Human Health and Ecological Risk Assessment: Callide Power Station – PFAS

Prepared for: EPIC Environmental Pty Ltd and CS Energy

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EnRiskS

Document History and Status

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Glossary of Terms and Acronyms

Additive Effect	An additive effect is where two or more substances act together to produce a total effect that is the same as the sum of the individual effects
Adsorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.
Adverse Health Effect	A change in body function or cell structure that might lead to disease or health problems
ANZECC	Australia and New Zealand Environment and Conservation Council
ASLP	Australian Standard Leaching Procedure
AT	Averaging Time
Background Level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
BW	Body weight
Carcinogen	A substance that causes cancer.
CF	Unit Conversion Factor
Chronic Exposure	Contact with a substance that occurs over a long time (more than 1 year) (compare with acute exposure and intermediate duration exposure)
Dermal Contact	Contact with (touching) the skin (see route of exposure).
Detection Limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
ED	Exposure Duration
EF	Exposure Frequency
EFSA	European Food Safety Authority
ET	Exposure time
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term (acute exposure), of intermediate duration, or long-term (chronic exposure).
Exposure Assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.
Exposure Pathway	The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has 5 parts: a source of contamination (such as chemical leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private groundwater bore); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all 5 parts are present, the exposure pathway is termed a completed exposure pathway.
FSANZ	Food Standards Australia New Zealand

Guideline Value	Guideline value is a concentration in soil, sediment, water, biota or air (established by relevant regulatory authorities such as the National Health and Medical Research Council (NHMRC), Australia and New Zealand Environment and Conservation Council (ANZECC) and World Health Organisation (WHO)), that is used to identify conditions below which no adverse effects, nuisance or indirect health effects are expected. The derivation of a guideline value utilises relevant studies on animals or humans and relevant factors to account for inter- and intra-species variations and uncertainty factors. Separate guidelines may be identified for protection of human health and the environment. Dependent on the source, guidelines will have different names, such as investigation level, trigger value, ambient guideline etc.
HI	Hazard Index
HIL	Health Investigation Level
HSL	Health Screening Level
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way (see route of exposure).
Inhalation	The act of breathing. A hazardous substance can enter the body this way (see route of exposure).
LOAEL	Lowest-observed-adverse-effect-level: The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals
LOR	Limit of Reporting
MDH	Minnesota Department of Health
No effect level	The tested dose of a substance that does not cause adverse effects in people or animals. See also NOAEL and LOAEL
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NOAEL	No-observed-adverse-effect-level: The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals
PFAS	Per- or Poly-fluoroalkyl Substance
PFOS	Perfluorooctanesulfonic Acid
PFOA	Perfluorooctanoic Acid
8:2 FTS	1H.1H.2H.2H-Perfluorodecanesulfonic Acid
4:2 FTS	1H.1H.2H.2H-Perfluorohexanesulfonic Acid
6:2 FTS	1H.1H.2H.2H-Perfluorooctansulfonic Acid
NEtFOSAA	N-Ethyl-Perfluorooctanesulfonamidoacetic Acid
NMeFOSAA	N-Methyl-Perfluorooctanesulfonamidoacetic Acid
PFBS	Perfluorobutanesulfonic Acid
PFDS	Perfluorodecanesulfonic Acid
PFDA	Perfluorodecanoic Acid
PFDoA	Perfluorododecanoic Acid
PFHpA	Perfluoroheptanoic Acid
PFHxS	Perfluorohexanesulfonic Acid
PFHxA	Perfluorohexanoic Acid
PFNA	Perfluorononanoic Acid
PFPeA	Perfluoro-n-Pentanoic Acid
PFOSA	Perfluorooctanesulfonamide
PFTeDA	Perfluorotetradecanoic Acid

PFTrDA	Perfluorotridecanoic Acid
PFUnA	Perfluoroundecanoic Acid
Point of Exposure	The place where someone can come into contact with a substance present in the environment (see exposure pathway).
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).
Receptor Population	People who could come into contact with hazardous substances (see exposure pathway).
Risk	The probability that something will cause injury or harm.
RME	Reasonable maximum exposure: The RME represents exposure scenario based on a set of exposure parameters that is representative of expected maximum exposure for that receptor and activity. The RME would not be expected to be exceeded except under highly specific and exceptional circumstances.
Route of Exposure	The way people come into contact with a hazardous substance. The 3 routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin (dermal contact)
SWL	Standing Water Level
Synergistic Effect	Synergistic effects are where two or more substances act together to produce a total effect that is greater than the sum of the individual effects
Toxicity	The degree of danger posed by a substance to human, animal or plant life.
Toxicity Data	Characterisation or quantitative value estimated (by recognised authorities) for each individual chemical for relevant exposure pathway (inhalation, oral or dermal), with special emphasis on dose-response characteristics. The data is based on available toxicity studies relevant to humans and/or animals and relevant safety factors.
Toxicological Profile	An assessment that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.
Toxicology	The study of the harmful effects of substances on humans or animals.
TRV	Toxicity Reference Value, e.g. an RfD, ADI, TDI, or PTWI. A guideline toxicity value that incorporates uncertainty or safety factors to identify a safe dose assuming daily lifetime exposure to a substance that is unlikely to cause harm in humans.
Uncertainty Factor	Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people (also sometimes called a safety factor).
USEPA	United States Environmental Protection Agency
WQG	Water quality guidelines (Australian guidelines based on the protection of ecosystems) (ANZG 2018)
WHO	World Health Organisation

Executive Summary

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by EPIC Environmental Pty Ltd (Epic), on behalf of CS Energy Ltd (CS Energy), to conduct a human health and ecological risk assessment (HHERA) in relation to the presence of per- and poly-fluoroalkyl substances (PFAS) on and off-site of the Callide Power Station located near Biloela, QLD (the “site”).

The site operates as a coal fired power station, operating two power plants, Callide B and Callide C. The power station receives up to 5.8 million tonnes of black coal annually from the neighbouring Callide Mine, owned by Batchfire Resources. The presence of PFAS has also been identified at this adjacent coal mine.

These chemicals have been found to be widespread in the environment in Australia and other countries (HEPA 2020).

Following release of the Queensland Department of Environment and Sciences’ (DES’s) (now the Department of Environment, Science and Innovation (DESI)) Operational Policy for the management of firefighting foam in 2016, CS Energy undertook a review of site operations and identified historical use of per- and poly-fluoroalkyl substances (PFAS). This review identified aqueous film forming foams (AFFF) had been used historically over the life of the station. Removal of all non-compliant AFFF commenced in late 2018, with all non-compliant AFFF removed from service and disposed to a licensed disposal facility prior to 2019.

CS Energy also undertook a detailed investigation into the nature and extent of PFAS contamination associated with historical use of PFAS in aqueous film forming foam (AFFF) used in fire training activities and equipment at the power station site.

Environmental investigations have been undertaken by EPIC Environmental. Initial work was completed in 2019. Investigations were then expanded to a range of off-site locations in 2021. These investigations were completed in a staged approach commencing immediately downstream of the Callide Power Station site (investigation Zone 1) and expanding downstream (investigation Zones 2, 3 5 and 6) and adjacent (investigation Zone 4) to the site.

This HHERA has been prepared making use of extensive data collected by EPIC Environmental in these investigations. It has focused on the area downgradient of the power station site and has evaluated all the uses of groundwater or surface water expected in rural areas to provide information to allow refinement of community advice, if appropriate.

Evaluation of potential for risks to people has been undertaken using the approaches recommended in national guidance provided in the ASC NEPM (supported by the PFAS NEMP) and by enHealth, and FSANZ (enHealth 2012a; FSANZ 2017a; HEPA 2020; NEPC 1999 amended 2013a, 1999 amended 2013b).

In regard to ecological risks, the environmental values determined by EPIC arising from the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (i.e. Water EPP) have been considered in this HHERA as well as the relevant Australian water quality guidelines (or other relevant guidelines for other media) (ANZG 2018; HEPA 2020).

On the basis of the available data and the assessment undertaken in this report, the following can be concluded:

Human Health

- Risks for each of the individual exposure pathways are acceptable in all zones (based on the guidance from national health authorities). These pathways include:
    - ingestion of groundwater for drinking (and all household uses of water)
    - incidental ingestion of groundwater during use of water for farming purposes
    - incidental ingestion of groundwater during outdoor domestic uses of water
    - consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater
    - consumption of home grown eggs which may contain PFAS due to chickens drinking groundwater
    - consumption of home grown meat which may contain PFAS due to stock watering using groundwater and consumption of fodder by the cattle where that fodder is irrigated with the relevant groundwater.
- Risks resulting from combining drinking groundwater with all or some of the pathways involving consumption of home grown produce are acceptable based on Australian health guidance for all zones except for the most impacted areas within Zone 1.
- Zone 1 has the highest concentration of PFOS+PFHxS. In this zone, if multiple exposure pathways for home grown produce (i.e. home grown eggs + home grown fruit & vegetables + home grown meat or home grown fruit & vegetables + home grown meat) are combined with using groundwater at the property as the sole source of drinking water, the risk to individuals would be slightly elevated when compared to the national guidelines for the locations with the highest concentrations (i.e. 0.3-0.4 µg/L). Based on the data available, it is understood that no individual household is exposed via the combination of all the possible exposures.
- It is understood that properties are being supplied with an alternate source of drinking water so use of groundwater as the sole source of drinking water is not occurring.
- For Zone 4, there was only 1 groundwater supply bore available for monitoring in this zone. The results for this bore were in compliance with the drinking water guideline for PFOS+PFHxS. Risks are, therefore, negligible and no further assessment was required for this zone.
- Risks due to exposures to people using Callide Creek for swimming/recreation are acceptable.
- Risks due to exposure to PFAS via consumption of fish caught in Lake Callide are acceptable based on the conservative national FSANZ trigger point.
- Risks due to exposure to PFAS via consumption of fish caught in Callide Creek are acceptable based on adjusted guidelines in line with the practical limitations on catch size and frequency of fishing.

It is important to note that the combination calculations (as per **Table 10.8a**) are based on the maximum concentrations reported and assume that people living/working on those properties will:

- use the groundwater as their sole source of drinking water and for all farming and/or domestic activities where incidental ingestion could occur
- consume 100% of eggs from chickens kept at the property

- consume 35% of meat from livestock kept at the property which are given groundwater to drink and that eat fodder that has been irrigated with groundwater
- consume 35% of fruit and vegetables from produce grown at the property and irrigated with groundwater.

It is understood that this combination is unlikely to have occurred.

Ecological

- No direct ecotoxicity effects from exposure to PFAS on aquatic species in Callide Creek and Lake Callide are expected.
- No effects in birds are expected due to consuming aquatic organisms from Callide Creek or Lake Callide that may contain PFOS.
- No effects in mammals are expected due to consuming aquatic organisms from Callide Creek or Lake Callide that may contain PFOS.

Other matters

The following points are also noted:

- This assessment has been based on the maximum reported concentrations for any sample type in each zone.
- While the site is likely to contribute to the levels of PFAS in Callide Creek, the site investigation shows that Callide Power Station is not the sole source of these chemicals to these waterways.
- For uptake of the chemicals into meat or eggs, the highest concentrations modelled for either PFOS or PFHxS have been used in the risk calculations.
- For uptake into meat, the combination scenario uses the risks based on the stock drinking groundwater and eating fodder that has been irrigated using the groundwater.
- There are no maximum residue levels for PFAS in meat/eggs (i.e. legally enforceable limits).
- FSANZ, however, has published trigger points to indicate when food may need more detailed investigation. The concentrations modelled in this assessment are generally in compliance with these trigger points.

This assessment shows that, based on a site-specific evaluation of risk, the concentrations of PFOS and PFHxS (and other PFAS) in groundwater or surface water do not pose an unacceptable risk to people when that water is accessed/used on properties in the off-site area downgradient of Callide Power Station based on national guidance for health risk assessment.

The levels of PFAS in groundwater or surface water also do not pose an unacceptable risk to ecosystems in and around Callide Creek based on national guidance for ecological risk assessment.

Section 1. Introduction

1.1 Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been engaged by EPIC Environmental Pty Ltd (Epic), on behalf of CS Energy Ltd (CS Energy), to conduct a human health and ecological risk assessment (HHERA) in relation to the presence of per- and poly-fluoroalkyl substances (PFAS) on and off-site of the Callide Power Station located near Biloela, QLD (the "site").

The site operates as a coal fired power station, operating two power plants, Callide B and Callide C. The power station receives up to 5.8 million tonnes of black coal annually from the neighbouring Callide Mine, owned by Batchfire Resources. PFAS has been identified at the adjacent coal mine.

Following release of the Queensland Department of Environment and Sciences' (DES's) (now the Department of Environment, Science and Innovation (DESI)) Operational Policy for the management of firefighting foam in 2016, CS Energy undertook a review of site operations and identified historical use of per- and poly-fluoroalkyl substances (PFAS). This review identified aqueous film forming foams (AFFF) have been used historically over the life of the station. Removal of all non-compliant AFFF commenced in late 2018, with all non-compliant AFFF removed from service and disposed to a licensed disposal facility prior to 2019.

CS Energy also undertook to investigate the nature and extent of PFAS contamination associated with historical use of PFAS in aqueous film forming foam (AFFF) used in fire training activities and equipment. Initial investigations were completed in 2019. Investigations were expanded to a range of off-site locations (up to 12 km downgradient of the site) in 2021. These investigations were completed in a staged approach commencing immediately downstream of the Callide Power Station site (investigation Zone 1) and expanding downstream (investigation Zones 2, 3 5 and 6) and adjacent (investigation Zone 4) to the site.

A HHERA has been prepared in this report making use of all of the collected data to assess potential risks.

Figure 1.1 shows the layout of the power station site.

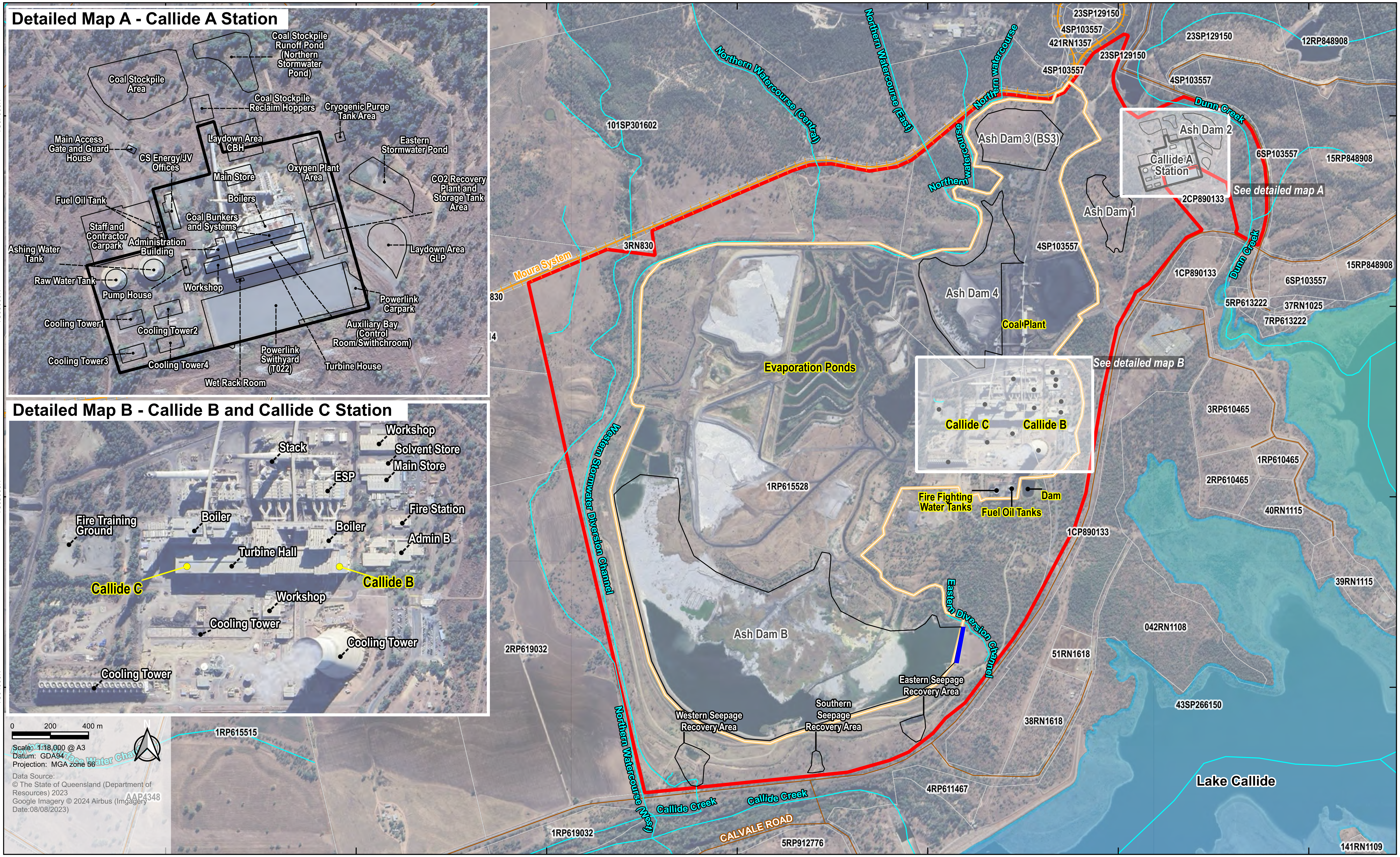
1.2 Objectives

The objectives of this HHERA are:

- Conduct an initial review of data and information to inform the development of a conceptual site model (CSM) relevant to the offsite environment (relevant to the investigation area as Zones 1 to 6).
- Undertake a HHERA in relation to the presence of PFAS in the off-site environment to address the following:
  - Risks to people
    - Rural residential uses of the off-site environment, which include:
      - potable and non-potable uses of water (groundwater and surface water)
      - agricultural activities such as large scale cropping or livestock

- home consumption of produce such as fruit and vegetables, eggs and potentially livestock
    - Recreational use of the off-site environment including recreational fishing and consumption of edible species
    - Workers involved in a range of activities in the off-site environment
  - Risks to the aquatic environment as relevant to the site and off-site areas.
- Where relevant, establish site-specific guidelines or triggers relevant to the site and offsite areas and land uses.

The HHERA will not consider or address any other chemicals in this environment.



Legend

- Callide power station - site boundary
- Ash Dam B catchment area
- Lake Callide
- Spillway
- Cadastre (DCDB)
- Railways
- Roads and tracks
- Watercourses

CS Energy
PFAS investigation (Callide Power Station)
Addendum Contaminated Land Investigation Document

Figure F1
Site features and layout

1.3 Approach

The approach taken for the quantitative assessment of human health and environmental risks is in accordance with the current national guidelines / protocols endorsed by Australian regulators, including:

- National Environmental Protection Measure – Assessment of Site Contamination (ASC NEPM) including:
  - Schedule B1 Investigation Levels for Soil and Groundwater (NEPC 1999 amended 2013c)
  - Schedule B4 Guideline on Health Risk Assessment Methodology (NEPC 1999 amended 2013b)
  - Schedule B5 Guideline on Ecological Risk Assessment (NEPC 1999 amended 2013a)
  - Schedule B7 Guideline on Health-Based Investigation Levels (NEPC 1999 amended 2013d)
- enHealth Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards (enHealth 2012a)
- enHealth Australian Exposure Factor Guide (enHealth 2012b)
- ANZG, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, A joint initiative of the Australian and New Zealand Governments in partnership with the Australian state and territory governments, Online (ANZG 2018).
- PFAS National Environmental Management Plan (the "PFAS NEMP") Version 2, January 2020 (HEPA 2020).

While the guidance documents from enHealth and the ASC NEPM are dated from 2012 and 2013, they are the most recent versions of these important national guidance documents.

Additional guidance has been sought from international sources where relevant, however, international guidance has not been adopted where it is inconsistent with the Australian regulatory or policy settings.

The overall approach to undertake a human health and ecological risk assessment (HHERA) is that from enHealth (2012a) and is shown in **Figure 1.2** (modified from enHealth 2012a).

The figure shows the risk assessment process in the centre of the figure (boxes shaded blue/grey) and the supporting processes of risk management and risk communication (boxes shaded white). Risk management and risk communication are usually undertaken by others once a risk assessment has been completed. It is important for a risk assessor to discuss the requirements of such an assessment with those responsible for managing or communicating about a risk to ensure the assessment covers all the required aspects.

