rationale
AQ1	Upstream monitoring site, identifying aquatic ecological values entering the site.
AQ4	Identifying impacts or changes to aquatic ecological values downstream of the rail and road crossing.
AQ8	Identifying impacts or changes to aquatic ecological values within the “Boot land”.
AQ12	Identifying impacts or changes to aquatic ecological values within the permanent refuge pool.
AQ13	Identifying impacts or changes to aquatic ecological values downstream of the overflow channel.
AQ14	Identifying impacts or changes to aquatic ecological values downstream of the dam culvert.

Recommended assessment types for each site under nominal conditions are detailed in Table 14. Under wet conditions where sites are found to hold suitable levels of water it is recommended that macroinvertebrate and surface water quality monitoring should also be undertaken.

Table 14 Recommended assessment types per monitoring site under nominal conditions

Type of assessment	Assessment protocol	AQ1	AQ4	AQ8	AQ12	AQ13	AQ14
Visual	DPI waterway classification	✓	✓	✓	✓	✓	✓
	NSW AUSRIVAS form	✓	✓	✓	✓	✓	✓
	HABSCORE assessment	✓	✓	✓	✓	✓	✓
	Ephemeral stream assessment	✓	✓	✓		✓	✓
Surface water and sediment quality	In situ water quality monitoring				✓		
	Nutrient, dissolved metal and PFAS sampling				✓		
	Sediment and PFAS sampling	✓	✓				✓
Aquatic macroinvertebrates	NSW AUSRIVAS and Signal2 sampling				✓		
Fish community	Fish community/habitat suitability				✓		

4.3 Baseline water quality assessment

Surface water quality could only be assessed at the refuge pool (site AQ12). The macroinvertebrate sampling results identified a moderate level of stream impairment and poor water quality, with the macroinvertebrate community impoverished when compared to a reference sites. This is supported by the water quality monitoring, which identified reduced dissolved oxygen values and elevated Aluminium levels outside of guideline values at this section of Anzac Creek. In acidic waters, Aluminium is acutely toxic to fish (Exley et al. 1991). The pH values recorded at site AQ11 are considered to be nominal and a relatively diverse fish community was recorded immediately downstream at site AQ12. Therefore, the elevated Aluminium values recorded at AQ11 were not considered to be having a significant impact on the aquatic biota of Anzac Creek at the time of survey. The source of elevated aluminium levels cannot be identified from the available data. It must be noted that a decrease in water pH levels may result in increased toxicity effects. Further sampling to identify the source of high Aluminium levels is recommended. Aluminium may be included in the sediment metal sampling upstream during future monitoring events.

4.4 Fish community status

A relatively diverse fish community was recorded within the refuge pool at site AQ12. While the native Striped and Empire Gudgeons were present in abundance, the invasive species Eastern Gambusia was by far the most prevalent species. Based on the length frequency analysis, the native Striped and Empire Gudgeons are considered to be breeding successfully within the refuge pool. Given the health of the fish community and number of native species present, repeat fish community survey is recommended during each monitoring event, to potentially identify any impacts to fish associated with changes in conditions or water quality.

4.5 Sediment

The level of Lead in the sediment sample at site AQ1 was the only exceedance of guideline values identified by the sediment sampling. Since the source of elevated Lead levels cannot be established with the existing data, it is recommended that metal sampling continue in future monitoring events to determine whether these Lead levels increase or pass downstream.

4.6 Stream stability

The results of the ephemeral stream assessment indicate that the upstream reaches of Anzac Creek within the study area, including those within the "Boot land" are stable and not subject to significant erosional processes. Due mainly to the degree of erosion resistant vegetation both instream and riparian. It is therefore anticipated that erosion resistance in the short term will be reduced in portions of Anzac Creek subject to bushfire. However the relatively cohesive nature of the banks along Anzac Creek and wide shallow channel geometry suggest a degree of inherent stability. It may also be assumed that rapidly regenerating understory species will provide an initial degree of soil binding before woody species regenerate. While the ephemeral stream assessment is not suitable at sites downstream of AQ10, due to the degree of stream modification, the presence of dense instream vegetation, vegetated banks and stream bed armouring result in a stable waterway along this section of Anzac Creek.