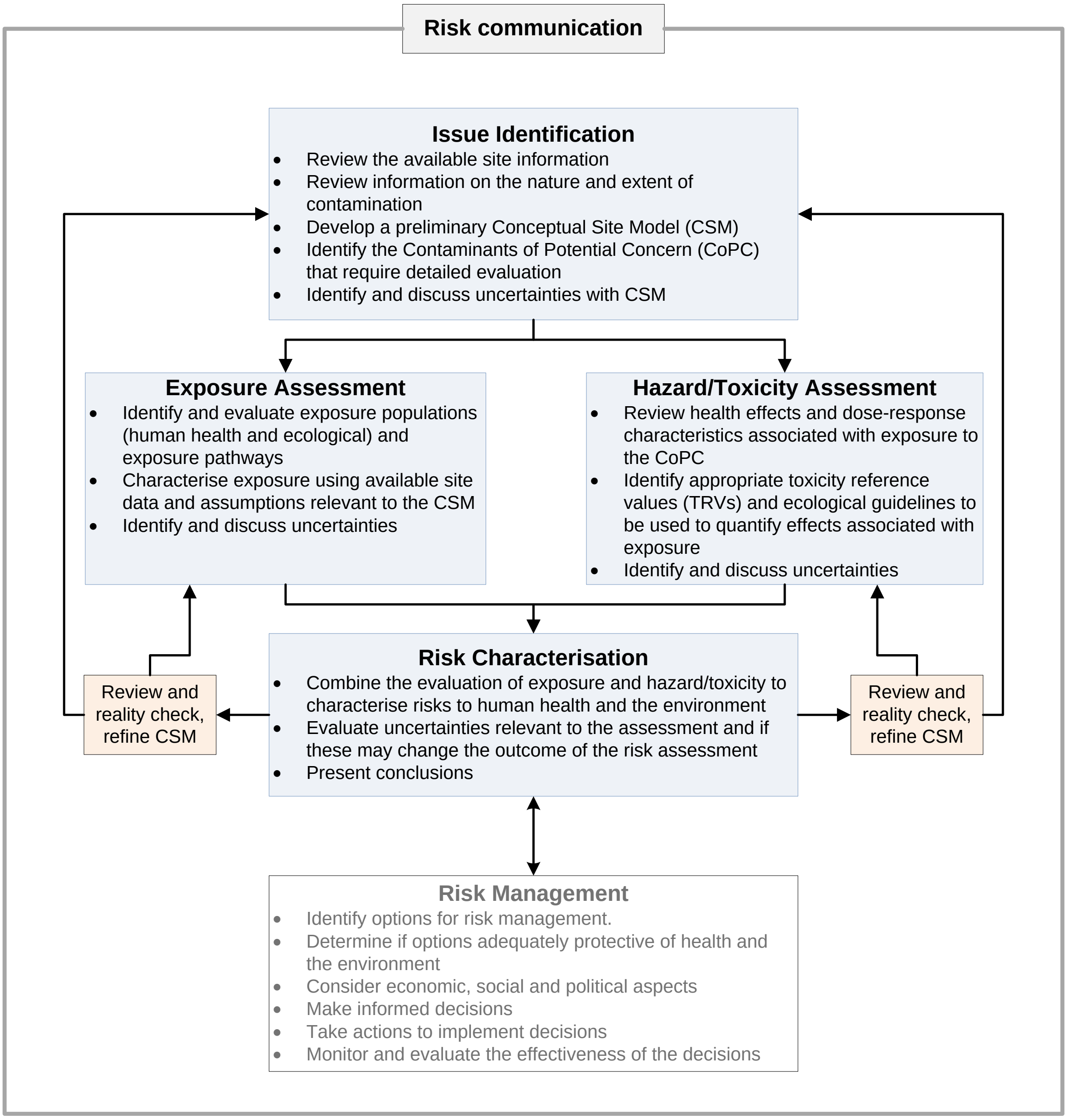


Figure 1.2 Risk Assessment Process as adapted from enHealth (2012a)

The normal approach for a HHERA is that they are undertaken in 2 stages:

- Screening assessment – this part of the assessment involves comparing the worst case concentrations of the chemicals of interest to national guidelines that are conservative. Those chemicals found to be higher than the national guidelines under these worst case circumstances are identified as the key chemicals for the assessment and they are carried through to the next stage.
- Detailed or refined assessment – this part of the assessment focuses on a more site-specific evaluation just for the chemicals identified as key in the screening step. This type of assessment considers the specific exposure pathways that are relevant to the site of interest and includes detailed calculations of how people or ecosystems could be exposed.

This HHERA has addressed the various aspects of a HHERA in the following sections:

- Summary of relevant site information and available data relevant to the development of a Conceptual Site Model (CSM) (**Section 2**)
- Introductory information on per and polyfluoroalkyl substances (PFAS) (**Section 3**)
- Nature and extent of PFAS contamination in the off-site area (**Section 4**)
- Summary information on ambient/background levels of PFAS in the environment in Australia (**Section 5**)
- Summary of conceptual site model (CSM) (**Section 6**)
- Identification of an appropriate dose-response relationship and quantitative values (toxicity reference values; TRV) for the assessment of potential human health effects associated with exposures to PFAS (**Section 7**)
- Identification of appropriate values for the assessment of potential environmental health effects associated with exposures to PFAS (**Section 8**)
- Screening assessment of all data relevant for the site (**Section 9**)
- Refined assessment based on human health (**Section 10**)
- Refined assessment based on ecosystems (**Section 11**)
- Conclusions of the HHERA with consideration of the assessment presented and the uncertainties identified (**Section 12**).

Section 2. Site information

2.1 General

This section provides a summary of the PFAS concentrations in relevant media at the site and downgradient of the site as well as site characteristics relevant to the assessment of potential exposures.

The following reports and information sources have been used in this HHERA:

- Enviropacific 2022, Site-Specific Remediation Plan Callide Power Station, CS Energy (September 2022)
- Environmental Management Strategies 2022, Conceptual Site Model for PFAS Migration – Callide PS (February 2022)
- EPIC 2020, Preliminary PFAS Environmental Investigation – Callide Power Station, CS Energy (June 2020)
- EPIC 2021, Callide Power Station – Targeted PFAS Environmental Investigation, CS Energy (January 2021)
- EPIC 2022a, Callide Power Station – Contaminated Land Investigation Document (Site Investigation), CS Energy (September 2022)
- EPIC 2022b, PFAS Investigation – Hydrogeological Review – Callide Power Station (April 2022)
- EPIC 2023, Landholder Water Use Investigation Summary Report – Callide Power Station (December 2023)
- EPIC 2024, Callide Power Station – Addendum Contaminated Land Investigation Document (Site Investigation), CS Energy (March 2024)
- Hydrobiology 2023, Callide Power Station Ecological and Contaminants Report (July 2023).

2.2 Site description

The site occupies two land parcels located at Biloela Callide Road, Mount Murchinson. Operational areas of the power station are split between the two lots, with the majority of the Waste Containment Facility located within Lot 1 on Registered Plan (RP) 615528 as shown in **Figure 1.1**.

Site details are provided in **Table 2.1**.

Aspect	Detail	Detail
Lot identification	1 RP615528	4 on Survey Plan (SP) 103557
Address	Biloela Callide Road, Mount Murchison QLD 4715	Biloela Callide Road, Mount Murchison QLD 4715
Site area (ha)	631.933	239.200
Site owner	CS Energy Limited	CS Energy Limited
Local government authority	Banana Shire Council	Banana Shire Council
Zoning	Special industry	Special industry

Both parts of the site are listed on the Environmental Management Register (EMR) for 1 or more of the following reasons:

- Petroleum Product or Oil Storage
- Chemical Storage
- Coal Fire Power Station

- Waste Storage, Treatment or Disposal
- Hazardous Contaminant: Asbestos and synthetic mineral fibres
- Asbestos Manufacture or Disposal

The presence of PFAS at the site was also notified.

2.3 Site history

The site consists of 3 coal fired power stations: Callide A, Callide B and Callide C.

Callide A Power Station was constructed in 1965, operating up until 1988 when Callide B Power Station was commissioned. Callide B continues to operate. Callide C Power Station was commissioned in 2001 and continues to operate. Callide A Power Station was retrofitted to trial low emission coal-fired power generation between 2012 and 2015, with the facility currently in the process of demolition (EPIC 2022a).

Site operations are managed under Environmental Authority EPPR00536313 (Callide A and B) and EPPR00707213 (Callide C) and the internal CS Energy Environmental Management System. Callide B and C manage ash and water internally within the adjacent Waste Containment Facility (EPIC 2022a).

The source of PFAS at this site is the historical use of AFFF (aqueous film forming foam).

The historical use of AFFF at the Callide B and C Power Stations was limited to testing, training and maintenance activities along with use as part of emergency response. No AFFF fire systems were installed during the construction of Callide C (water-based deluge/suppression systems). AFFF fire systems and areas where AFFF is reported to have been used are associated with Callide B (turbine halls) and the shared infrastructure including the fuel oil tanks, sulfur plant, coal plant and fire station) (EPIC 2022a).

The historical use of AFFF at the site is considered to have comprised infrequent use of smaller quantities (generally less than 10 L per event). The largest reported use is associated with emergency response associated with coal fires at the coal plant, with multiple fires reported and AFFF use reported between 20-160 L per event. It is noted that use of AFFF at the coal plant was undertaken to control fires, rather than fully extinguish, with coal material continuing to the boiler (>1,000^{o}C) (EPIC 2022a).

Historical information available for the site identifies that potential on-site releases (use) of AFFF at the Callide B and C Power Station site is likely to be less than 1,000 L over the life of the station, including use of up to 300 L of AFFF concentrate in training activities, system tests and use/maintenance of extinguishers, and a further approximately 500 L of AFFF concentrate used in emergency response associated with coal fires at the Coal Plant. It is noted that a number of events are reported to have been fully contained within on-site bunding and cleaned up by licenced contractors. Limited information was available for use of AFFF at the Callide A Power Station site. By comparison, the Oakey Army Aviation Centre is reported to have released approximately 1.2 million litres of AFFF concentrate over 25 years of operation (EPIC 2022a).

2.4 Geology and hydrogeology

The site is underlain by the Youlambie Conglomerates (formally known as the Rainbow Creek Beds), the Biloela Formation and the Lochenbar Formation (formally known as the Kroombit Creek Beds) comprised predominantly of andesitic rocks. The Youlambie Conglomerate also underlays Callide A, which is then underlain by the Lochenbar Formation which extends under the current Callide B and C stations including Ash Dam B (EPIC 2022a).

The Youlambie Conglomerates, the Biloela Formation, and the Lochenbar Formation are all overlain by Tertiary sediments in the southwest portion of the site grading into the Quaternary alluvium floodplain clays, silts, sands and gravels associated with Callide Creek (EPIC 2022a).

The Lochenbar Formation is highly fractured beneath the site, with a potential fault running north-south in line with the Callide Dam spillway. Dioritic dykes are likely associated with faulting. Dykes have been observed at more than 50 m width and have been noted as being deeply weathered (in excess of 22 m in MW27 on the western side of ADB) (EPIC 2022a).

The site is located in a broad shallow valley on the southern slopes of the Callide Range which rises to a height of 524 m Australian Height Datum (AHD) at Mt Murchison (peak approximately 3.5 km north of the site). The local topography has been highly modified by development including the power station sites, mining and installation of Callide Dam (EPIC 2022a).

Ground surface levels across the site fall in a south-westerly direction from approximately 280 m AHD in the north-eastern corner to 190 m AHD in the south-western corner. The topography on-site has been modified by development which includes levelled areas associated with site infrastructure, surface water management features including dam/bund walls and surface water channels and filled areas associated with the ash dams and evaporation cells (EPIC 2022a).

The elevation of the Ash Dam B spillway is reported to be 214.95 m AHD, with the base of the dam wall (external) approximately 200 m AHD. Ground surfaces immediately south of Ash Dam B drop steeply towards Callide Creek, located at approximately 180 m AHD (EPIC 2022a).

Surface water within the WCF drains to the DRD, located immediately west of Callide C Power Station, with overflow from the DRD directed to Ash Dam B via the eastern dirty drain (EDD), in the southern portion of the WCF. With the exception of Callide A Power Station and the immediate surrounds, all operational areas of the site are located within the WCF watershed catchment which includes Ash Dam B, DRD and the evaporation ponds (EPIC 2022a).

Stormwater diversion channels (western and eastern) are located around the external perimeter of the WCF to divert external catchment runoff around the WCF and into Callide Creek, south of the site (EPIC 2022a).

Seepage from Ash Dam B is reported to have been expected to occur, with the design including provision for seepage collection and management. A seepage collection trench has been installed between the external wall of Ash Dam B and the external stormwater diversion channels to intercept and control seepage. The channels direct seepage to two seepage collection ponds, from which seepage is returned to Ash Dam B (EPIC 2022a).

Ash Dam B is reported to have been constructed over 3 former drainage channels, with all 3 watercourses intersected by the wall of Ash Dam B. Surface waters from Ash Dams 1 and 2, located south-west and north-east of Callide A respectively, discharge to Dunn Creek via licenced discharge points (EPIC 2022a).

The principal aquifers (i.e. groundwater) identified on-site comprise:

- Tertiary and Quaternary alluvial sediments
- Weathered/fractured bedrock of the Lochenbar Formation under Callide A, B and C
- The Youlambie Conglomerate under the northeast corner of Callide A (EPIC 2022a)..

A former alluvial channel of Suicide Gully is suspected to be present at the southwestern portion of Ash Dam B, which will likely facilitate surface water infiltration in the area immediately southwest (down gradient) of the dam wall (EPIC 2022a).

Groundwater flow across the site is typically consistent with topography, with groundwater generally flowing from the northeast boundary down to the southwestern boundary of the site. Groundwater contours were assessed in July 2021. It is noted that seepage recovery wells are installed along the southern site boundary which locally influence groundwater flow within the seepage recovery area (EPIC 2022a).

The hydraulic conductivities for various geological materials have been adopted based on previous investigation by Aurecon (2011):

- Coal Ash: 0.0864 m/day
- Tertiary sediments: 2.2 m/day
- Fresh bedrock (bulk mass): 0.05 m/day
- Fractured bedrock: 10.25 m/day (EPIC 2022a).

Section 3. Introduction to PFAS

3.1 Exposure to chemicals in everyday life

The fundamental building blocks for the entire planet are chemical substances. The building blocks of all matter are the chemical elements like carbon or hydrogen or copper or gold. These elements combine to form chemical substances or compounds.

Whether it is the water we drink, the air we breathe, the food we eat, the ground we walk on, the houses we live in, the things we have inside our houses or workplaces or what we ourselves are made of, everything is made of chemicals.

Some chemical substances like water, oxygen and nutrients are essential to keeping us alive or to let plants or other animals live.

Other chemical substances are naturally occurring, but they can kill us – like spider and snake venoms or well-known poisons like arsenic or mercury.

The same applies to the chemical substances we manufacture – some substances are quite benign and some are quite toxic.

A range of chemical substances are used to manufacture things we use every day like food, clothes, computers, kitchen appliances, cars, houses, roads, trains, planes, hair dyes, beauty products, toothpaste, shampoo, flea rinse for our pets and many other things.

3.2 What are PFAS?

PFAS are a family of manufactured chemicals that contain the element fluorine. They have unique properties and make materials stain- and stick-resistant. Manufacturers have developed a host of compounds in this family to repel oil and water from clothing, carpeting, furniture, and food packaging such as pizza boxes and fast-food containers. Fire-fighting foams have used them, as have cleaners, paints, roof treatments, and hardwood floor protectant (USEPA 2017).

These chemicals are made up of a chain of carbon atoms that have fluorine atoms attached. They also commonly have an end group which carries a charge which allows them to be water soluble.

One of the uses of this family of chemicals was in aqueous film forming foams (AFFFs). These foams were used in firefighting particularly for hazardous liquid fires such as fuels (e.g. petrol, avgas). One of the main legacy AFFFs was 3M Lightwater (i.e. used historically). It contained PFOS and small amounts of other related chemicals that could break down in the environment over time into PFOS or PFHxS. AFFFs containing PFOS were manufactured between the 1960s and 2002. Other AFFFs that contained PFOA or chemicals that could break down into PFOA were manufactured between 1970s and 2016. The newer AFFFs currently in use for firefighting at airports etc are made from short chain PFAS or from chemicals that do not contain fluorine (i.e. use a different family of chemicals) (see AFFF Fact sheet at ITRC[1]).

The requirement to have firefighting foams on the Callide Power Station site (and at other sites upstream) in case of emergencies is likely to be the main reason PFAS are being reported here.

[1] https://pfas-1.itrcweb.org/fact-sheets/

Given this is the likely source, the PFAS most likely to be found at this site are those commonly included in the standard analytical suite provided by commercial laboratories in Australia.

The use of these chemicals in products used around the home (for purposes such as in food packaging or as waterproofing/stain proofing agents) may result in a wider range of these chemicals being present. When doing a risk assessment at a landfill or a wastewater treatment plant where such household products may be the driver for these chemicals, it will be important to consider the potential for a wider range of PFAS to be present including precursor chemicals (i.e. chemicals that can break down in the environment to key PFAS as discussed below).

3.3 Properties of PFAS

Many of the more common PFAS are extremely persistent, bioaccumulative and toxic (PBT). Unlike other compounds that have these characteristics (e.g. organochlorine pesticides, PCBs or dioxins) these compounds are also highly water soluble. In addition, they accumulate in blood rather than in fatty tissue (USEPA 2017).

Bioaccumulation is the term applied when a chemical accumulates inside an organism because the chemical is taken up by the organism faster than it can excrete or break down the chemical[2]. Chemicals that bioaccumulate are ones that are not easy to remove from the organism or they are difficult to break down into their component parts or both. Not all PFAS have this characteristic but some of the most common ones do.

The shorter chain PFAS – including PFBA, PFBS, PFPeA, PFPeS are not bioaccumulative but the key PFAS compounds (PFOS, PFOA, PFHxS) and other ones with longer carbon chains have high potential for bioaccumulation.

In addition, many of the PFAS precursor compounds break down to give PFOS or PFOA when released into the environment. Degradation stops at PFOS and PFOA because they are so persistent.

PFOS, PFHxS and PFOA are commonly found in the environment at higher concentrations than the rest of the commonly measured PFAS for a number of reasons including:

- PFOS, PFHxS and PFOA were the major components of PFAS products produced prior to 2000 – i.e. products were mostly 1 of these 3 key compounds with only minor amounts of other PFAS
- These were the chemicals that were manufactured in the highest volumes especially pre-2000
- PFOS, PFHxS and PFOA are the terminal break down products for many of the precursors.

The structure of these 3 compounds means they are chemically and biologically stable in the environment, resisting typical environmental degradation processes (like biodegradation, photolysis and hydrolysis) making them extremely persistent. These compounds are mobile in soil and leach into groundwater. They are more water soluble than lipid soluble. They do not readily volatilise

[2] https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=349938&Lab=CCTE

(evaporate) from soil or water. These compounds are not found in the environment from natural sources, only from anthropogenic sources (ATSDR 2015, 2018, 2021).

Their water solubility and persistence mean they last a long time and they can easily move away from the areas where they were used. During rain they wash out of the soil into stormwater as it runs off overland toward surface waters. They also wash out of the soil into soil water that percolates down through the soil profile and into groundwater. They also move easily with the groundwater as it travels away from a site toward surface water.

PFOS is a sulfonic acid. Manufacture of PFOS was phased out in 2000-2002. A variety of PFAS compounds break down to PFOS in the environment and it has been found to be widespread in the environment (COT 2006a).

PFOA is carboxylic acid. It has been used as an emulsifier in the production of fluoropolymers like Teflon (polytetrafluoroethylene). (COT 2006b).

3.4 Types of PFAS analysis

There are 3 commercially available methods that can be used for the laboratory analysis of PFAS – standard analysis, total oxidisable precursors (TOP) assay analysis and total organic fluorine (TOF) analysis.

There are some differences between the 3 methods, in relation to:

- status of method development
- type and reproducibility of the data obtained
- information that is provided by the analysis
- whether there are any Australian guidelines for the analysis results.

Hence, not all PFAS analysis results can be considered equal and further discussion is presented in **Appendix A**.

It is noted that the environmental guidelines presented in the PFAS NEMP are based on results from the standard analysis. The guidelines in the PFAS NEMP are those usually relied on by environmental regulators. There are no guidelines available in Australia or internationally for the results of TOP assay or TOF analysis.

When a chemical is detected in our environment (e.g. in drinking water or a waterway) that does not necessarily mean that the chemical poses a health or environmental risk. There needs to be a high enough concentration for there to be a risk. This is clearly supported by the fact that national guidelines have been developed by governments to indicate what concentrations of a chemical can be in soil or water without concern.

Australia has guidelines for drinking water, recreational water, recycled water, air, soil based on human health protection and ecosystem protection guidelines for water and soil (ANZG 2018; HEPA 2020; NEPC 1999 amended 2013c, 2021; NHMRC 2008, 2011 updated 2022, 2019; NRMMC 2006, 2008, 2009a, 2009b). These national guidelines allow us to determine whether a chemical present in water or soil or air might pose a risk to people or the environment. The guidelines indicate that no further action is required if the concentration found is low enough (i.e. below the guideline). Further investigation might be required if the concentration reported is higher than the relevant guideline value.

The Australian chemical management system focuses on key chemicals where the potential for toxicity to human health and the environment has been identified.

For example, there are more than 100 different polycyclic aromatic hydrocarbons (PAHs) (ATSDR 1995). In Australia, we commonly analyse for only 16 of this group of chemicals (called the priority PAHs). The national government guidelines are focused on these 16. Focusing on the key ones allows us to manage the presence of this whole group of chemicals appropriately.

A similar approach has been adopted in the PFAS NEMP for PFAS. The 3 key chemicals in this family – PFOS, PFHxS and PFOA – are the focus of all of the guidelines in Australia. Understanding the concentrations of these 3 PFAS in a sample allows management of the whole group.

Section 4. Nature and extent of PFAS contamination in the off-site area

4.1 General

Initial investigations completed at the site in 2019 targeted existing on-site and off-site environmental monitoring locations (i.e. monitoring wells), with the investigation expanded during 2020 and 2021 to include sampling of private groundwater supply bores at properties up to 12 km downstream of the site. Monitoring at both monitoring wells and groundwater supply bores has continued through to 2024 and has been undertaken by EPIC Environmental (EPIC 2020, 2021, 2022a&b, 2023, 2024).

Groundwater sampled at monitoring wells and supply bores reporting concentrations above the Australian Drinking Water Guideline (0.07 µg/L) (for sum of PFOS and PFHxS) have been identified on-site and off-site (PFOS+PFHxS up to 33.5 µg/L (on-site) and 6.59 µg/L (off-site)) (based on adding maximum PFOS and maximum PFHxS concentrations regardless of well/bore).

Surface water samples collected on and off-site have also reported concentrations above the Australian Drinking Water Guideline (PFOS+PFHxS up to 0.595 µg/L (on-site) and 0.187 µg/L (off-site)) (based on adding maximum PFOS and maximum PFHxS concentrations regardless of location).

In addition, Hydrobiology has undertaken biota sampling along Callide Creek and from Lake Callide and Lake Kroombit.

The data from the groundwater and surface water sampling in the off-site area and the biota data have been used in this assessment.

An assessment of data quality assurance and quality control was undertaken and presented in the various reports of the work prepared by the consultants (EPIC 2020, 2021, 2022a&b, 2024 and Hydrobiology 2023 and related data tables). These evaluations identified that the data were of suitable quality for interpretation and these data have been relied on for this assessment.

4.2 Groundwater

Groundwater has been sampled at more than 150 locations both on and off the Callide Power Station site. The sampling locations include the CS Energy monitoring network (monitoring wells), QLD Department of Resources monitoring wells and groundwater supply bores on individual properties in the downgradient area. This assessment focuses on the off-site area so only those sampling locations located off the power station site have been considered here.

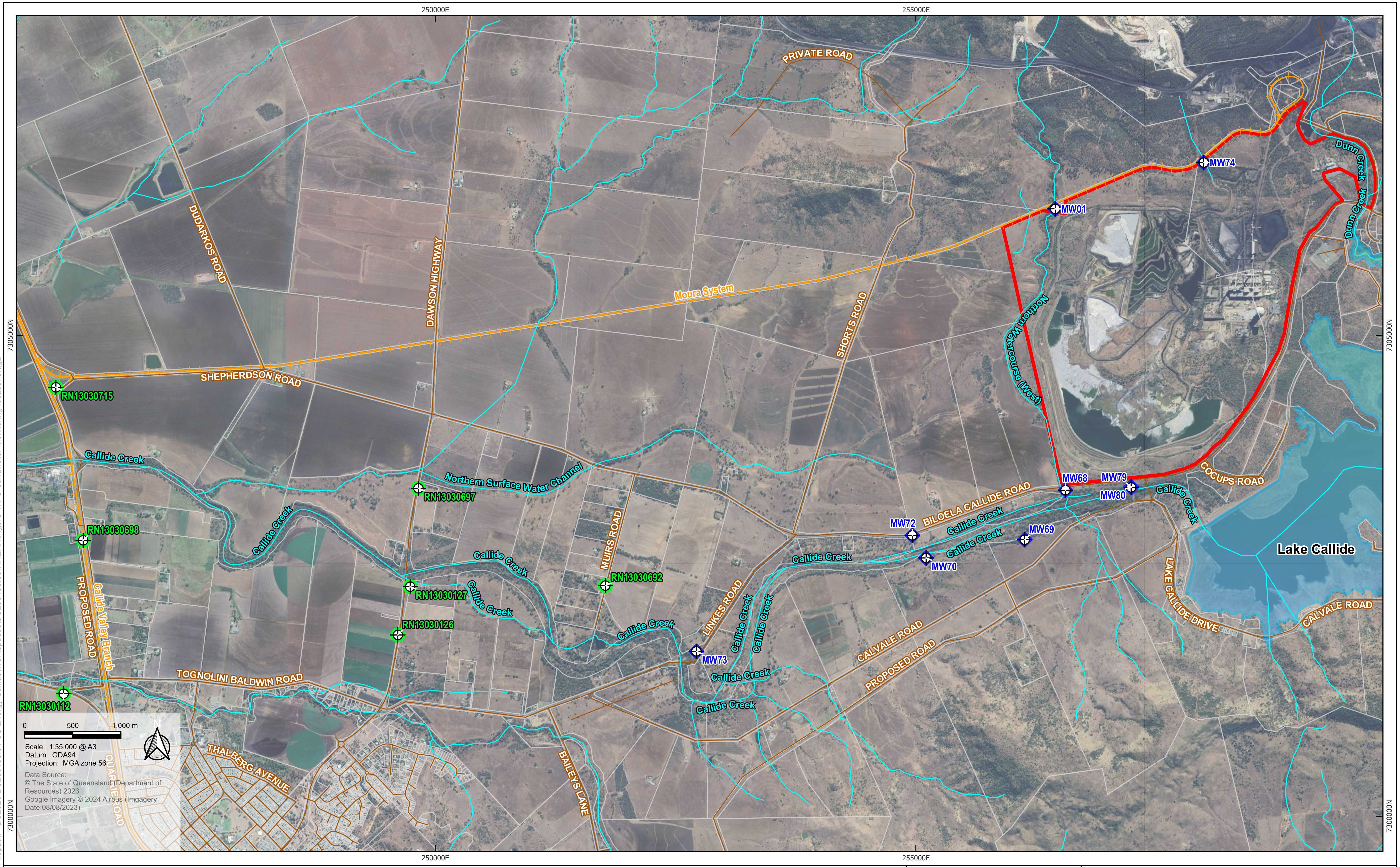
The groundwater sampling locations are shown on **Figure 4.1** and a summary of the data for these locations is provided in **Appendix B**. Maximum concentrations for individual PFAS at locations upgradient of the power station site are provided in **Table 4.1**. Maximum concentrations for individual PFAS at locations downgradient of the power station site are provided in **Table 4.2**.

The sampling locations relevant for the off-site area upgradient of the site include MW01 and MW74 (i.e. monitoring wells). It is noted that MW74 is actually located on the power station site but it is only just within the site boundary on the upgradient side of the site so is considered to be representative of the nature of groundwater coming onto the power station site.

The sampling locations relevant for the off-site area downgradient of the site include MW68, MW69, MW70, MW72, MW73, MW79, MW80, RN13030692, RN13030126, RN13030127, RN13030697, RN13030698, RN13030715 and RN13030112.

Groundwater sampling of the monitoring wells (i.e. CS Energy monitoring network and QLD Department of Resources monitoring wells) occurred in November 2020, February and October 2021, January, March/April, July and October/November 2022 and January, March, June, September and December 2023 (i.e. up to 12 rounds for some locations) (i.e. data used to respond to the EE issued by DESI). Not all locations were sampled on all occasions.

Results for the groundwater supply bores are discussed in the refined assessment later in this report.



Legend

- Callide power station - site boundary
- Lake Callide
- Cadastre (DCDB)
- Watercourses
- Roads and tracks
- Railways
- CS Energy bore
- DRDMW bore
- Groundwater investigation locations (Quarterly scope)

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PFAS investigation (Callide Power Station)
Human Health and Ecological Risk Assessment

Figure 4.1
Groundwater monitoring locations

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Table 4.1: Maximum groundwater concentrations at each off-site sampling location – upgradient

Location	Maximum Concentration (µg/L)														
	PFOS	PFHxS	PFBS	PFPeS	PFBA	PFPeA	PFHxA	PFHpS	PFDoDA	PFHpA	PFOA	PFNA	6:2FTS	PFDA	8:2FTS
MW01	ND	ND	ND	ND	ND	0.012	0.0140	ND	ND	0.0019	ND	ND	0.04	ND	ND
MW74^	**0.024**	**0.364**	**0.2170**	**0.15**	**0.9540**	**2.24**	**0.9260**	**0.0063**	ND	**0.18**	**0.0175**	**0.0007**	**0.05**	ND	ND

Notes:
Bolded – highest of maximum concentrations
^ groundwater well on the upgradient side of the Callide power station site just at the boundary – considered representative of groundwater quality arriving at the site

Table 4.2: Maximum groundwater concentrations at each off-site sampling location – downgradient

Location	Maximum Concentration (µg/L)														
	PFOS	PFHxS	PFBS	PFPeS	PFBA	PFPeA	PFHxA	PFHpS	PFDoDA	PFHpA	PFOA	PFNA	6:2FTS	PFDA	8:2FTS
MW68	**0.4590**	**0.367**	**0.0767**	**0.06**	0.02	**0.017**	**0.1320**	**0.0158**	ND	**0.0032**	**0.0105**	ND	0.042	ND	**0.03**
MW69	0.0944	0.0173	0.0024	0.0017	0.0187	0.014	0.095	0.001	ND	ND	ND	ND	0.009	ND	ND
MW70	0.3	0.0172	0.0019	0.0011	0.025	0.015	0.048	0.0012	ND	ND	ND	ND	0.003	ND	ND
MW72	0.0113	0.0089	0.0011	0.0012	ND	ND	0.006	ND	ND	ND	ND	ND	0.001	ND	ND
MW73	0.1840	0.0784	0.0074	0.0099	ND	ND	0.02	0.006	ND	ND	ND	ND	0.009	ND	ND
MW79	0.062	0.0378	0.0163	0.0086	ND	0.0053	0.016	0.0025	ND	0.0012	0.0012	ND	0.113	ND	ND
MW80	0.115	0.059	0.0116	0.0089	**0.048**	0.004	0.004	0.0006	ND	ND	ND	ND	0.02	ND	ND
RN13030692	0.0308	0.0085	0.0039	0.0006	ND	ND	ND	ND	ND	ND	ND	ND	0.004	ND	ND
RN13030126	0.0119	0.0137	0.0013	0.0014	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND
RN13030127	0.0163	0.0616	0.0414	0.0072	ND	ND	0.0011	0.0011	ND	ND	0.0009	ND	0.096	ND	ND
RN13030697	0.098	0.204	0.0123	0.0255	ND	0.0066	0.006	0.0042	ND	0.0007	0.0017	ND	**0.3140**	ND	ND
RN13030698	0.008	0.0436	0.0045	0.005	ND	ND	ND	0.0007	ND	ND	ND	ND	0.012	ND	ND
RN13030715	0.0041	0.0048	0.0021	0.001	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND
RN13030112	ND	0.0259	0.0046	0.005	ND	ND	ND	ND	ND	ND	0.0019	ND	0.006	ND	ND

Notes:
Bolded – highest of maximum concentrations

4.3 Surface water

Surface water has been sampled at around 50 locations both on and off the Callide Power Station site. This assessment focuses on the off-site area so only those sampling locations off the power station site will be considered here.

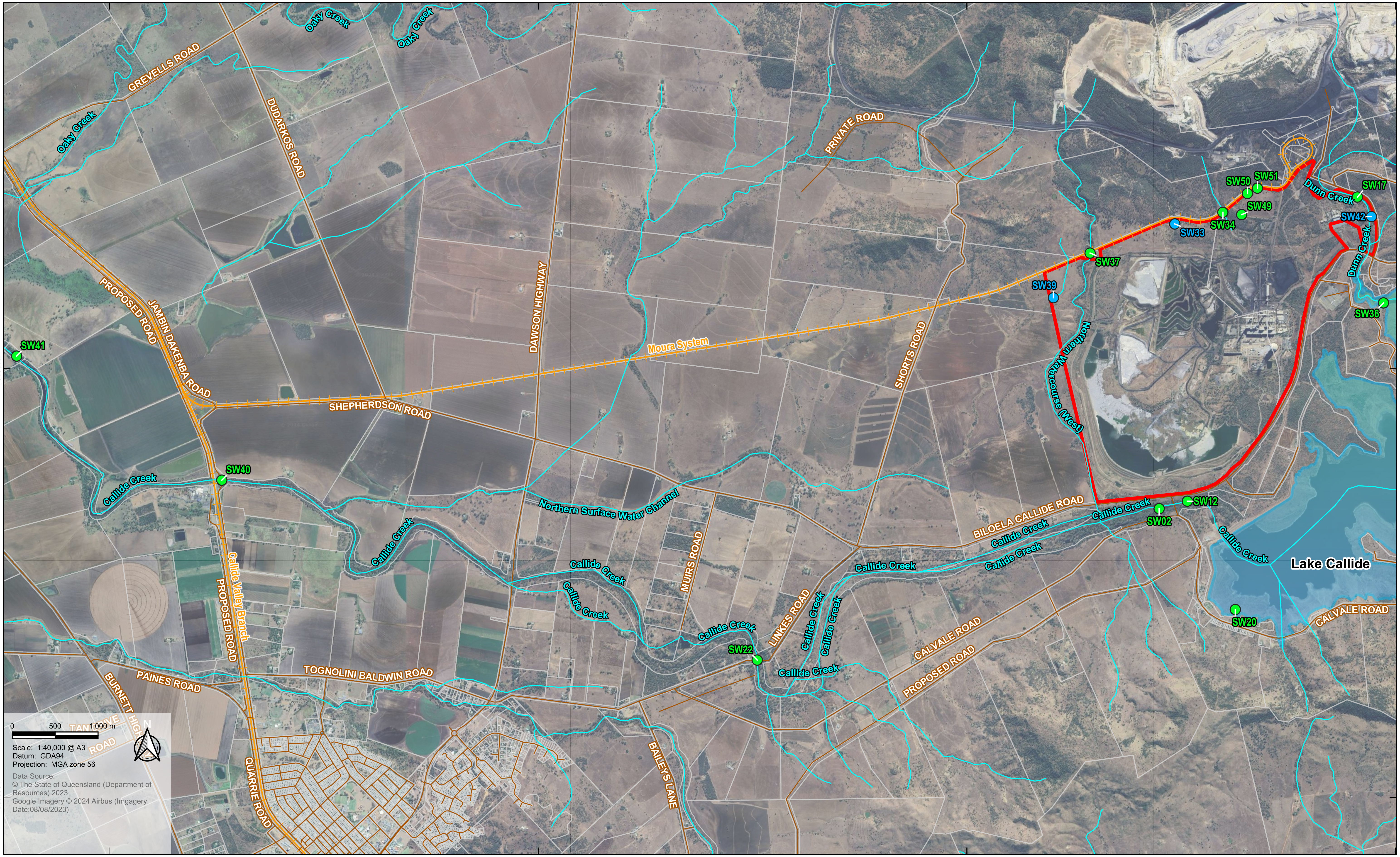
The surface water sampling locations are shown on **Figure 4.2** and a summary of the data for all these locations is provided in **Appendix B**. Maximum concentrations for individual PFAS at locations upstream of the power station site are provided in **Table 4.3**. Maximum concentrations for individual PFAS at locations downstream of the power station site are provided in **Table 4.4**.

The sampling locations relevant for the off-site area upgradient of the site include SW17, SW33, SW34, SW37, SW39, SW50 and SW51.

The sampling locations relevant for the off-site area downgradient of the site include:

- Dunn Creek: SW20, SW36, SW42
- Callide Creek: SW02, SW12, SW22, SW40 and SW41.

Surface water sampling occurred in November 2020, January, April/May, October and December 2021, January, March, July and October 2022 and February, June and December 2023 (i.e. up to 12 rounds for some locations). Not all locations have been sampled on all occasions.



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Legend

- Callide power station - site boundary
- Lake Callide
- Cadastre (DCDB)
- Railways
- Roads and tracks
- Watercourses
- Surface water investigation locations (Quarterly scope)
- Previous surface water investigation locations

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Figure 4.2
Surface water monitoring locations

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Table 4.3: Maximum surface water concentrations at each off-site sampling location – upstream

Location	Maximum Concentration (µg/L)														
	PFOS	PFHxS	PFBS	PFPeS	PFBA	PFPeA	PFHxA	PFHpS	PFDoDA	PFHpA	PFOA	PFNA	6:2FTS	PFDA	8:2FTS
SW17	0.0185	0.0328	0.0152	0.0072	0.0065	0.0308	0.0171	ND	ND	0.0085	0.0035	0.0008	ND	ND	ND
SW33	0.0144	0.0152	0.0035	ND	0.037	0.0981	0.0320	ND	ND	ND	0.0077	ND	ND	ND	ND
SW34	0.1950	0.25	**0.1880**	**0.0528**	**0.8190**	**3.02**	**1.38**	0.0143	ND	**0.706**	**0.0984**	**0.0189**	**0.24**	**0.0013**	**0.013**
SW37	ND	ND	ND	ND	ND	0.0056	0.0046	ND	ND	0.0019	ND	ND	ND	ND	ND
SW39	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW50	**0.303**	**0.294**	0.0726	0.0517	0.152	0.573	0.317	**0.0214**	ND	0.144	0.0672	0.0112	0.045	ND	ND
SW51	ND	ND	ND	ND	0.0059	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:
Bolded – highest of maximum concentrations

Table 4.4: Maximum surface water concentrations at each off-site sampling location – downstream

Location	Maximum Concentration (µg/L)														
	PFOS	PFHxS	PFBS	PFPeS	PFBA	PFPeA	PFHxA	PFHpS	PFDoDA	PFHpA	PFOA	PFNA	6:2FTS	PFDA	8:2FTS
Callide Creek															
SW02	0.0059	0.0134	0.003	0.0018	0.0046	0.002	0.0005	ND	ND	ND	ND	ND	ND	ND	ND
SW12	0.0181	**0.0594**	**0.0111**	**0.0113**	ND	0.002	0.0038	**0.0019**	**0.0011**	ND	ND	ND	ND	ND	ND
SW22	0.0195	0.0187	0.0048	0.0019	ND	0.0022	ND	ND	ND	ND	ND	ND	0.002	ND	ND
SW40	**0.0606**	0.0281	0.0082	0.0025	ND	ND	ND	0.0014	ND	ND	ND	ND	ND	ND	ND
SW41	0.0339	0.023	0.0047	0.0022	ND	0.0046	ND	0.0011	ND	ND	ND	ND	ND	ND	ND
Dunn Creek															
SW20	ND	ND	0.0029	ND	ND	0.002	0.003	ND	ND	ND	ND	ND	**0.01**	ND	ND
SW36	ND	ND	0.0295	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW42	0.018	0.0242	0.0104	0.0046	**0.022**	**0.0265**	**0.0138**	ND	ND	**0.0052**	**0.002**	ND	ND	ND	ND

Notes:
Bolded – highest of maximum concentrations

4.4 Biota

Hydrobiology undertook sampling of biota in the local waterways in February 2023 (Hydrobiology 2023). Samples were collected from Callide Creek up and downstream of the power station and within Lake Callide and Lake Kroombit. These consultants also looked at the quality of the habitat in these waterways. Sampling locations are shown in **Figure 4.3**.