4.7 Bushfire

The key effects of the bushfire in the Holsworthy area upon Anzac Creek can be expected to include the temporary removal of instream and riparian vegetation, resulting in a decrease in flow resistance during high rainfall events and potentially and increase in erosion susceptibility until the vegetation regenerates. Should the ash and sediments resulting from the fire be mobilised and pass downstream through Anzac Creek this can be expected to result in low dissolved oxygen levels within any standing water resulting in deleterious impacts to aquatic biota, primarily through reduced dissolved oxygen levels (Lyon & O'Connor 2008). It is anticipated that there will be a considerable degree of sediment filtering before any water passes from the "Boot Land" section of Anzac Creek into the modified channel downstream of AQ10. Due to the "Boot Land" vegetation being relatively intact, the wide and shallow geometry of the majority of Anzac Creek and the discontinuous vegetated section within the "Boot Land". Therefore acute and significant impacts to areas of high ecological value, such as the refuge pool (AQ12) are not expected. However further monitoring events may need to take into account ongoing impacts from the bushfire in terms of vegetation condition and extent, erosion and sediment mobilisation. The HABSCORE and ephemeral stream assessments will be useful tools for tracking these changes.

PFAS is still in the process of being phased out and it is possible that this substance was utilised in fighting the bushfire that occurred along Moorebank Avenue impacting the study area. It is therefore recommended that PFAS is included in the sediment and water sampling conducted during the next round of survey.

5 Biodiversity Monitoring Strategy

This biodiversity monitoring strategy, as specified below, has been established to meet the objectives of CoCs B43, B44 and B106, in concurrence with DPI Fisheries and OEH. This report also presents the baseline findings in compliance with B106, for the collection of the baseline data.

5.1 Monitoring frequency

Monitoring should be undertaken four times annually during the pre-construction and construction phases of the project, with the frequency reduced to twice annually during the operational phase of the project. Two surveys should take place during both monitoring seasons, one being undertaken early in the season and the second late in the season. A hypothetic Gantt chart is provided in Table 15. Monitoring should be conducted within the spring and autumn seasons as defined in the NSW AUSRIVAS sampling and processing manual (Turak et al. 2004).

Table 15 Proposed survey frequency

Project phase	Pre-construction				Construction								Operational	
Survey number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2018 autumn survey 1														
2018 autumn survey 2														
2018 spring survey 1														
2018 spring survey 2														
2019 autumn survey 1														
2019 autumn survey 2														
2019 spring survey 1														
2019 spring survey 2														
2020 autumn survey 1														
2020 autumn survey 2														
2020 spring survey 1														
2020 spring survey 2														
2021 autumn														
2021 spring														

5.2 Aquatic monitoring site locations

Six continued monitoring sites have been established along Anzac Creek. The locations of these sites are provide in Table 16 and displayed in Figure 1.

Table 16 Aquatic monitoring site coordinates

Site	Latitude	Longitude
AQ1	-33.96111	150.92249
AQ4	-33.960588	150.928069

Site	Latitude	Longitude
AQ8	-33.95566	150.935332
AQ12	-33.948845	150.937305
AQ13	-33.946779	150.936964
AQ14	-33.946449	150.937093

5.3 Site assessment methodology

The flow chart provided in Figure 3 identifies the assessments to be undertaken at each site. Assessment methodologies have been detailed in section 2. The visual assessments should be undertaken at each site regardless of water status. Five sites should be sampled for sediment or dissolved metals, hydrocarbons and PFAS during the next survey event (autumn 2018 survey 2), with the necessity for continued sediment sampling re-evaluated following analysis of the data and will be provided in the report. If substantial changes in sediment metal or PFAS values, or additional exceedances of guideline values are detected at the monitoring sites, further sampling would be recommended. The assessment methods for wet sites should be undertaken wherever water levels permit survey. For example, water may be present but not at a volume suitable to submerge a water quality probe or conduct fish community sampling.