The habitat quality in these waterways was largely classified as good to excellent with good bank stability based on national guidance. It is noted though that many parts of Callide Creek are ephemeral waterways so won't always have sufficient water to support ecosystems. Water quality characteristics such as pH, electrical conductivity and dissolved oxygen were also collected. The dissolved oxygen levels were quite low at most locations based on low flow through the creek during 2022 (Hydrobiology 2023).

Tissue analysis for PFAS was undertaken for fish that might be consumed by people and fish and other species that may be consumed by birds and mammals.

The species that were considered relevant for consumption by people included:

- Barramundi *Lates calcarifer* (listed in SAQP) (collected at AB2 and AB3)
- Crayfish *Cherax quadricarinatus* (listed in SAQP) (collected at AB1, AB2 and AB3)
- Yellowbelly *Macquaria ambigua* (listed in SAQP) (collected at AB1 and AB8)
- Eeltail catfish *Tandanus tandanus* (additional species identified during sampling) (collected at AB9, AB1 and AB4)
- Hyrtl's catfish *Neosilurius hyrtlii* (additional species identified during sampling) (collected at AB9, AB1 and AB8)
- Rendahl's catfish *Porochius rendahli* (additional species identified during sampling) (collected at AB1, AB4 and AB5)
- Sleepy cod *Oxyeleotris lineolata* (additional species identified during sampling) (collected at AB1 and AB4).

The species that were considered relevant for consumption by birds or mammals included:

- Eeltail catfish *Tandanus tandanus* (listed in SAQP) (none collected)
- Eastern rainbowfish *Melanotaenia splendida* (listed in SAQP) (none collected)
- Freshwater mussels *Velesunio* sp. (listed in SAQP) (none collected)
- Spangled perch *Leiopotherapon unicolour* (listed in SAQP) (none collected)
- Freshwater prawn *Macrobrachium* sp. (listed in SAQP) (collected at AB9, AB1, AB2 and AB3)
- Agassiz's perchlet *Ambassis agassizii* (additional species identified during sampling) (collected at AB9, AB1, AB3, AB4, AB5, AB7 and AB8)
- Fly specked hardyhead *Craterocephalus stercusmuscarum* (additional species identified during sampling) (collected at AB1, AB2, AB3, AB4, AB7 and AB8)
- Freshwater shrimp Atyidae sp. (additional species identified during sampling) (collected at AB4 and AB7).

The results for these samples are listed in **Tables 4.5** (human health relevant species) and **4.6** (ecological relevant species).

A total of 42 samples were analysed – 23 samples for human health relevant species and 19 samples for ecological relevant species.

Of the 23 human health related samples, only 5 samples had detections for PFOS. Only 1 sample had a detection for PFHxS (at the limit of reporting) – i.e. around 20% of samples had PFOS/PFHxS.

Of the 19 ecosystem related samples, only 8 samples had detections for PFOS and this was the only PFAS reported in any of these samples – i.e. around 40% of samples.

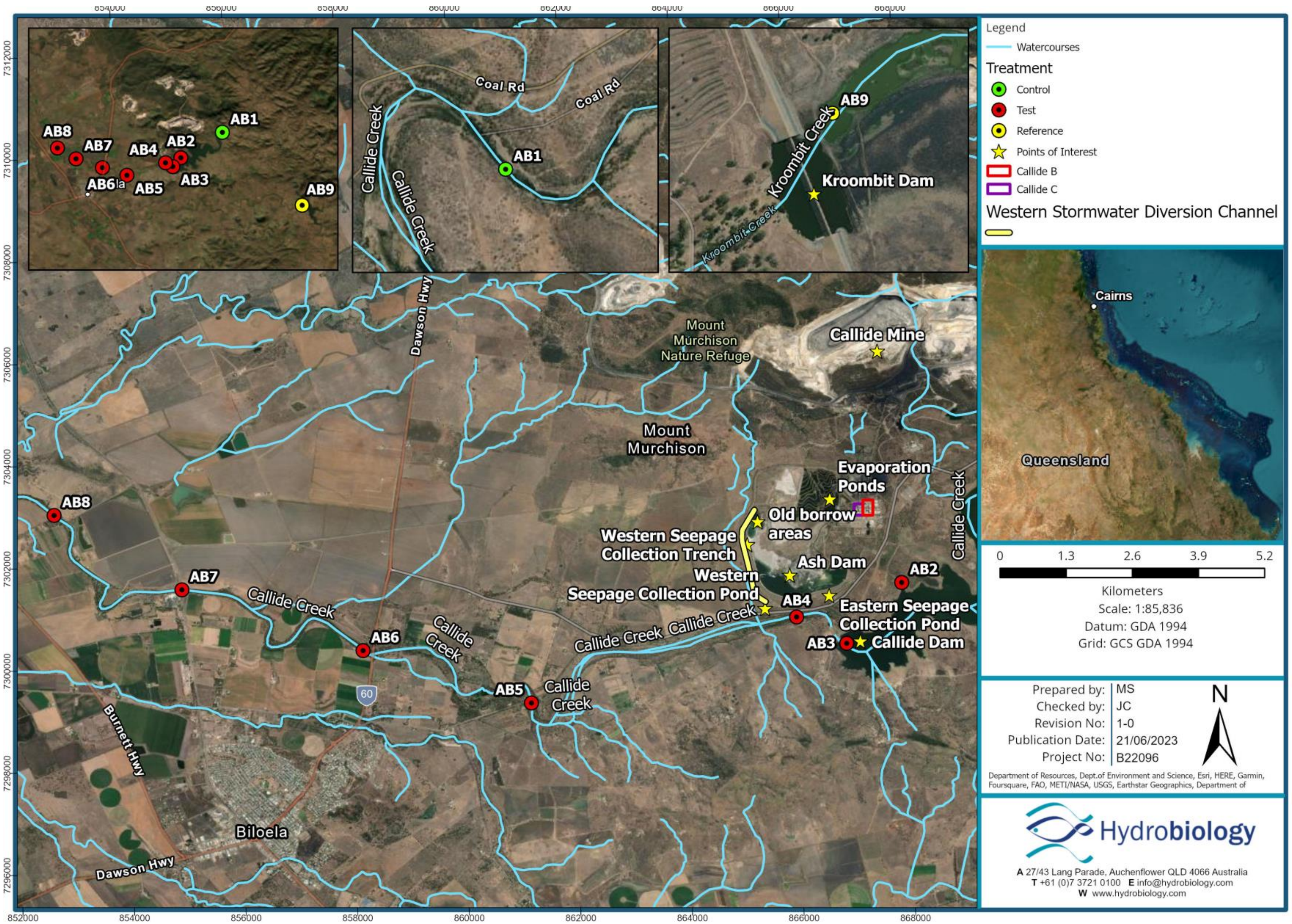


Figure 4.3 Monitoring sites with watercourses, infrastructure and other points of interest

Table 4.5: Results summary PFAS tissue concentrations (µg/kg) – human health relevant

Location	Barramundi	Crayfish	Yellowbelly	Eeltail catfish	Hyrtl's catfish	Rendahl's catfish	Sleepy cod
AB1	None caught	No PFAS detected	No PFAS detected (3 samples)	No PFAS detected	No PFAS detected	2 µg/kg PFOS only	No PFAS detected
AB2	No PFAS detected	No PFAS detected (2 samples)	None caught	No PFAS detected	None caught	None caught	None caught
AB3	No PFAS detected	No PFAS detected	None caught	None caught	None caught	None caught	None caught
AB4	None caught	None caught	None caught	4 µg/kg PFOS 1 µg/kg PFHxS	None caught	16 µg/kg PFOS only	1 µg/kg PFOS only
AB5	None caught	None caught	None caught	None caught	None caught	44 µg/kg PFOS only	
AB7	None caught	None caught	None caught	None caught	None caught	None caught	None caught
AB8	None caught	None caught	5-6 µg/kg PFOS only (2 samples)	None caught	8 µg/kg PFOS only	None caught	None caught
AB9	None caught	None caught	None caught	No PFAS detected	No PFAS detected (3 samples)	None caught	None caught

Table 4.6: Results summary PFAS tissue concentrations (µg/kg) – ecosystem relevant

Location	Agassiz's perchlet	Fly specked hardyhead	Freshwater prawn	Freshwater shrimp
AB1	No PFAS detected	No PFAS detected	No PFAS detected	None caught
AB2	None caught	No PFAS detected	No PFAS detected	None caught
AB3	No PFAS detected	No PFAS detected	No PFAS detected	None caught
AB4	10 µg/kg PFOS only	No PFAS detected	None caught	3 µg/kg PFOS only
AB5	40 µg/kg PFOS only	None caught	None caught	None caught
AB7	84 µg/kg PFOS only	40 µg/kg PFOS only	None caught	31 µg/kg PFOS only
AB8	89 µg/kg PFOS only	68 µg/kg PFOS only	None caught	None caught
AB9	None caught	None caught	No PFAS detected	None caught

For the human health relevant species, the results indicate that:

- Barramundi and crayfish reported no detections for any PFAS above the limit of reporting at any location.
- Most other species reported detections for PFOS in the range 1-5 µg/kg. These results are in compliance with the FSANZ trigger value – i.e. 5.2 µg/kg.
- Rendahl's catfish reported higher concentrations above the FSANZ trigger value in a number of locations (AB4 and AB5).
- Rendahl's catfish reported a detection for PFOS at a location upstream of the Callide Power Station (i.e. AB1).
- A single sample of Hyrtl's catfish reported a concentration slightly above the FSANZ trigger value at AB8 – likely within sampling and measurement uncertainty.

For the ecological relevant species, the results indicate that:

- None of these species reported PFOS detections at AB1 (i.e. upstream of Callide Power Station).
- Agassiz's perchlet reported detections of PFOS at AB4, AB5, AB7 and AB8 with concentrations increasing going downstream.
- Fly specked hardyhead reported detections of PFOS at AB7 and AB8 only.
- Freshwater prawns reported no detections at all for any PFAS at any location.
- Freshwater shrimp reported detections for PFOS at AB4 and AB7 – the only locations where this species could be collected.
- Concentrations at AB8 for all species ranged between non-detect and 89 µg/kg.

4.5 Uncertainties

The sampling and analysis of environmental media from any site results in some level of error that is inherent in the data reported. In addition, sampling involves the collection of samples from discrete locations and inferring the level of contamination between these sampling points. The actual concentration between the sample points cannot be guaranteed.

This HHERA has considered the available site assessment data on face value and assumed that the data are representative of the PFAS contamination at the site and in the off-site area and are suitable for interpretative use.

Section 5. Ambient/background PFAS

5.1 General

These chemicals are commonly present in soil and water throughout Australia (especially urban areas) due to the nature of these chemicals, the ways they have been used, their use in common household products as well as for industrial purposes from the 1940s and the lack of analytical procedures until the early 2000s.

While they are a group of chemicals that do not naturally exist in the environment, they are widespread in our environment at low levels.

Therefore, it is important to understand what sort of concentrations might be found in water in areas where there are no major sources of PFAS – i.e. the ambient/background concentrations.

Concentrations for PFOS in surface water and groundwater in urban areas are mostly within the range of 0.01 to 0.05 µg/L where there is no specific contamination source such as an airport or defence base. This range has been based on studies from Victoria, NSW, Western Australia and Queensland. The studies used are those designed to measure levels in normal urban areas.

The PFAS present in urban waterways come from a range of diffuse and point sources including, for example:

- runoff from around homes where products containing these chemicals have been used (waterproof clothing, furniture etc)
- leaks from sewage collection systems
- discharges from sewage treatment plants
- discharges/runoff from landfills
- use of recycled water for irrigation
- emissions/runoff from contaminated sites upstream of a location of interest.

A range of studies have been undertaken in Australia specifically looking at ambient levels of these chemicals (Allinson et al. 2019; Baddiley et al. 2020; Coggan et al. 2019; Richmond 2022; Sardiña et al. 2019; Sharp et al. 2021; Szabo et al. 2018; Thompson et al. 2011).

These studies indicate that these chemicals are routinely detected in urban surface waters but may only be occasionally present in water away from urban areas (i.e. more remote areas). They also indicate that a wide range of PFAS may be found in urban waters.

The following summaries indicate the investigations that have been undertaken in various jurisdictions in Australia to determine PFAS concentrations found in the general environment. Data are available for a larger study in Queensland. Those results are supported by data from studies in Victoria, NSW and Western Australia.

5.2 Queensland

The largest study of ambient PFAS concentrations in surface waters, sediments and fish (and other aquatic biota) in Australia has been undertaken in Queensland by the Department of Environment, Science and Innovation. The goal of this work was to establish an understanding of baseline/ambient levels of PFAS in surface waters across Queensland (Baddiley et al. 2020).

Samples were collected at 55 locations along the Queensland coast on 6 occasions over a 1 year period (May 2019 – March 2020) (Baddiley et al. 2020).

PFOS concentrations throughout Southeast Queensland ranged up to 0.017 µg/L.

Sampling was also undertaken in the Calliope River, Fitzroy River, Auckland Creek and Boyne River. These waterways are in the area closer to the Callide Power Station. The only PFAS detected in these water samples was PFOS. The PFOS concentrations ranged from <0.0001 to 0.0005 µg/L – i.e. generally lower than the values in southeast Queensland which is in line with a lower level of urbanisation in this region (Baddiley et al. 2020).

5.3 Victoria

Victorian studies of PFAS concentrations in surface waters have included sampling in freshwaters, estuarine areas and in rivers and streams in urban and agricultural areas.

PFOS concentrations ranged:

- up to 0.0452 µg/L in a study of a number of freshwater locations
- up to 0.0749 µg/L in some estuarine locations
- up to 0.1 µg/L in a larger study on rivers and streams in urban or agricultural areas (Allinson et al. 2019; Baddiley et al. 2020; Sardiña et al. 2019).

Many of the PFAS that were detected in these samples were detected in 100% of the samples – i.e. every sample on every occasion.

A wide range of other PFAS were also reported in these studies with concentrations ranging up to 0.04 µg/L for each individual chemicals (Allinson et al. 2019; Baddiley et al. 2020; Sardiña et al. 2019).

5.4 NSW

Levels of PFAS have been measured in surface waters collected in Homebush Bay/Parramatta River (i.e within Sydney Harbour). PFOS concentrations ranged up to 0.021 µg/L. Other PFAS were detected in these samples with concentrations ranging up to 0.0064 µg/L for individual chemicals (Baddiley et al. 2020; Thompson et al. 2011).

5.5 Western Australia

Data are also available for ambient levels of PFAS in the Perth Metropolitan Area (Richmond 2022). PFOS concentrations ranged up to 0.044 µg/L in surface waters and 0.03 µg/L in groundwater. PFOA concentrations ranged up to 0.038 µg/L in surface waters and 0.034 µg/L in groundwater.

Section 6. Summary of conceptual site model (CSM)

Investigations undertaken at the Callide Power Station have detected some PFAS compounds in surface water from upstream of the site, within the site and downstream of the site in Callide Creek. These investigations also found groundwater had detectable concentrations of some PFAS compounds upgradient of the site, within the site and downgradient of the site – the main aquifer that is sourced by local landowners.

These chemicals are likely to be present in these environments due to their historical use in AFFFs at the Callide Power Station. They are also likely to be present due to activities at sites upgradient of the power station site including the coal mine where AFFFs are also likely to have been used. They may also be present due to the use of products containing these chemicals around people's homes (e.g. food packaging, water proofed equipment, stain proofed furniture etc).

The PFAS commonly present in older AFFFs such as 3M Lightwater or Ansulite products are PFOS/PFHxS or PFOA. It is assumed that historical use of AFFFs would be the main source of these chemicals at the upgradient locations and at Callide Power Station.

The mix of PFAS present, particularly upgradient of the Callide Power Station, is dominated by short chain carboxylic acids like PFBA, PFPeA and PFHxA which may reflect the use of more modern AFFFs or products other than AFFFs.

As discussed in **Section 5**, PFAS can also be present in urban waterways from a range of diffuse and point sources including, for example:

- runoff from around homes where products containing these chemicals have been used (waterproof clothing, furniture etc)
- leaks from sewage collection systems
- discharges from sewage treatment plants
- discharges/runoff from landfills
- use of recycled water for irrigation
- emissions/runoff from contaminated sites upstream of a location of interest.

This HHERA has focused on the assessment/interpretation of the data collected in the area downgradient of Callide Power Station.

The area is primarily rural and not heavily urbanised so it is assumed that the use of AFFFs at the industrial sites in the area would be the main source of these chemicals to this environment. This is supported by the findings of the DESI investigation of ambient levels of PFAS in waterways in QLD (Baddiley et al. 2020) which found ambient PFOS concentrations in other waterways around this region in the range <0.0001 to 0.0005 µg/L.

Figures 6.1 and **6.2** illustrate the conceptual site model for groundwater and surface water respectively. These figures show how it is expected that the PFAS could move from the power station site (or from sites upgradient of the power station) into the environment (groundwater and surface water) downgradient – the area where people live and/or undertake agricultural activities.

The following groups have been identified as present in the area downgradient of the power station:

People

- Residents who access groundwater or surface water or consume home grown produce
- Farmers who access groundwater or surface water or consume home grown produce

Ecosystems

- Aquatic organisms within Callide Creek
- Terrestrial organisms in the off-site area

Pathways

Ecosystems or people need to be exposed to a chemical before that chemical can cause any effects. Exposure pathways describe how a chemical that is present in water or soil or air at a site could reach a person or organisms.

The pathway by which people are most likely to be exposed to PFAS in water or soil is when they eat or drink the water or soil or foods grown in that soil or water – i.e. ingestion.

Other pathways that may be important for some chemicals include:

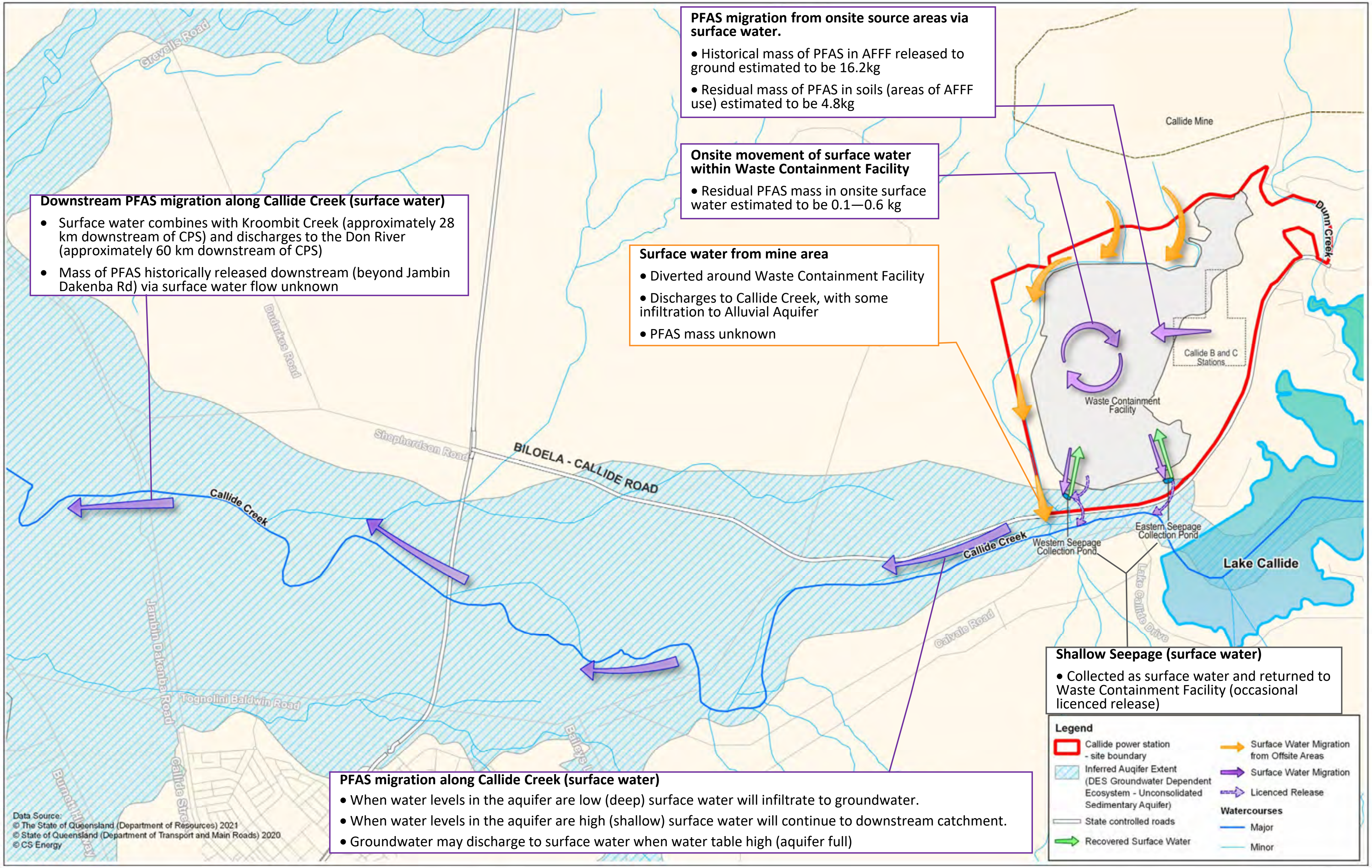
- absorption through the skin
- inhalation of the chemical when it is present in air.

These 2 pathways are considered minor for PFAS because:

- when key PFAS such as PFOS, PFOA are present in natural waters (like Callide Creek) they are present as negatively charged ions (ATSDR 2021) – chemicals in this form do not easily cross the skin to be absorbed into the body
- the key PFAS have low vapour pressure and are highly water soluble, so they do not evaporate from water or soil into the air (ATSDR 2021) – if they do not evaporate into the air, the potential to inhale them is negligible.

As a result, the exposure pathways important for this assessment are:

- use of groundwater for drinking (includes all uses of water around the home – e.g. drinking, cooking, showering, cleaning, backyard garden irrigation)
- incidental ingestion of groundwater or surface water during use of water for farming purposes (i.e. small amounts swallowed from splashes or from wet hands touching the mouth)
- incidental ingestion of groundwater or surface water during other domestic uses of water (e.g. filling pools, sprinkler play etc) (i.e. small amounts swallowed from splashes or from wet hands touching the mouth)
- consumption of home grown fruit/vegetables which were irrigated with groundwater or surface water in the area downgradient of Callide Power Station
- consumption of home grown eggs, milk or meat from livestock that may have drunk groundwater or surface water in the area downgradient of Callide Power Station
- consumption of fish/seafood that lived in Callide Creek.



0 500 1,000 1,500 2,000 m

Scale: 1: 38,000@A3

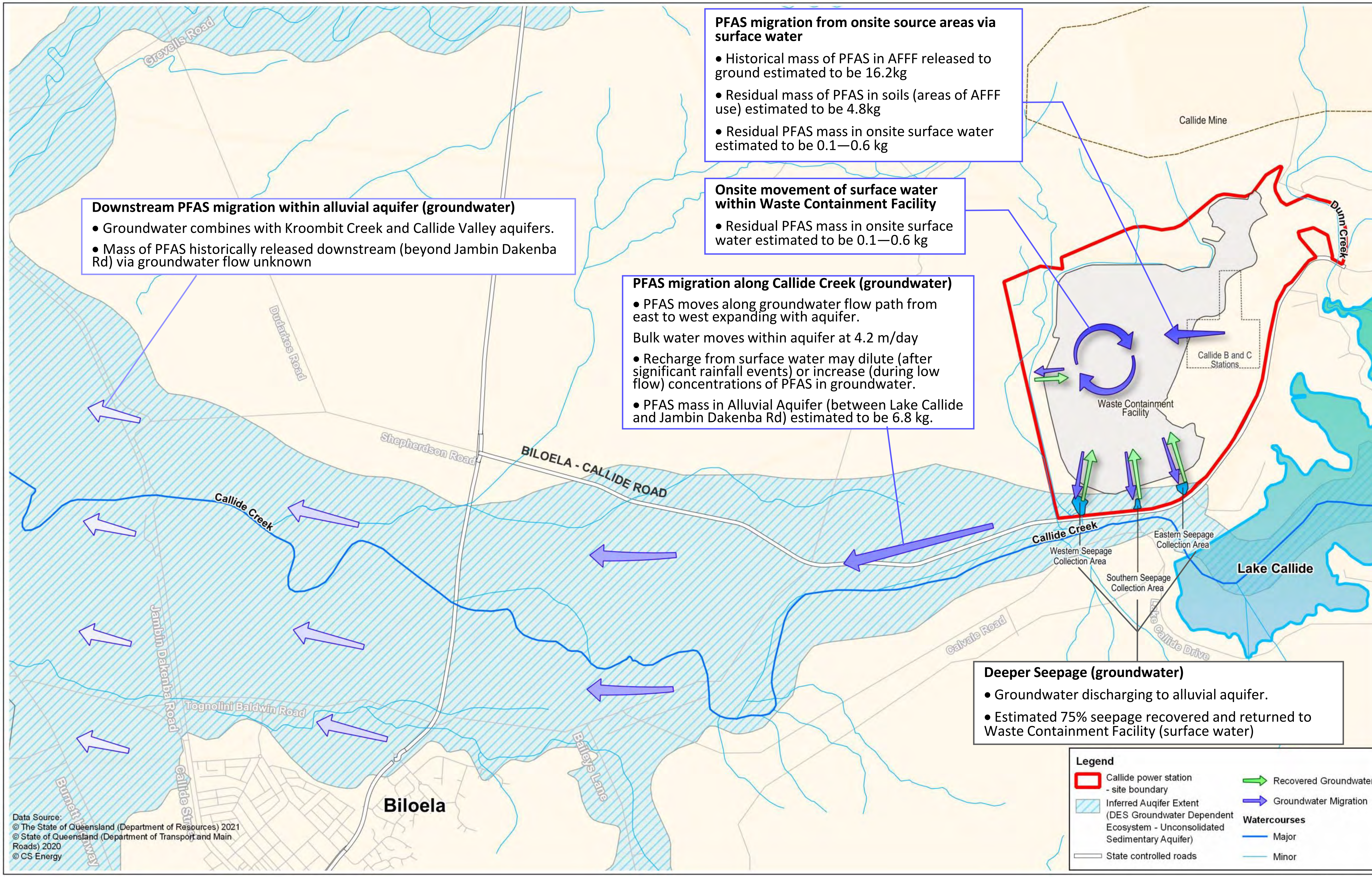
Datum: GDA94 Projection: MGA zone 56

CS Energy
PFAS investigation (Callide Power Station)
Hydrogeological Summary Report

Figure F7
PFAS Migration in Surface Water

Figure 6.1

BC200153.04 Rev 0 05/04/2022



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Datum: GDA94 Projection: MGA zone 56

Figure 6.2

CS Energy
PFAS investigation (Callide Power Station)
Hydrogeological Summary Report

Figure F8
PFAS Migration in Groundwater

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Section 7. Toxicity of PFAS to humans

7.1 General

This section outlines the approach used to assess the toxicity of PFAS to human health.

7.2 Approach for chemicals in general

The quantitative assessment of potential risks to human health for any chemical requires the consideration of the types of effects seen in studies, what doses/concentrations were related to those effects, and, where possible, mechanisms of action (i.e. how the chemical caused the effect).

Most chemicals have a threshold below which there are no adverse effects. That means there is a dose or concentration below which no adverse effects are seen because there is not enough of the chemical in the body to cause enough of a change/enough damage. The threshold is determined by taking the lowest dose that did not cause effects in a study (typically from animal or human (e.g. occupational) studies) to which a number of uncertainty factors are applied (based on type of study, how many studies are available etc). This value is termed the toxicity reference value (TRV). When intakes / exposures are lower than the TRV, they are considered to not be associated with an adverse health risk (NHMRC 1999). This is the approach taken for PFAS based on the understanding of the effects of these chemicals.

Some chemicals have the potential to cause cancer by directly damaging DNA. These chemicals are described as non-threshold as it is assumed that they could cause some level of effect even at low doses. While this can be interpreted to mean that there is no safe dose, this is a policy choice/assumption built into the calculations to ensure risks are not underestimated. It actually means the risk of effects due to exposure to such a chemical increases with increasing dose or exposure – i.e. at low exposure, risk is low or even negligible and at high exposure, risk is much higher. The difference between threshold and non-threshold chemicals is chemicals that act via a threshold mechanism of action have no risk when exposure is to levels below the threshold while chemicals that act via a non-threshold mechanism of action have a low risk at low exposure. This approach does not apply to PFAS as they are dealt with using the approach described above.

Dose-response values (threshold or non-threshold), i.e. TRVs, that are considered relevant to the characterisation of potential health effects associated with exposure to PFAS have been selected for this assessment from credible peer-reviewed sources in accordance with the current approved national guidance from enHealth and NEPC (enHealth 2012a; NEPC 1999 amended 2013e).

A summary of the key health effects and aspects relevant to the identification and selection of appropriate toxicity reference values for the key PFAS is provided in the following sections. A more detailed review is provided in **Appendix C**.

7.3 Human health effects

Toxicological studies using laboratory animals for this family of chemicals have focused to date on PFOS, PFHxS and PFOA. A more detailed review is provided in **Appendix C**.

The following provides a general summary of health effects that have been associated with PFOS and PFOA (ATSDR 2021; Burgoon et al. 2023):

- Various effects have been seen in people and in laboratory animals including effects on the liver and immune system.
- Key PFAS have been shown to be quite long lived in the human body (half life is years) while they can be eliminated from the body in mice and rats in as little as a few hours.
- Doses that cause effects in laboratory animals do vary depending on the species being studied which is common for many chemicals.
- In relation to the key PFAS, this is probably due to the differences in how these chemicals are removed from the body (i.e. elimination rates).
- These differences mean a higher dose is needed to reach the same internal concentration for species that can easily eliminate the chemicals from their bodies and a lower dose is needed for species that take much longer to eliminate them. These differences between species are very obvious for the key PFAS chemicals and make interpreting these studies difficult.
- Many effects in laboratory animals have been linked to how these chemicals interact with a particular receptor inside cells (peroxisome proliferator-activated receptor (PPAR-ά). There are differences between species in how this receptor gets activated. People are not as sensitive to this process as rats and mice. This may mean interaction with this receptor is not the primary mechanism of action in people.
- High-dose studies in animals indicate that cancer, developmental delays, endocrine disruption, immunotoxicity and neonatal mortality are potential effects, but people are not usually exposed to such high levels.

The following sections provides a summary of the key aspects that specifically relate to the identification of TRVs for the quantitative assessment of potential health effects in this HHERA.

7.4 Toxicity reference values for PFOS, PFHxS and PFOA

Food Standards (FSANZ) undertook a detailed review of the toxicity of these chemicals. It was published in April 2017. The values recommended by FSANZ (2017) are listed in **Table 7.1.**

Further discussion on the toxicity of PFOS, PFOA and PFHxS is provided in **Appendix C**.

Table 7.1: TRV for PFAS – Australia

PFAS Compound	TRV	Background intake	Reference
PFOS + PFHxS	0.02 µg/kg/day	0.0014 µg/kg/day (7% of the TDI)	(FSANZ 2017b)
PFOA	0.16 µg/kg/day	0.00078 µg/kg/day (negligible)	(FSANZ 2017b)

The values listed in **Table 7.1** are the values used in this HHERA.

7.5 Human health based screening criteria

In addition to these overarching toxicity reference values, other types of screening criteria have been developed for use in contaminated land investigations involving PFAS chemicals.

These screening criteria are listed in **Table 7.2** and are sourced from the PFAS NEMP guidance developed by Commonwealth Department of Environment and Energy and State EPAs for soil and water as well as the food based criteria developed by FSANZ and drinking water guidelines from the Commonwealth Department of Health (FSANZ 2017b, 2017c; HEPA 2020; NHMRC 2011 updated 2022). These are the guidelines that have been used in this assessment, where they are relevant.

Table 7.2: Screening Criteria for PFAS – Human Health

Criteria Type	Screening Criteria	
	PFOS + PFHxS	PFOA
Drinking water (µg/L) [1]	0.07	0.56
Recreational water (µg/L) [2]	2	10
Soil (residential with accessible gardens) (mg/kg) [3]	0.01	0.1
Soil (residential with minimal soil access) (mg/kg)[3]	2	20
Soil (public open space) (mg/kg) [3]	1	10
Soil (commercial/industrial) (mg/kg) [3]	20	50
Sediment (mg/kg) [5]	0.01	0.1
Finfish (mg/kg) [4]	0.0052	0.041
Fish liver (mg/kg) [4]	0.28	2.24
Crustaceans/Molluscs (mg/kg) [4]	0.065	0.52
Meat (mg/kg) [4]	0.0035	0.028
Milk (mg/kg) [4]	0.0004	0.0028
Honey (mg/kg) [4]	0.033	0.264
Offal (mg/kg) [4]	0.096	0.765
Eggs (mg/kg) [4]	0.011	0.085
Fruit (mg/kg) [4]	0.0006	0.0051
Vegetables (mg/kg)[4]	0.0011	0.0088

Notes:

1 NHMRC Drinking Water Guidelines (NHMRC 2011 updated 2022)
2 NHMRC Recreational Water Quality Guidelines for PFAS (NHMRC 2019)
3 National Environmental Management Plan (HEPA 2020)
4 FSANZ Dietary Assessment (FSANZ 2017c)
5 No sediment guidelines have been developed by relevant authorities as yet. In this case the most conservative screening guideline for soil has been adopted. It is noted that this screening guideline for soil includes consideration of uptake into fruit and vegetables (10% homegrown produce) which is clearly not relevant for sediments as such crops will not grow in sediment. This is, therefore, a conservative screening guideline to adopt. CSIRO researchers have studied sediment toxicity for PFOS and recommend a value of 0.06 mg/kg based on protection of sediment organisms confirming that the use of the soil values is conservative (Simpson et al. 2021).

It has been assumed that the soil guidelines can be used to screen the sediment data for this assessment. It is acknowledged that there may be limitations to this assumption but there are currently no sediment specific criteria available. In regard to human health, it is likely that exposure to PFAS in sediments will be lower than that from soils, given the nature of the materials and how people interact with them (moisture content, washoff etc) so using soil guidelines will be conservative.

7.6 Recent international assessments

Since the work by FSANZ was completed in 2017, several international agencies have published updated toxicological reviews for these chemicals. These include the USEPA, WHO, US ATSDR and EFSA (ATSDR 2021; EFSA Panel on Contaminants in the Food Chain et al. 2020; USEPA 2022a, 2022d, 2023c, 2023a; WHO 2022). Some discussion of the findings of these agencies is provided in **Appendix C**.

While updated assessments have been provided by these international organisations, the primary agency in Australia assessing the potential effects of these chemicals – FSANZ – has determined that the values determined in 2017 remain appropriate.

These Australian values (as determined by FSANZ and listed in the PFAS NEMP) have been adopted in this HHERA. These are the values listed in **Tables 7.1** and **7.2**.

7.7 Other PFAS

Most international guidelines focus on PFOS and PFOA although this is changing with new guidance being developed to apply to the sum of groups of PFAS in Europe and the US. Guidelines in Australia focus on PFOS, PFHxS and PFOA.

There are, however, many other chemicals that may be included in the PFAS chemicals class. For most of these “other PFAS”, limited data are available to evaluate their toxicity. What is available indicates that these other chemicals are likely to be less toxic than PFOS and PFOA. Given these limitations, this assessment has considered the guidelines specifically as indicated in the PFAS NEMP (HEPA 2020) as well as whether there is any change in the conclusions if the sum of all PFAS detected in a sample (i.e. total PFAS) is considered. In particular, other PFAS compounds have been assessed in this HHERA using either the TRV for PFOS+PFHxS for sulfonic acid PFAS and the fluorotelomers including 6:2 FTS or the TRV for PFOA for carboxylic acid PFAS and other PFAS (sulfonamides etc)).

7.8 Uncertainties

In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals, although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response, as is particularly the case for PFAS compounds. There may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to extrapolate results of short-term or sub-chronic animal studies to humans exposed over a lifetime has inherent uncertainty.

Overall, the toxicological data presented are considered to be current and adequate for the assessment of risks to human health associated with the potential exposure to PFOS, PFOA and PFHxS. The uncertainties inherent in the toxicological values adopted are considered likely to result in an overestimation of actual risk assessed for long-term or chronic exposures.

Section 8. Toxicity of PFAS to the environment

8.1 General

This section outlines the approach used to assess the toxicity of PFAS to aquatic and terrestrial organisms. More detail is provided in **Appendix D**.

Australian authorities have developed national guidance about how to determine concentrations of chemicals that are likely to be protective (or concentrations likely to cause effects). These include guidance on the development of water quality guidelines for aquatic systems and ecological investigation levels for soil to protect terrestrial systems (ANZECC/ARMCANZ 2000; ANZG 2018; NEPC 1999 amended 2013a). The approaches outlined in these documents are similar to those adopted in other countries (CCME 1995, 1998, 2005, 2006b, 2006a, 2007; USEPA 2005b, 2007).

The guidance documents focus on how the Australian authorities developed guideline values for particular priority chemicals but the approaches provided can also be applied in site specific risk assessments where chemicals present at a site are not covered in national or international guidance. These approaches involve the collection and review of information on the toxicity of the specific chemical of interest to aquatic or terrestrial organisms from the scientific literature.

If toxicity information is available for a sufficient number of organism types, a species sensitivity distribution (SSD) is developed showing the range of concentrations where organisms show effects. These distributions allow the calculation of a concentration that is likely to be protective of 95% of organisms (or some other percentage as specified in the guidance documents – e.g. 99%).

For chemicals where toxicity information is limited, the most sensitive effect concentration is used with relevant uncertainty factors to determine a protective concentration (i.e. assessment or uncertainty factor approach).

Ecological guidelines are available for PFOS primarily from Canadian authorities. Some limited ecological guidelines are available for PFOA but there are no ecological guidelines for most other PFAS.

For PFAS that have potential to bioaccumulate, this characteristic must be considered in developing the guideline. For those PFAS that are not bioaccumulative only the potential for direct toxicity needs to be considered.

To deal with the limited availability of guidelines (in Australia or overseas), the approach adopted for this HHERA has been:

- guidelines for PFOS related to direct toxicity are applicable to all sulfonates as well as the sulfonamides (if detected) and the fluorotelomers
- guidelines for PFOA related to direct toxicity are applicable to all carboxylic acids
- guidelines for PFOS related to bioaccumulation into higher organisms (birds and mammals) are applicable to all PFAS included in this assessment – as noted not all PFAS are bioaccumulative so making this assumption is conservative.

8.2 Terrestrial ecosystems

The PFAS NEMP (HEPA 2020) provides direct and indirect exposure soil guidelines for the protection of terrestrial environments in 2 land use settings – a residential setting and a commercial/industrial setting.

The PFAS NEMP adopted guidelines directly from Environment Canada (Environment Canada 2017, 2018). Australian authorities have not developed specific terrestrial guidelines due to the lack of any Australia specific data. This is the approach commonly adopted for all chemicals as Australia specific data are rarely available.

Guidelines are available for PFOS (for direct toxicity and bioaccumulation – based on dietary items for mammals and birds) and PFOA (for direct toxicity only). These guidelines are listed in **Table 8.1.**

Table 8.1: Guidelines for protection of terrestrial environments (HEPA 2020)

Basis of Guideline	Adopted Guideline		Notes
	PFOS	PFOA	
Soil: Indirect exposure (mg/kg [soil])			
Agricultural land	0.01	0.01	Guideline for indirect exposure (i.e. includes some consideration of uptake into plants or animals that may be eaten by other organisms and leaching to and impacts on water quality [protection of freshwater species]) (Environment Canada 2018; HEPA 2020)
Residential	0.01	0.01	
Parkland and recreational	0.01	0.01	
Commercial/industrial	0.14	0.14	
Soil: direct toxicity (mg/kg [soil])			
Terrestrial environments – Soil	1	10	Guideline for direct exposure for public open space, which is recommended to be used for all land use scenarios (HEPA 2020)
Terrestrial biota (mg/kg [diet])			
Terrestrial species (mammals)	0.0046	0.0046	Guideline for dietary material consumed by higher organisms (for PFAS that are bioaccumulative) as listed in PFAS NEMP. There is no value listed for PFOA so the value for PFOS has been adopted (HEPA 2020).
Terrestrial species (birds)	0.0082	0.0082	Guideline for dietary material consumed by higher organisms (for PFAS that are bioaccumulative) as listed in PFAS NEMP. There is no value listed for PFOA so the value for PFOS has been adopted (HEPA 2020).

The guidelines for dietary material are those that apply to food items that may be consumed by mammals and birds such as fish or invertebrates. They indicate what levels of PFOS can be present in the food items without causing impacts on the higher organisms. These guidelines were developed by Environment Canada (Environment Canada 2018).