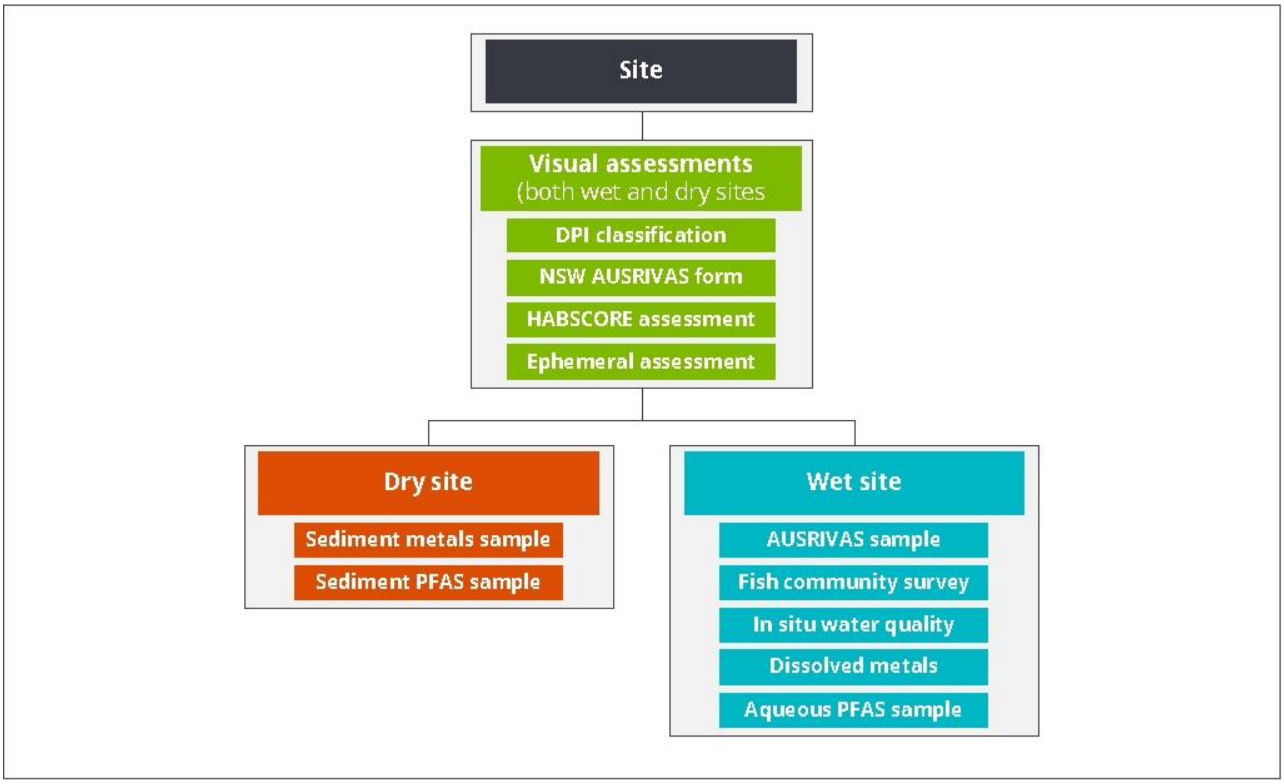

Figure 3 Assessment flow chart

6 Adaptive management

An adaptive management approach is to be employed in respect of the works forming part of this Monitoring Plan. An adaptive management approach involves an integrated process of monitoring, reviewing and then responding to the relative condition of Anzac Creek as well as the status of the beds and banks to identify any alterations to the mitigation measures that may be required to ensure the objectives of the of those measures are achieved.

The biannual reporting and associated review process, will identify aspects of the results that may be associated with the construction/operation of the project. Table 17 identifies potential results, problems and contingency measures that may require consideration during ongoing monitoring. This list is not exhaustive and only represents possible common issues with results.

Table 17 Adaptive management contingency measures

Result	Potential problem	Contingency measure
Increases in results of water quality parameters	Introduction or exacerbation of pollutants entering Anzac Creek.	Identify source and undertake corrective measures.
Reduction in results of biological monitoring	Subtle effects of construction and operation are influencing stream health within Anzac Creek.	Identify components causing decline. Assess feasibility of suitable corrective actions. If corrective measures can be implemented, these aspects are to be the focus of future monitoring. If corrective measures cannot be implemented, regulatory authority to be notified of change.
Increase scour of bed and banks of waterways	Reduction in bed and bank stability or loss of instream vegetation.	Identify point source/s of increased flow velocities or changes in stream hydraulics and discuss with project engineers to determine best methods for flow reduction or rectification of stream hydraulics.

It is important to note that any changes should comply with the aims of this monitoring plan and any licensing or approval conditions issued before implementation. An Adaptive Management Statement (or similar) will be prepared and signed by both parties prior to implementation of any adaptive management actions.

7 References

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Appendix 1 – Water and sediment sampling data

Table 18 Dissolved metal results: autumn 2018

Physicochemical parameter	ANZECC (2000) 90% protection criteria	AQ11
Dissolved metals (µg/L)		
Aluminium	80	260
Arsenic	42 (Arsenic as V)	<1
Barium	-	2
Beryllium	-	<1
Boron	680	<50
Cadmium	0.4	<0.1
Chromium	6	<1
Cobalt	-	<1
Copper	1.8	2
Iron	-	450
Lead	5.6	<1
Manganese	2500	3
Mercury	1.9 (inorganic Mercury)	<0.1
Molybdenum	-	<1
Nickel	13	<1
Selenium	18	<10
Strontium	-	52
Vanadium	-	<10
Zinc	15	<5
Total petroleum hydrocarbons (µg/L)		
C6 - C9 Fraction	-	<20
C10 - C14 Fraction	-	<50
C15 - C28 Fraction	-	<100
C29 - C36 Fraction	-	<50
C10 - C36 Fraction (sum)	-	<50
Total recoverable hydrocarbons - NEPM 2013 Fractions (µg/L)		
C6 - C10 Fraction	-	<20
C6 - C10 Fraction minus BTEX (F1)	-	<20
>C10 - C16 Fraction	-	<100
>C16 - C34 Fraction	-	<100
>C34 - C40 Fraction	-	<100
>C10 - C40 Fraction (sum)	-	<100
BTEXN (µg/L)		
Benzene	1300	<1
Toluene	-	<2