8.3 Aquatic ecosystems

8.3.1 Guidance for direct effects on aquatic organisms

Australian water quality guideline values indicate the concentration of a chemical that can be present in the water in which an organism lives without causing impacts. These guidelines are developed in accordance with national guidance – Warne et al. (2018).

Determining such guidelines uses data from ecotoxicity studies on a range of aquatic organisms. Such studies involve exposing a type of organism (i.e. fish, alga, invertebrate) to a number of different concentrations of the chemical of interest and observing whether the organisms are impacted in some way. Effects might include reduced growth, reduced reproduction or even death depending on the chemical and the type of study. The data from these studies are used to calculate the concentration at which no effects are observed. This is the value used in setting the guideline value.

Such guidelines have been developed by Australian authorities for PFOS and PFOA using data from the scientific literature.

8.3.2 Guidance for chemicals that bioaccumulate

In addition to direct effects on aquatic organisms, potential for chemicals to bioaccumulate must also be considered.

Bioaccumulation is the term that describes when a chemical accumulates inside an organism because the chemical is taken up by the organism faster than it can excrete or break down the chemical[3].

Most chemicals get taken up by organisms, but they do not accumulate inside the organism because there are mechanisms to remove them (excretion) or to break them down into their component parts (metabolism/break down). Chemicals that bioaccumulate are ones that are not easy to remove from the organism or they are difficult to break down into their component parts or both.

The most common PFAS have this characteristic, so it is important that this potential is considered appropriately in any risk assessment. These most common PFAS (i.e. PFOS, PFOA, PFHxS) are not the only chemicals that might bioaccumulate. Other examples include DDT and PCBs.

The ANZG guidance material provides the following information on how to consider bioaccumulation for all chemicals that might have this characteristic:

- *Dietary accumulation can be an important route of uptake for some chemicals, and it will need to be addressed in future revisions of the Guidelines*
- *There is currently no formal and specific international guidance for incorporating bioaccumulation into water quality guidelines*
- *For those chemicals that have the potential to bioaccumulate, the decision scheme provides for site-specific re-assessment of this issue if suitable data become available. Field investigations of residue levels in appropriate organisms may provide additional evidence for whether or not bioaccumulation is an issue at the site under study*
- *In the absence of such local data, a higher level of protection is recommended (e.g. 99% protection for slightly–moderately disturbed systems instead of 95%) (ANZECC/ARMCANZ 2000).*

[3] https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=349938&Lab=CCTE

The last dot point about the adoption of the 99% protection trigger value notes that this is not the preferred approach recommended by ANZECC. However, it often represents the default position adopted for most contaminated land sites.

The use of the 99% protection trigger value is a policy decision that does not include specific consideration of scientific information relating to bioaccumulation processes (i.e. does not actually assess the potential for bioaccumulation in aquatic organisms). The “step up” of a protection level is simply a trigger for more careful and detailed assessment as the chemical has been identified to be bioaccumulative.

There are a number of other options to address potential for accumulation including:

- Modelling based on characteristics of the chemical
- Sampling and analysis of biota from the area of interest.

The use of models to consider potential for bioaccumulation for PFOS or PFOA is not straightforward as the characteristics of these chemicals do not work well in the models that are available. Where modelling and monitoring has been undertaken results have not been consistent.

Sampling and analysis of field samples from the area of interest helps determine whether organisms are actually being exposed to chemicals like PFOS in a form that can get into their systems and be accumulated. This approach also has limitations/issues in relation to the practicalities of catching the organisms and the ethics of collecting organisms for analysis.

When considering biota monitoring, it is important to recognise that such monitoring involves killing organisms. That means the monitoring causes actual harm to the waterway which can be acceptable under certain circumstances (such as needing to understand the risks in a particular situation) as has been undertaken for this assessment. Ongoing monitoring of biota is, however, unlikely to be acceptable. Such monitoring is covered by animal ethics legislation in most states including Queensland[4] which requires such monitoring be undertaken only for justifiable scientific purposes (i.e. information cannot be obtained using surrogate processes) and that it be undertaken by appropriately qualified staff with appropriate permits as per the legislation. It is also important to consider the size of the waterway under investigation. Small waterways may be difficult to sample due to small population size or lack of species altogether. It is also important to not collect so many samples from such waterways that they are “fished out”.

Regardless, it is important to use an approach or approaches that consider the potential for bioaccumulation in aquatic organisms that may impact on mammals or birds that consume fish/ invertebrates from a waterway that may contain elevated levels of PFAS.

The currently preferred approach for sites where PFOS may be present is to use the 95% protection trigger value to determine if there is a potential for direct toxicity to aquatic organisms and to use field sampling of aquatic biota to assess the potential for bioaccumulation and secondary poisoning.

In this case, screening has used both 99% and 95% species protection guidelines and aquatic biota sampling has been undertaken to provide a more detailed picture in regard to bioaccumulation.

[4] https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/livestock/animal-welfare/animals-science/using-animals

8.3.3 Guidelines for PFOS and PFOA

There were no trigger values for PFOS and PFOA in the ANZECC/ARMCANZ guidelines published in 2000 or the online system launched in 2018 [5].

Between 2016 and 2018, various state regulatory authorities published guidelines for investigating PFAS contaminated sites including draft WQG for PFOS and PFOA that were based on draft determinations by ANZECC. The supporting information about how these values were determined was released to regulators for comment but has never been publicly released (EPA Victoria 2019b; NSW OEH 2017; WA DER 2017a). The demand for guidance during this time period was significant, so it is understandable that these draft values were adopted.

These draft values are listed in **Table 8.2**.

Table 8.2: Guidelines for PFOS and PFOA – protection of freshwater ecosystems (HEPA 2020)

Species Protection Value	PFOS (µg/L)	PFOA (µg/L)
High conservation value systems (99% species protection)	0.00023	19
Slightly to moderately disturbed systems (95% species protection)	0.13	220
Highly disturbed systems (90% species protection)	2.0	623
Highly disturbed systems (80% species protection)	31	1,824

These values are listed in the current version of the PFAS NEMP and are recommended for screening both fresh and marine waters (HEPA 2020).

These guideline values, however, have never been finalised by the technical committee that oversees these ecosystem protection based guidelines. This is because a range of technical issues have been raised about the calculation of the values for PFOS. The values for PFOA have not been considered flawed.

The issues for these PFOS values from 2016 were:

- problems with the application of the statistical analysis to the dataset for PFOS
- new data that should be included in the dataset
- older data that should be removed from the dataset.

Further discussion about the wide range of technical issues that have arisen when reviewing the original draft Australian guidelines for PFOS and the currently proposed updated draft guidelines is provided in **Appendix D**.

CSIRO scientists have undertaken a number of recalculations of the 99% species protection value for PFOS to try and address some of these issues. These recalculations have resulted in 99% species protection values for PFOS of around 0.05 µg/L (Batley et al. 2018; Page et al. 2019).

As is normal practice, the technical committee that oversees the water quality guidelines issued a new draft value for PFOS in May 2023 as a draft for public consultation. Comments closed in

[5] www.waterquality.gov.au

August 2023 and the comments received are currently being considered prior to finalisation of the guideline for official release and implementation.

The new draft 2023 guidelines for PFOS provided for consultation were those listed in **Table 8.3**.

Table 8.3: Newly released draft Australian water quality guidelines for PFOS (ANZG 2023)

Species protection level	2023 draft PFOS water quality guideline (µg/L)
99%	0.0091
95%	0.48
90%	2.7
80%	17

Further changes to the dataset and the statistical tools are currently being considered by the oversight committee (discussed in **Appendix D**). If these changes are implemented the water quality guidelines listed in **Table 8.4** could be listed in the future for PFOS.

Table 8.4: Recalculated Australian water quality guidelines for PFOS using new software and SERDP study data (ANZG 2023)

Species protection level	Draft PFOS water quality guideline (µg/L)
99%	0.03
95%	0.7
90%	2.7
80%	13

There are no specific guidelines in Australia for soil, water or sediment based on ecological protection for PFAS other than PFOS and PFOA.

The PFAS NEMP recommends the use of guidelines for PFOS for screening PFHxS in regard to ecological protection but national guidance does not address any other PFAS.

In situations where chemicals other than PFOS, PFHxS or PFOA contribute significantly to the PFAS profile present at a site, other PFAS are often screened using the guidelines for PFOS.

This is on the basis that, where data are available for both PFOS and other relevant PFAS, the values for PFOS are more stringent than for the other PFAS (e.g. PFOS and PFOA water quality guidelines). Meeting the guidelines for PFOS will, therefore, be expected to be protective/conservative.

Regardless of the potential for the PFOS guideline to be changed by Australian authorities, the water quality guideline values adopted for this assessment are those listed in **Table 8.2** – i.e. the values currently recommended for use in site investigations by the PFAS NEMP (HEPA 2020).

Section 9. Screening assessment

9.1 General

This section presents a screening risk assessment of the data for the various media sampled for the off-site area downstream of Callide Power Station. The aim of the review is to identify whether PFAS chemicals are present at levels requiring more detailed evaluation of risk.

9.2 Screening – Groundwater

9.2.1 Human health

Groundwater in this area may be extracted for drinking water so the relevant screening criteria for human health are those for drinking water use. In addition, the groundwater may be extracted for uses around a farm or around a home and so the recreational water use guidelines are relevant.

The maximum groundwater concentrations in the monitoring wells reported in this investigation have been reviewed against the relevant screening criteria noted in **Section 7**.

The chemicals listed are only the key PFAS with guidelines published in the PFAS NEMP (HEPA 2020).

All of the other PFAS where at least 1 sample contained that chemical at a concentration above the limit of reporting (i.e. where individual PFAS were detected) have been discussed in **Section 10.5.4**.

The screening assessment for groundwater (human health) is shown in **Table 9.1**.

Table 9.1: Screening risk assessment – groundwater

Detected PFAS	Maximum Concentration – upgradient (µg/L)	Maximum Concentration – downgradient (µg/L)	Screening criteria (µg/L) – recreational	Screening criteria (µg/L) – drinking
Chemicals in Australian Guidance (PFAS NEMP)				
PFOS+PFHxS	0.388	0.826	2	0.07
PFOA	0.0175	0.0105	10	0.56

Notes:
Screening criteria used here are from **Table 7.2**
ND = not detected

The maximum concentration for PFOS+PFHxS is below the recreational water use guideline for PFOS but above the drinking water guideline. The maximum concentration for PFOS+PFHxS is lower in the upgradient monitoring wells compared to the downgradient monitoring wells.

The maximum concentration for PFOA is similar in the upgradient monitoring wells and the downgradient monitoring wells. The maximum concentration for PFOA is below both the drinking water guideline and the recreational water use guideline.

Given that the groundwater in the downgradient area may be used for drinking a refined assessment is required, where maximum concentrations are above drinking water guidelines. This refined assessment is provided in **Section 10.2**.

In addition, Hydrobiology (2023) collected relevant fish that might be consumed by people caught in Callide Creek. The results for these aquatic biota data are screened in **Section 9.4** using the screening guideline provided by FSANZ for PFOS in fish to be consumed by people.

9.2.2 Ecological

The maximum groundwater concentrations in the monitoring wells reported in this investigation have been reviewed against the relevant screening criteria noted in **Section 8**.

The chemicals listed are only the key PFAS with guidelines published in the PFAS NEMP (HEPA 2020).

All of the other PFAS where at least 1 sample contained that chemical at a concentration above the limit of reporting (i.e. where individual PFAS were detected) have been discussed in **Section 10.5.4**.

The screening assessment for groundwater (ecological) is shown in **Table 9.2**.

Table 9.2: Screening risk assessment – groundwater

Detected PFAS	Maximum Concentration – upgradient (µg/L)	Maximum Concentration – downgradient (µg/L)	Screening criteria – ecological (95% species protection) (µg/L)	Screening criteria – ecological (99% species protection) (µg/L)
PFOS	0.024	0.4590	0.13	0.00023
PFOA	0.0175	0.0105	220	19

Notes:
Screening criteria used here are from **Table 8.2**
ND = not detected

For PFOS, the maximum concentrations in the monitoring wells up and downgradient of the site are above the 99% species protection water quality guideline.

For PFOA, the maximum concentrations in the monitoring wells up and downgradient of the site are in compliance with both the 95% and 99% species protection values and require no further assessment.

Refined assessment of the groundwater concentrations for PFOS is provided in **Section 11**.

It is noted that the Australian water quality guidelines indicate that the 99% species protection value is to be used as a trigger for a more specific assessment of bioaccumulation in aquatic organisms collected in the waterway of interest.

Such sampling was undertaken for this site. Hydrobiology (2023) collected fish and invertebrates in relevant surface water bodies to which groundwater may discharge. These data are screened in **Section 9.4**.

9.3 Screening – surface water

9.3.1 Human health

Surface water on the site is not extracted for drinking water so the relevant screening criteria for human health for the surface water samples are the recreational water use guidelines.

People could come into contact with surface water in Callide Creek, Dunn Creek and the other waterways when walking, wading, fishing or during other types of recreation. For these uses, the recreational criteria are appropriate.

Drinking water guidelines have also been considered as some waterways such as Lake Callide are used as a drinking water source, however, the concentrations in Lake Callide are much lower than the smaller waterways where recreation may occur.

The maximum surface water concentrations reported in this investigation have been reviewed against the relevant screening criteria noted in **Section 7**.

The chemicals listed are only the key PFAS with guidelines published in the PFAS NEMP (HEPA 2020).

All of the other PFAS where at least 1 sample contained that chemical at a concentration above the limit of reporting (i.e. where individual PFAS were detected) have been discussed in **Section 10.5.4**.

The screening assessment for surface water (human health) is shown in **Table 9.3.**

Table 9.3: Screening risk assessment – surface water

Detected PFAS	Maximum concentration upstream of the power station (µg/L)	Maximum Concentration downstream of the power station (µg/L)	Screening criteria (µg/L) – recreation	Screening criteria (µg/L) – drinking
PFOS+PFHxS	0.597	0.12	2	0.07
PFOA	0.0984	0.002	10	0.56

Notes:
Screening criteria used here are from **Table 7.2**

For PFOS+PFHxS, the maximum concentrations in surface water are lower in the downstream sampling locations compared to the upstream sampling locations. The maximum concentrations are below the recreational water use guideline for PFOS for all locations. The maximum concentrations of PFOS+PFHxS in the downstream locations are also higher than the drinking water guideline.

For the PFOA, all maximum concentrations in surface water are lower in the downstream sampling locations compared to the upstream sampling locations. The maximum concentrations for PFOA are below the recreational water use guideline and the drinking water guideline.

Given that there are surface water bodies where water may be taken for drinking, a refined assessment is required where maximum concentrations are above drinking water guidelines. This refined assessment is provided in **Section 10.3**.

In addition, Hydrobiology (2023) collected relevant fish that might be consumed by people caught in Callide Creek. The results for these aquatic biota data are screened in **Section 9.4** using the screening guideline provided by FSANZ for PFOS in fish to be consumed by people.

9.3.2 Ecological

The maximum surface water concentrations reported in this investigation have been reviewed against the relevant screening criteria noted in **Section 8**.

The chemicals listed are only the key PFAS with guidelines published in the PFAS NEMP (HEPA 2020).

All of the other PFAS where at least 1 sample contained that chemical at a concentration above the limit of reporting (i.e. where individual PFAS were detected) have been discussed in **Section 10.5.4**.

The screening assessment for surface water (ecological) is shown in **Table 9.4.**

Table 9.4: Screening risk assessment – surface water – on-site

Detected PFAS	Maximum concentration upstream of the power station (µg/L)	Maximum Concentration downstream of the power station (µg/L)	Screening criteria – ecological (95% species protection) (µg/L)	Screening criteria – ecological (99% species protection) (µg/L)
PFHxS	0.294	0.0594	0.13	0.00023
PFOS	0.303	0.0606		
PFOA	0.0984	0.002	220	19

Notes:
Screening criteria used here are from **Table 8.2**

As noted above (**Section 9.3.1**), the maximum concentrations for PFOS, PFHxS and PFOA were higher upstream of the Callide Power Station site.

For PFOS and PFHxS, maximum concentrations are above the 99% species protection water quality guideline for PFOS. For the upstream sampling locations, the maximum concentrations for PFOS and PFHxS are also above the 95% species protection value.

For PFOA, maximum concentrations are in compliance with both the 95% and 99% species protection values and require no further assessment.

Refined assessment of the surface water concentrations is provided in **Section 11**.

It is noted that the Australian water quality guidelines indicate that the 99% species protection value is to be used as a trigger for a more specific assessment of bioaccumulation in aquatic organisms collected in the waterway of interest.

Such an assessment has been undertaken for this site. Hydrobiology (2023) collected relevant fish and invertebrates in relevant surface water bodies to which groundwater may discharge. These data are screened in **Section 9.4**.

9.4 Screening – aquatic biota

9.4.1 General

Many PFAS have the potential to bioaccumulate in organisms and magnify up food chains, especially PFOS, PFOA and PFHxS (UNEP 2006, 2016).

Bioaccumulation occurs because organisms take in these chemicals through the food and water they consume (this is common for most chemicals not just PFAS) but are not able to remove them from their bodies quickly enough so concentrations build up over time. Different organisms accumulate PFAS at different rates because some types of organisms can remove these chemicals from their bodies more quickly.

Given that the key PFAS (i.e. PFOS, PFHxS and PFOA) have this characteristic, it is important to assess the potential for organisms or people to be exposed to elevated levels of PFAS in fish or other seafood.

Many of the other PFAS (discussed in **Section 10**), are not bioaccumulative (i.e. organisms can taken them in and remove them so they do not accumulate).

As discussed above, Hydrobiology undertook appropriate sampling of fish and invertebrates in Callide Creek, Lake Callide and Lake Kroombit (Hydrobiology 2023).

9.4.2 Human health

PFOS was almost the only PFAS detected in any of the fish samples. It was not detected in every sample. It was detected in a small number of fish samples for fish that people might catch and eat. PFHxS was detected in a single sample at the limit of reporting. No other PFAS were reported above the limit of reporting in any sample.

The relevant screening criteria for PFOS concentrations in fish (or other seafood) that people may eat is the FSANZ trigger point for fin fish (FSANZ 2017c) – as listed in **Table 7.2**.

The trigger point is 5.2 µg/kg for PFOS + PFHxS individually or combined. This health based screening guideline for consumption of fish is based on a small child eating a large portion of fish on every day of the year (FSANZ 2017c).

AB2 and AB3 are sampling locations within Lake Callide. No fish samples collected at AB2 or AB3 reported any detections for any PFAS including PFOS.

For the species that were relevant for consumption by people:

- Barramundi and crayfish (samples collected at AB1, AB2, AB3) did not contain detectable levels of any PFAS at any location.
- Yellowbelly (samples collected at AB1 and AB8) had detections for PFOS only at 1 sampling location (AB8). The concentration was in compliance with the FSANZ trigger value for fish of 5.2 µg/kg.
- Eeltail catfish (samples collected at AB1, AB2, AB4 and AB9) had detections for PFOS and PFHxS at 1 sampling location (AB4). The detections were in compliance with the FSANZ trigger value for fish of 5.2 µg/kg.
- Sleepy cod (samples collected at AB1 and AB4) had detections for PFOS only at 1 sampling location (AB4). The detection was in compliance with the FSANZ trigger value for fish of 5.2 µg/kg.
- Hyrtl's catfish (samples collected at AB1, AB8 and AB9) had no detections of any PFAS at 2 of the locations where it was collected but had a detection of 8 µg/kg at 1 location. This concentration is slightly above the FSANZ trigger point so further discussion has been provided in **Section 10.4**.
- Rendahl's catfish (samples collected at AB1, AB4, AB5) had detections for PFOS in all samples at all locations with concentrations ranging from 2-44 µg/kg. The results for samples collected at AB4 and AB5 were above the FSANZ trigger point so further discussion has been provided in **Section 10.4**.

9.4.3 Ecological

For the samples collected to assess potential ecological risks, only PFOS was detected. No other PFAS were reported above the limit of reporting in any sample.

The PFAS NEMP provides guidelines for screening PFAS in smaller organisms likely to form the diet of birds or mammals to check for potential for secondary poisoning/impacts due to bioaccumulation (HEPA 2020). The guidelines recommended are 4.6 µg/kg for organisms that might be consumed by mammals and 8.2 µg/kg for organisms that might be consumed by birds. These guidelines were developed by Environment and Climate Change Canada (Environment Canada 2017, 2018) and were adopted unchanged by Australian authorities.

They are based on toxicity reference values (TRVs) relevant for birds and mammals plus assumptions about food ingestion rate to body weight ratios (Environment Canada 2017, 2018).

The screening guideline for birds assumes that a bird will consume almost its entire body weight every day of the fish or other seafood relevant for this site – the food ingestion rate to body weight ratio assumed is 0.94 (i.e. they consume 94% of their body weight every day) (Environment Canada 2017, 2018).

For the mammals, the food ingestion rate to body weight ratio is assumed to be 0.24 (i.e. they consume around 25% of their body weight per day of the fish/seafood in Callide Creek) (Environment Canada 2017, 2018).

In addition, both of these guidelines include an uncertainty factor of 100 in calculating the toxicity reference value (TRV). Environment Canada did not include this uncertainty factor when they calculated soil quality guidelines due to some inconsistency in their national guidance. These dietary guidelines are, therefore, conservative.

For the species that were relevant for consumption by birds and mammals:

- Agassiz's perchlet were collected in all locations apart from AB2 and AB9. Concentrations ranged from non-detect (AB1/AB3) to 89 µg/kg at AB8 – i.e. concentrations increasing going downstream along Callide Creek.
- Fly specked hardyhead were collected in all locations apart from AB5 and AB9. Most locations did not report detections of PFOS (or any other PFAS). Only AB7 and AB8 reported detections for PFOS and ranged from 40-68 µg/kg.
- Freshwater prawns were collected at AB1, AB2, AB3 and AB9 only. No PFOS or any other PFAS were detected in any samples.
- Freshwater shrimp were collected at AB4 and AB7 only. PFOS was detected in both of these samples with the concentration at AB4 being 3 µg/kg and at AB7 being 31 µg/kg.

Almost all of the maximum concentrations of PFOS detected in these species were above the PFAS NEMP screening criteria for both birds and mammals so further discussion has been provided in **Section 11**.

9.5 Refinement of conceptual site model (CSM)

Comparison of maximum upstream or upgradient concentrations in groundwater or surface water with the maximum downstream or downgradient concentrations shows that the concentrations entering the Callide Power Station site (or traversing around the site) (i.e. upstream/upgradient) are higher for most of the individual PFAS than the concentrations downstream/downgradient of the site.

For groundwater, PFOS and 6:2 FTS are the only PFAS which have a significantly higher maximum concentration downgradient of the site. For surface water, the maximum concentrations downstream of the site are much lower than those present upstream of the site.

The focus of this assessment is the contribution made by Callide Power Station to the presence of these chemicals in the off-site area downgradient. As a result, the refined assessments in **Section 10** and **Section 11** of this assessment have focused on the presence of PFOS and 6:2 FTS as the key PFAS.

Section 10. Refined assessment – human health

10.1 Background

Callide Creek is a small creek in a rural area as shown in the following photos of the biota sampling locations within the creek line (Hydrobiology 2023). It is not an area that would be subject to commercial fishing, given creek size and accessibility constraints. The photos included in **Figure 10.1** show some views of the creek and the 2 dams.

AB1 – upstream Callide Creek – native vegetation and roads	
AB2 – Lake Callide – reservoir, natural vegetation, roads, residential and farming	

AB3 – Lake Callide – reservoir, natural vegetation, roads, residential and farming	
AB4 – Callide Creek below dam spillway – native vegetation, wetland and road/access tracks	
AB5 – downstream Callide Creek – native vegetation, wetland, farming	

AB7 – downstream Callide Creek – wetland and native vegetation partially cleared for road infrastructure. Irrigated cropping upstream and piggery downstream.	
AB8 – downstream Callide Creek/ Callide Weir – native vegetation and wetland area with grazing and farm infrastructure.	
AB9 Lake Kroombit Dam	

Figure 10.1: Photos of the various biota sampling locations along Callide Creek

DESI defined relevant environmental values for the Callide Creek system in 2011[6]. The relevant values for this system include that water should be suitable for:

- aquatic ecosystems
- irrigation
- farm supply
- stock watering
- consumption of seafood by people
- primary recreation
- secondary recreation
- visual appreciation
- drinking water
- industrial uses
- cultural/spiritual values.

The nature of the habitats in the creek and the types of food that are present in the creek define what species of fish might inhabit the creek and the potential for them to be useful for consumption by people. It is considered that the species in Callide Creek that might grow to sufficient size to comply with relevant minimum legal size requirements for recreational fishing will be limited. Therefore, it is not expected that people would fish in this creek system to provide a routine part of their diet. This applies regardless of whether any organisms present in the creek contain contaminants like PFAS or not.

Lake Callide, on the other hand, is stocked with fishable species and fishing occurs there regularly. All samples collected from Lake Callide did not contain any measurable levels of PFAS.

10.2 Use of groundwater

10.2.1 General

Water is sourced from Lake Callide to provide drinking water to Biloela. In addition, groundwater may be extracted from supply bores for a range of activities on properties downgradient of the power station including the provision of water for drinking and other domestic/household purposes.

The screening assessment for groundwater and surface water in **Section 9** notes that the maximum concentrations for some of the individual PFAS are above the relevant drinking water guideline. This triggers a more detailed or refined assessment.

The first step in undertaking a refined assessment is understanding how drinking water guidelines are determined for the NHMRC Australian Drinking Water Guidelines (NHMRC 2011 updated 2022).

[6] https://environment.des.qld.gov.au/management/water/policy/fitzroy-basin

10.2.2 NHMRC approach

The NHMRC guidelines provide the methodology for determining drinking water guidelines. The approach taken is covered by the following equation:

$$\begin{aligned} &Drinking\ water\ guideline \\ &\quad = (reference\ dose * body\ weight \\ &\quad * source\ contribution)/(water\ ingestion\ rate) \end{aligned}$$

The calculation assumes:

- Water ingestion rate = 2 L of water from the same source per day every day for their lifetime
- Body weight = 70 kg (a conservative choice for this type of calculation)
- Reference dose = toxicity reference value (TRV) for the chemical of interest
- Source contribution = only 10% of the toxicity reference value (TRV) can come from drinking water.

Assuming drinking water can only make a 10% contribution to a person's total exposure to a particular chemical is appropriate when setting national guidelines that cover all situations across Australia. It acknowledges that there are many pathways by which a person may be exposed to a particular chemical, not just drinking water. Because that cannot be accounted for in a national generic guideline, the guideline limits the proportion of the toxicity reference value that can come from drinking water.

It is source contribution part of the calculation that can be adjusted when a site specific assessment is being undertaken for a particular location – as part of a multi-pathway assessment. This is because such an assessment specifically considers all the different ways people may be exposed at a particular location.

10.2.3 Multi-pathway assessment

A multi-pathway assessment considers all of the potential exposure pathways by which a person can be exposed. One of those pathways can be ingestion of drinking water but this type of assessment also includes consideration of all the other ways a person may be exposed.

For this assessment, the following exposure pathways are relevant for consideration in regard to the groundwater and/or surface water downgradient/downstream of Callide Power Station:

- ingestion of groundwater for drinking (drinking water guidelines include use of water for cooking, showering and other uses of water around the home as well as drinking)
- incidental ingestion of groundwater during use of water for farming purposes
- incidental ingestion of groundwater during domestic uses of water (e.g. filling pools, sprinkler play, cleaning etc)
- consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater
- consumption of home grown eggs, milk or meat which may contain PFAS due to stock watering using groundwater (and/or irrigation of fodder)
- incidental ingestion of surface water while recreating (swimming/boating) in Callide Creek
- consumption of fish/seafood from Callide Creek.

A figure showing all the ways people might be exposed to PFAS when these chemicals are present in the environment is provided in the PFAS NEMP (HEPA 2020). The figure is shown below in **Figure 10.2**.

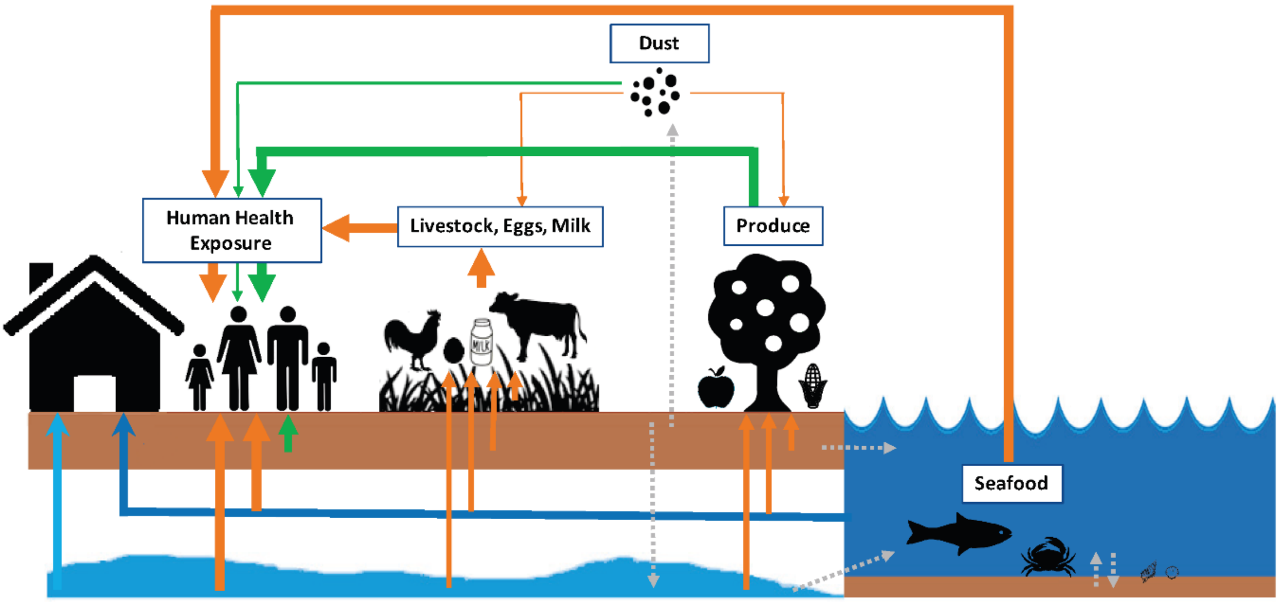

Figure 10.2: Example conceptual site model showing all the exposure pathways that might be relevant for this assessment

A multi-pathway assessment is the name applied when all of the pathways relevant at a site are considered, evaluated and added together to determine the potential exposure of a person living in that environment. This total exposure is then compared to the toxicity reference value.

These multi-pathway assessments are discussed in the current approved national guidance for health risk assessments in Australia from enHealth (enHealth 2012a). Such calculations are also documented in detail by the USEPA for use when assessing large industrial developments (USEPA 2005a) and some of the information in this US guidance document can be useful to support the approach recommended in Australia.

The multi-pathway assessment approach has been adopted here to fully consider all the ways people living and working in the area downgradient/downstream of Callide Power Station might be exposed.

The generic equations to calculate risk for each of these pathways are:

$$Daily\ chemical\ intake = concentration\ x\ \ (IR\ x\ FI\ x\ B\ x\ CF\ x\ EF\ x\ ED) / (BW\ x\ AT)$$

$$Risk = \ (daily\ chemical\ intake) / (toxicity\ reference\ value\ (adjusted\ for\ background\ exposure)\ )$$

where:

IRdw	= ingestion rate for drinking water (L/day)
IRiw	= incidental ingestion rate for water during recreation or farming uses (L/day)
IRfood	= ingestion rate of relevant type of food (kg/day)
FI	= fraction ingested from the site for water/food
B	= oral bioavailability (unitless, expressed as a fraction of 1)
CF	= conversion factor of $1x10^{-6}$ to convert mg to kg (where required)
EF	= exposure frequency (days/year)
ED	= exposure duration (years)
BW	= body weight (kg)
AT	= averaging time for threshold contaminants (days) (i.e. ED x 365 days for oral/dermal exposures)
TRV	= toxicity reference value relevant for the chemical
BI	= background intakes relevant to oral/dermal or inhalation exposures (from sources other than soil or groundwater at the site, which include food, water, air and consumer products where relevant) (as % of the TRVx) (assumed to be 10% for these PFAS)

The values to be used for these parameters in this assessment are listed in **Table 10.1**.

Table 10.1: Exposure parameter assumptions

Parameter		Young children	Adults
BW	Body weight (kg)	15	70
EF	Exposure frequency (days/year)	365	365
ED	Exposure duration (years)[3]	6	29
		As per (enHealth 2012b) and ASC NEPM (NEPC 1999 amended 2013d) for all above	
AT	Averaging time (days)	Threshold = ED x 365 days/year; Non-threshold = 70 years x 365 days/year	
C_M	Concentration of chemical substance in media of relevance (groundwater, surface water, fruit and vegetables, eggs, meat, milk) (µg/L or mg/kg)	Concentrations as per **Section 10.2.4**	
IRdw	Ingestion rate – drinking water (L/day)	2	
		As per (NHMRC 2011 updated 2022)	
IRiw	Ingestion rate – incidental ingestion (L/day)	0.02 (farm activities or domestic/recreational uses (e.g. sprinkler play/ filling pools) 0.2 (swimming in Callide Creek)	
		As per (NHMRC 2008; NRMMC 2006)	
IRfood	Fruit (kg/day)	0.18	0.14
	Green vegetables (kg/day)	0.055	0.1534
	Root vegetables (kg/day)	0.017	0.0468
	Tuber vegetables (kg/day)	0.028	0.0598
		as per ASC NEPM (NEPC 1999 amended 2013d) for all of fruit & vegetables	
	Eggs (kg/day)	0.036	0.059
		Ingestion rate of eggs per day – P90 consumption for consumers from FSANZ (FSANZ 2017c)	
	Meat (kg/day)	0.085	0.16
		Ingestion rate of beef per day – P90 consumption (FSANZ 2017c) Relevant for home slaughtered meat	
	Milk (kg/day)[1]	1.097	1.295
		Ingestion rate of milk per day – P90 consumption (FSANZ 2017c) Relevant for on farm produced milk	
FI	Fruit and vegetables	35%	35%
		Standard conservative assumption for rural residential production	
	Eggs	100%	100%
		Assume all eggs consumed are home-produced	
	Meat	35%	35%
		Conservative assumption[2]	
	Milk	100%	100%
		Assume all milk consumed on farm is produced at the farm	
B	Bioavailability or absorption of chemical substance via ingestion	100%	100%
		Conservative assumption – maximum possible	

Notes:

1 Even though milk is a liquid the intake rate is expressed here in terms of kg/day for ease of calculation

2 A conservative assumption has been made that up to 35% of a person's intake of meat across a year has been derived from livestock produced at the farm at which a person is living (i.e. home slaughtered). This is in line with other assessments in Australia and is considered conservative. It is noted that there are strict limitations on home slaughtering in Queensland which mean

livestock may be killed and consumed on a property but that meat cannot be sold/traded or bartered and cannot be taken off the property https://www.safefood.qld.gov.au/home-kill-legislation-in-queensland/?keyword=HOME%20 .

3 The standard exposure duration assumptions as recommended in the ASC NEPM are listed here. It is noted that, because PFAS act via a threshold mechanism, this parameter cancels out in the calculation (i.e. ED is in the numerator and AT=EDx365 days is in the denominator). Therefore, even if a person has lived in this area for much longer than 35 years, the risk estimates calculated in this assessment would be the same regardless of how many years is assumed for the calculation – i.e. the risk estimates are still the same for longer exposure durations.

10.2.4 Relevant environmental concentrations

The investigations by EPIC Environmental have divided up the area downgradient of the Power Station into zones for the assessment of groundwater (EPIC 2023). In this case, the data collected at the groundwater supply bores at properties in the downgradient area have been used as these data better reflect actual exposure.

Refining the assessment requires consideration of more realistic expected concentrations in each zone as inputs to the multi-pathway assessment rather than the maximum concentrations used in the screening assessment.

The zones defined by EPIC (2023) are as follows:

- Zone 1 – Callide Power Station to Muirs Rd/Baileys Lane
- Zone 2 – Muirs Rd to Dawson Highway – north of Callide Creek
- Zone 3 – Baileys Lane to Dawson Highway – south of Callide Creek
- Zone 4 – eastern site boundary of Power Station to Lake Callide
- Zone 5 – Dawson Highway to Jambin Dakenbah Rd – north of Callide Creek
- Zone 6 – Dawson Highway to Jambin Dakenbah Rd – south of Callide Creek (EPIC 2023).

As discussed in **Section 9.5**, the levels of individual PFAS in groundwater and surface water are mostly higher in water upgradient/upstream of the Callide Power Station site than in the downgradient/downstream area of interest for this assessment. This means that, while the power station may be contributing these chemicals to the local area, it is not the only source of these chemicals and may not be the major contributor to the downgradient area that is relevant for this assessment.

There are 2 chemicals reported in groundwater which do not follow this pattern, at least based on maximum concentrations – PFOS and 6:2 FTS. These 2 chemicals had maximum concentrations in groundwater in monitoring wells downgradient of the site above the maximum concentrations reported in groundwater from monitoring wells upgradient of the site. Therefore, this refined assessment has focused on these 2 chemicals.

EPIC undertook surveys of all landowners in the downgradient area – the focus of this assessment. Groundwater supply bores and water at the point of use were sampled on multiple occasions (EPIC 2023).

The survey information indicated that keeping dairy cattle is not a relevant exposure scenario for this area so uptake into milk has not been evaluated (EPIC 2023). Given the climate in the area, this is to be expected.

Data from these monitoring events (i.e. groundwater supply bores and point of use) have provided an extensive picture of the concentrations of PFOS (and PFHxS) in the area of focus for this assessment (i.e. downgradient of the site) and these data have been used in this refined assessment as these data better reflect actual exposure.

For 6:2 FTS, the picture is less clear. This refined assessment has considered the extensive data in this downgradient area. For 6:2 FTS, none of the samples from any of the groundwater supply bores on individual properties in the downgradient area reported any detections for this chemical.

Further review of the data collected at the monitoring wells close to the power station showed that this chemical was:

- only detected at these monitoring wells on a small number of occasions
- mostly was detected at concentrations similar to those upgradient of the power station site
- detected at higher concentrations in the downgradient monitoring wells than in the upgradient monitoring wells on only 1 occasion or 2 occasions depending on the wells
- not moving away from the power station monitoring wells toward the downgradient groundwater supply bores (i.e. not moving with groundwater) potentially due to it being more readily broken down (i.e. degradation).

This refined assessment has, therefore, focused on PFOS and PFHxS as the key PFAS. PFHxS has been included as the national health guidance applies to the sum of these 2 chemicals.

The ranges in concentration for PFOS and PFHxS for groundwater and water at the point of use for each property within the various zones are provided in **Tables 10.2** to **10.7**. The maximum concentration for each zone has been based on the maximum sum of PFOS+PFHxS in an individual sample.

Table 10.2: Concentrations – Zone 1

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
1		
groundwater	0.0107-0.0182	0.0069-0.0262
point of use	0.0007-0.0118	<0.0005-0.0097
2		
groundwater	0.031-0.0955	0.0124-0.0564
point of use	0.02	0.0025
3		
groundwater	0.0271-0.0459	0.0191-0.0468
point of use	0.0018-0.0158	0.0006-0.0139
4		
groundwater	0.0084-0.0125	0.0034-0.0036
point of use	0.0011-0.0077	0.0008-0.0022
5		
groundwater	0.0567-0.16	0.0151-0.033
point of use	0.0008-0.1	<0.0005-0.0198
6		
groundwater	0.0391-0.136	0.009-0.0577
point of use	0.0288	0.0036
7		
groundwater	NA	NA
point of use	0.0017-0.0092	<0.0005-0.0026
9		
groundwater	0.0043-0.007	0.001-0.0016
point of use	0.0047-0.0081	0.0006-0.0024
10		
groundwater	0.0074-0.0376	0.0022-0.0027
point of use	<0.0002	<0.0005

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
11		
groundwater	0.194-0.289	0.0707-0.117
point of use	0.015-0.289	0.0102-0.155
12		
groundwater	0.0092-0.018	0.0105-0.0242
point of use	NA	NA
13		
groundwater	<0.0018-0.0032	<0.0016-0.0015
point of use	NA	NA
14		
groundwater	0.0274-0.0453	0.0048-0.0388
point of use	NA	NA
15		
groundwater	0.198-0.257	0.0609-0.109
point of use	0.26	0.0951
17		
groundwater	0.0025-0.0045	<0.0005-0.0009
point of use	NA	NA
18		
groundwater	0.0184-0.103	0.0082-0.0146
point of use	NA	NA
20		
groundwater	0.0008-0.0094	0.0042-0.0262
point of use	0.0048-0.0075	0.0122-0.0126
22		
groundwater	0.047-0.0532	0.0397-0.043
point of use	<0.0008-0.0121	<0.0005-0.005
36		
groundwater	0.0053-0.0071	0.0012-0.0042
point of use	NA	NA
83		
groundwater	0.0432-0.0938	0.0202-0.0539
point of use	0.0681-0.0734	0.0522

Notes:
NA = not available/not relevant

The maximum PFOS+PFHxS concentration in this zone was 0.369 µg/L in groundwater and 0.444 µg/L for the point of use samples. This latter concentration has been used for calculations for this zone.