Physicochemical parameter	ANZECC (2000) 90% protection criteria	AQ11
Ethylbenzene	-	<2
meta- & para-Xylene	-	<2
ortho-Xylene	470	<2
Total Xylenes	-	<2
Sum of BTEX	-	<1
Naphthalene	85	<5

Table 19 Sediment metal results: autumn 2018

Physicochemical parameter	ISQG Trigger value	AQ1	AQ2	AQ4	AQ14
Total metals (mg/kg)					
Arsenic	20	<5	<5	<5	<5
Barium		110	110	60	<10
Beryllium		<1	<1	1	<1
Boron		<50	<50	<50	<50
Cadmium	1.5	<1	<1	<1	<1
Chromium	80	23	19	21	3
Cobalt		8	4	6	<2
Copper	65	31	40	12	<5
Lead	50	91	36	44	<5
Manganese		45	252	69	16
Mercury	0.15	<0.1	<0.1	<0.1	<0.1
Nickel	21	14	11	9	<2
Selenium		<5	<5	<5	<5
Vanadium		48	35	54	10
Zinc	200	93	103	96	17

Table 20 Sediment PFAS sample results: autumn 2018

Physicochemical parameter	Urban/residential investigation levels (DEE 2016)	AQ1	AQ2	AQ4	AQ14
Perfluoroalkyl Sulfonic Acids (mg/kg)					
Perfluorobutane sulfonic acid (PFBS)		<0.0002	<0.0002	<0.0002	<0.0002
Perfluorohexane sulfonic acid (PFHxS)		0.0036	0.0008	0.0007	<0.0002
Perfluorooctane sulfonic acid (PFOS)	32	0.0444	0.0037	0.0061	0.0005
Perfluoroalkyl Carboxylic Acids (mg/kg)					
Perfluorobutanoic acid (PFBA)		<0.001	<0.001	<0.001	<0.001
Perfluoropentanoic acid (PFPeA)		<0.0002	<0.0002	<0.0002	<0.0002
Perfluorohexanoic acid (PFHxA)		<0.0002	<0.0002	<0.0002	<0.0002
Perfluoroheptanoic acid (PFHpA)		<0.0002	<0.0002	<0.0002	<0.0002

Physicochemical parameter	Urban/residential investigation levels (DEE 2016)	AQ1	AQ2	AQ4	AQ14
Perfluorooctanoic acid (PFOA)	**29**	0.0003	<0.0002	<0.0002	<0.0002
Fluorotelomer Sulfonic Acids (mg/kg)					
4:2 Fluorotelomer sulfonic acid (4:2 FTS)		<0.0005	<0.0005	<0.0005	<0.0005
6:2 Fluorotelomer sulfonic acid (6:2 FTS)		<0.0005	<0.0005	<0.0005	<0.0005
8:2 Fluorotelomer sulfonic acid (8:2 FTS)		<0.0005	<0.0005	<0.0005	<0.0005
10:2 Fluorotelomer sulfonic acid (10:2 FTS)		<0.0005	<0.0005	<0.0005	<0.0005
PFAS Sums (mg/kg)					
Sum of PFHxS and PFOS		0.048	0.0045	0.0068	0.0005
Sum of PFAS (WA DER List)		0.0483	0.0045	0.0068	0.0005

Table 21 Water PFAS sample results: autumn 2018

Physicochemical parameter	95% species protection (DEE 2016)	AQ11
Perfluoroalkyl Sulfonic Acids (µg/L)		
Perfluorobutane sulfonic acid (PFBS)		<0.02
Perfluorohexane sulfonic acid (PFHxS)		0.02
Perfluorooctane sulfonic acid (PFOS)	**0.13**	0.03
Perfluoroalkyl Carboxylic Acids (µg/L)		
Perfluorobutanoic acid (PFBA)		<0.1
Perfluoropentanoic acid (PFPeA)		<0.02
Perfluorohexanoic acid (PFHxA)		<0.02
Perfluoroheptanoic acid (PFHpA)		<0.02
Perfluorooctanoic acid (PFOA)	**220**	<0.01
Fluorotelomer Sulfonic Acids (µg/L)		
4:2 Fluorotelomer sulfonic acid (4:2 FTS)		<0.05
6:2 Fluorotelomer sulfonic acid (6:2 FTS)		<0.05
8:2 Fluorotelomer sulfonic acid (8:2 FTS)		<0.05
10:2 Fluorotelomer sulfonic acid (10:2 FTS)		<0.05
PFAS Sums (µg/L)		
Sum of PFHxS and PFOS		0.05
Sum of PFAS (WA DER List)		0.05