Most of the properties in this zone, however, had concentrations less than 0.1 µg/L for the sum of PFOS and PFHxS so, in addition to the calculations based on the maximum location in this zone, a concentration of 0.1 µg/L has also been used for calculations for this zone. About half of the properties in this zone had concentrations of PFOS and PFHxS that were in compliance with the Australian drinking water guideline.

Where possible, water samples were collected directly from the groundwater supply bore(s) and also from a tap at the property – i.e. point of use.

Table 10.3: Concentrations – Zone 2

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
8		
groundwater	0.0303-0.0937	0.0099-0.0167
point of use	NA	NA
16		
groundwater	0.0233-0.0305	0.0057-0.0091
point of use	0.0022-0.0173	0.0005-0.0055
19		
groundwater	0.0139-0.0285	0.0085-0.0235
point of use	0.0076	0.0069
19-T1		
groundwater	0.0044-0.0304	0.0014-0.0103
point of use	0.0109	0.0035
21		
groundwater	0.044-0.0798	0.0102-0.0136
point of use	0.0767	0.0124
28		
groundwater	0.0068-0.031	0.0012-0.0153
point of use	0.0115	<0.0016
31		
groundwater	0.0625-0.0855	0.0724-0.0935
point of use	0.0604-0.0729	0.0758-0.0922
32		
groundwater	0.0153-0.0284	0.0042-0.0084
point of use	0.0006	<0.0005
33		
groundwater	0.0288-0.0422	0.0074-0.009
point of use	0.043	0.0084
34		
groundwater	0.023-0.0422	0.006-0.0116
point of use	0.0394-0.0459	0.0094-0.0103
35		
groundwater	<0.0002	<0.0005-0.0076
point of use	NA	NA
37		
groundwater	0.0026-0.115	0.0113-0.0186
point of use	0.0034-0.0035	0.0104-0.0113
42		
groundwater	0.0435-0.0736	0.0106-0.0123
point of use	NA	NA
47		
groundwater	0.0347-0.0694	0.0061-0.0188
point of use	NA	NA
51		
groundwater	0.0056-0.0074	0.0008-0.0034
point of use	NA	NA
52		
groundwater	0.0186-0.0393	0.0047-0.008
point of use	NA	NA
55		
groundwater	0.0006-0.12	<0.0005-0.108
point of use	0.0005-0.119	<0.0005-0.0203
56		
groundwater	<0.0002	<0.0005
point of use	<0.0002	<0.0005
59		

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
groundwater	0.0808-0.106	0.0149-0.0182
point of use	NA	NA

Notes:
NA = not available/not relevant

The maximum PFOS+PFHxS concentration reported was 0.184 µg/L which has been used for calculations for this zone. Approximately half of the properties in this zone (11 out of 19) had groundwater concentrations in compliance with the Australian drinking water guidelines.

Table 10.4: Concentrations – Zone 3

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
20-T1		
groundwater	0.0071-0.0094	0.0154-0.0244
point of use	0.0122-0.0115	0.0221-0.0184
23		
groundwater	0.0081-0.0105	0.0074-0.013
point of use	0.0074-0.0085	0.0076-0.0107
24		
groundwater	0.0103-0.017	0.007-0.0219
point of use	NA	NA
25		
groundwater	0.0121-0.0237	0.0167-0.0362
point of use	0.0004-0.0229	<0.0005-0.0361
26		
groundwater	0.0063-0.0221	0.0119-0.0455
point of use	0.0201	0.0417
27		
groundwater	0.0057-0.009	0.0036-0.0097
point of use	0.0084-0.0094	0.0073-0.0084
43		
groundwater	0.0039-0.0057	0.0152-0.0159
point of use	NA	NA
44		
groundwater	NA	NA
point of use	0.0019-0.0041	0.0039-0.0074
45		
groundwater	0.0065-0.01	0.0078-0.0122
point of use	NA	NA
46		
groundwater	0.0079-0.0114	0.0088-0.0163
point of use	0.0013	0.001
48		
groundwater	0.0102-0.0128	0.0079-0.0169
point of use	0.0147	0.0168
49		
groundwater	0.0026	0.0119
point of use	NA	NA
50		
groundwater	0.0084-0.0117	0.0102-0.0157
point of use	0.0116	0.0143
53		
groundwater	<0.0008-0.0111	<0.0008-0.0155
point of use	0.0013	<0.0008
54		

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
groundwater	0.0103-0.0152	0.0199-0.0343
point of use	0.0026-0.0118	0.0064-0.0314

Notes:
NA = not available/not relevant

The maximum PFOS+PFHxS concentration reported for this zone was 0.0676 µg/L which has been used for calculations for this zone. All the properties in this zone had groundwater concentrations in compliance with the Australian drinking water guidelines.

Table 10.5: Concentrations – Zone 4

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
57		
groundwater	<0.0002-0.0002	<0.0005
point of use	NA	NA

Notes:
NA = not available/not relevant

There is only 1 property in this zone relevant for this assessment. The groundwater supply bore at this property had concentrations of PFOS and PFHxS below the drinking water guideline for PFOS+PFHxS. No further assessment is required for this zone.

Table 10.6: Concentrations – Zone 5

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
35		
groundwater	0.0464-0.0789	0.0125-0.0187
point of use	NA	NA
61		
groundwater	0.0736-0.09	0.0151-0.0224
point of use	0.0074-0.0766	0.0015-0.0197
62		
groundwater	0.0939-0.0995	0.0208-0.0289
point of use	0.0027	0.0008
63		
groundwater	0.0679-0.0803	0.0108-0.0191
point of use	0.0011	<0.0005
64		
groundwater	0.0151-0.0381	0.0088-0.0472
point of use	0.0028-0.0685	0.0013-0.0425
65		
groundwater	<0.0002-0.0012	0.0068-0.0705
point of use	NA	NA
66		
groundwater	0.0009-0.0066	0.0395-0.0596
point of use	<0.0002-0.0028	<0.0005-0.0491

Notes:
NA = not available/not relevant

The maximum PFOS+PFHxS concentration in groundwater within this zone was 0.125 µg/L. This is the concentration that has been used in calculations for all properties within this zone. One property had groundwater concentrations in compliance with the Australian drinking water guidelines.

Table 10.7: Concentrations – Zone 6

Landowner	Concentration (µg/L)	
	PFOS	PFHxS
67		
groundwater	0.0095-0.0116	0.0275-0.0406
point of use	0.0009	0.0017
68		
groundwater	0.0058-0.0085	0.0316-0.0361
point of use	0.0059	0.035
69		
groundwater	0.0058-0.0079	0.0301-0.034
point of use	0.0084	0.0295
70		
groundwater	0.0025-0.0036	0.0154-0.0174
point of use	NA	NA
71		
groundwater	0.0032-0.0046	0.0166-0.019
point of use	0.0015-0.0041	<0.0005-0.002
73		
groundwater	0.0122-0.0342	0.0177-0.0443
point of use	NA	NA
74		
groundwater	0.0094-0.0111	0.0346-0.0381
point of use	0.0113	0.037
75		
groundwater	0.0082-0.028	0.0232-0.0422
point of use	<0.0002-0.0254	<0.0005—0.0355
76		
groundwater	0.0054-0.0121	0.021-0.0308
point of use	NA	NA
77		
groundwater	0.0061-0.0193	0.0335-0.0439
point of use	NA	NA
78		
groundwater	0.0037-0.0105	0.0119-0.0279
point of use	0.0003-0.0124	<0.0005-0.0221
81		
groundwater	<0.0002-0.0042	0.0027-0.0047
point of use	NA	NA
82		
groundwater	0.0056-0.0091	0.0273-0.0299
point of use	0.0003-0.0005	<0.0005
84		
groundwater	0.0022-0.0026	0.017-0.0197
point of use	<0.0002	<0.0005

Notes:
NA = not available/not relevant

The maximum PFOS+PFHxS concentration in groundwater within this zone was 0.075 µg/L. This is almost in compliance with the Australian drinking water guideline. This concentration has been used in calculations for all properties within this zone. Most of the properties in this zone (12 out of 14) had groundwater concentrations in compliance with the Australian drinking water guidelines.

10.2.5 Risk characterisation

Approach

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure and toxicity assessment to provide a quantitative evaluation of risk. Risk is characterised separately for threshold and non-threshold carcinogenic effects. This is described below.

The quantification of potential exposure and risks for threshold effects (i.e. chemicals like PFAS which act via mechanisms where there is a threshold dose below which no effects occur) has been undertaken by comparing the estimated intake with the threshold TRV. The relevant TRV represents a tolerable intake or reference dose with consideration for background intakes and should indicate an intake that will not result in any adverse effects on health.

The calculated ratio comparing the estimated exposure to the relevant TRV is termed a Hazard or Risk Quotient (HQ or RQ). The hazard or risk index (RI/HI) is the sum of all ratios (i.e. the Hazard or Risk Quotients [HQ or RQ]) over all relevant pathways of exposure which provides some consideration of the potential for unacceptable risks due to the mix of chemicals to which people are usually exposed, particularly when the chemicals in a mix act via similar mechanisms which is assumed to be the case for PFAS.

These quotients and indices are calculated using the following equations:

$$Hazard/Risk\ quotient\ = \frac{Daily\ chemical\ intake}{TRV - background\ intake}$$

As discussed in **Section 7**, the background intake is the intake of a chemical from ambient sources that the whole population is exposed too. For PFAS, this is considered to be around 10% of the TRV.

$$Hazard/risk\ index = \sum_{all\ chemicals\ \&\ pathways} HQ/RQ$$

The interpretation of an acceptable HI/RI needs to recognise the inherent degree of conservatism that is built into the establishment of appropriate guideline (threshold) values (using many uncertainty factors) and also built into the exposure assessment. An acceptable HI/RI is outlined in the ASC NEPM as being equal to or less than 1 (NEPC 1999 amended 2013b).

In reviewing and interpreting the calculated HI/RI for this assessment the following is noted:

- A HI/RI less than or equal to a value of 1 (where intake or exposure is less than or equal to the threshold – i.e. the toxicity reference value) represents no cause for concern (i.e. is considered acceptable) (as per risk assessment industry practice and national guidance from Australian health authorities – i.e. ASC NEPM and enHealth (enHealth 2012a; NEPC 1999 amended 2013b))

- A HI/RI greater than 1 requires further consideration within the context of the assessment undertaken, particularly with respect to the level of conservatism in the assumptions adopted for the quantification of exposure and the level of uncertainty within the toxicity (threshold) values adopted. It may indicate that risks are above an acceptable level as per risk assessment industry practice and national guidance from Australian health authorities – i.e. ASC NEPM and enHealth (enHealth 2012a; NEPC 1999 amended 2013b) once assumptions and exposure pathways are considered to be adequately refined to appropriate values for the site specific situation.

Calculated Risks – general

Tables 10.8-10.12 present summaries of the HQ/RQs for each pathway assessed and the total HI/RIs for each zone calculated for all exposures relevant in the off-site area downgradient of Callide Power Station.

A range of exposure scenarios have been assessed including:

- ingestion of groundwater for drinking (drinking water guidelines include use of water for cooking, showering etc as well as drinking)
- incidental ingestion of groundwater during use of water for farming purposes
- incidental ingestion of groundwater during domestic uses of water (e.g. filling pools, sprinkler play, cleaning etc)
- consumption of home produced fruit/vegetables which may contain PFAS due to irrigation by groundwater
- consumption of home produced eggs or meat which may contain PFAS due to the chickens or cattle drinking groundwater
- consumption of home produced meat which may contain PFAS due to the cattle consuming fodder grown on the property which is irrigated with groundwater.

Each of these exposure scenarios has been assessed in isolation. In addition, a number of combinations of these exposure scenarios have also been evaluated.

As noted in **Section 10.2.4**, the groundwater at the single property in Zone 4 only reported concentrations well below drinking water guidelines, so no further refined assessment has been undertaken for this zone.

Exposure via consumption of fish or during incidental ingestion while recreating in Callide Creek has been considered in **Sections 10.3** and **10.4**.

The values presented in these tables (and all other risk calculations) are rounded to 1 significant figure reflecting the level of certainty inherent in risk calculations. Detailed calculations are presented in **Appendix E.**

Zone 1

Table 10.8a: Calculated Risks – Zone 1 – maximum concentration

Receptor/Exposure Pathway	Threshold Risk (HI/RI) Adults	Children
Individual exposure pathways		
Ingestion of groundwater for drinking	0.7	1
Incidental ingestion of groundwater during use of water for farming purposes	0.007	0.03
Incidental ingestion of groundwater during use of water for domestic purposes	0.007	0.03
Consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater	0.02	0.01
Consumption of home grown eggs which may contain PFAS due to the chickens drinking groundwater	0.1	0.4
Consumption of home grown meat which may contain PFAS due to stock watering using groundwater[1]	0.07/0.2	0.2/0.5
Combination exposure scenarios		
Drinking groundwater and consuming home grown fruit and vegetables	0.7	1
Drinking groundwater and consuming home grown eggs	0.8	1
Drinking groundwater and consuming home grown meat[2]	0.9	**1.5**
Drinking groundwater and consuming home grown eggs and meat[2]	1	**2**
Acceptable Risk (based on Australian health guidance)	**≤1**	**≤1**

Notes:

1 The 2 values listed are for the situation where cattle eat fodder that is not irrigated by the groundwater or surface water that contains PFAS and for the situation where cattle eat fodder that is irrigated by the groundwater or surface water. The higher value has been used in the combination scenarios.

2 This value is the maximum for any of the properties within Zone 1. It assumes that people use groundwater as their sole source of drinking water and that they eat eggs and meat (or just meat) from poultry/cattle grown on the property and exposed via stock water (for poultry and cattle) and consumption of fodder irrigated with groundwater (for the cattle). Based on the information available, this combination is unlikely to have occurred. Further discussion is provided below.

Table 10.8b: Calculated Risks – Zone 1 – refined assessment based on 0.1 µg/L for PFOS+PFHxS

Receptor/Exposure Pathway	Threshold Risk (HI/RI) Adults	Children
Individual exposure pathways		
Ingestion of groundwater for drinking	0.2	0.3
Incidental ingestion of groundwater during use of water for farming purposes	0.002	0.007
Incidental ingestion of groundwater during use of water for domestic purposes	0.002	0.007
Consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater	0.004	0.002
Consumption of home grown eggs which may contain PFAS due to the chickens drinking groundwater	0.03	0.08
Consumption of home grown meat which may contain PFAS due to stock watering using groundwater[1]	0.02/0.04	0.04/0.1
Combination exposure scenarios		
Drinking groundwater and consuming home grown fruit and vegetables	0.2	0.3
Drinking groundwater and consuming home grown eggs	0.2	0.4
Drinking groundwater and consuming home grown meat	0.2	0.4
Drinking groundwater and consuming home grown eggs and meat	0.3	0.5
Acceptable Risk (based on Australian health guidance)	**≤1**	**≤1**

Notes:

1 The 2 values listed are for the situation where cattle eat fodder that is not irrigated by the groundwater that contains PFAS and for the situation where cattle eat fodder that is irrigated by groundwater. The higher value has been used in the combination scenarios.

These results indicate the following for Zone 1:

- Risks for each of the following individual exposure pathways are acceptable (based on the guidance from national health authorities):
  - ingestion of groundwater for drinking (and all household uses of water)
  - incidental ingestion of groundwater during use of water for farming purposes
  - incidental ingestion of groundwater during outdoor domestic uses of water
  - consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater
  - consumption of home grown eggs which may contain PFAS due to chickens drinking groundwater
  - consumption of home grown meat which may contain PFAS due to stock watering using groundwater and consumption of fodder by the cattle where that fodder is irrigated with the relevant groundwater.
- This is the case for both sets of calculations for this zone – for both the maximum and refined assessment.
- If the following exposure pathways are combined:
  - drinking groundwater (and incidental ingestion of water during farm and/or domestic activities)
  - consuming home grown fruit & vegetables

  OR
  - drinking groundwater (and incidental ingestion of water during farm and/or domestic activities)
  - consuming home grown eggs

  then the risks from exposure to PFAS from groundwater are acceptable based on Australian health guidance for both the maximum and refined assessment (i.e. HI/RI≤1).
- If the following exposure pathways are combined:
  - drinking groundwater (and incidental ingestion of water during farm and/or domestic activities)
  - consuming home grown eggs
  - consuming home grown meat
  - consuming home grown fruit & vegetables

    or
  - drinking groundwater (and incidental ingestion of water during farm and/or domestic activities)
  - consuming home grown meat
  - consuming home grown fruit & vegetables

  then the risks from exposure to PFAS arising from groundwater are acceptable based on Australian health guidance for the refined assessment (i.e. where the water concentration of PFOS+PFHxS is 0.1 µg/L or less).
- For the maximum locations (i.e. where the maximum groundwater concentration of PFOS+PFHxS was 0.3-0.4 µg/L), either of the following exposure pathway combinations:

- drinking groundwater (and incidental ingestion of water during farm and/or domestic activities)
- consuming home grown eggs
- consuming home grown meat
- consuming home grown fruit & vegetables

or

- drinking groundwater (and incidental ingestion of water during farm and/or domestic activities)
- consuming home grown meat
- consuming home grown fruit & vegetables

results in a risk estimate that is slightly elevated based on Australian health guidance.

- It is important to note that these calculations (as per **Table 10.8a**) assume that people living/working on those properties with the highest concentrations of PFAS in groundwater will:
  - use the groundwater as their sole source of drinking water and for all farming and/or domestic activities where incidental ingestion could occur
  - consume 100% of eggs from chickens kept at the property (where relevant)
  - consume 35% of meat from livestock kept at the property which are given groundwater to drink and that eat fodder that has been irrigated with groundwater
  - consume 35% of fruit and vegetables from produce grown at the property and irrigated with groundwater.

  It is understood that this combination is unlikely to have occurred.

Zone 2

Table 10.9: Calculated Risks – Zone 2

Receptor/Exposure Pathway	Threshold Risk (HI/RI) Adults	Threshold Risk (HI/RI) Children
Individual exposure pathways		
Ingestion of groundwater for drinking	0.3	0.5
Incidental ingestion of groundwater during use of water for farming purposes	0.003	0.01
Incidental ingestion of groundwater during use of water for domestic purposes	0.003	0.01
Consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater	0.008	0.004
Consumption of home grown eggs which may contain PFAS due to the chickens drinking groundwater	0.05	0.15
Consumption of home grown meat which may contain PFAS due to stock watering using groundwater[1]	0.02/0.06	0.07/0.2
Combination exposure scenarios		
Drinking groundwater and consuming home grown fruit and vegetables	0.3	0.5
Drinking groundwater and consuming home grown eggs	0.4	0.65
Drinking groundwater and consuming home grown meat	0.4	0.7
Drinking groundwater and consuming home grown eggs and meat	0.4	0.85
Acceptable Risk (based on Australian health guidance)	**≤1**	**≤1**

Notes:

1 The 2 values listed are for the situation where cattle eat fodder that is not irrigated by the groundwater that contains PFAS and for the situation where cattle eat fodder that is irrigated by groundwater. The higher value has been used in the combination scenarios.

Zone 3

Table 10.10: Calculated Risks – Zone 3

Receptor/Exposure Pathway	Threshold Risk (HI/RI) Adults	Children
Individual exposure pathways		
Ingestion of groundwater for drinking	0.1	0.2
Incidental ingestion of groundwater during use of water for farming purposes	0.001	0.005
Incidental ingestion of groundwater during use of water for domestic purposes	0.001	0.005
Consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater	0.003	0.002
Consumption of home grown eggs which may contain PFAS due to the chickens drinking groundwater	0.02	0.06
Consumption of home grown meat which may contain PFAS due to stock watering using groundwater[1]	0.01/0.03	0.03/0.07
Combination exposure scenarios		
Drinking groundwater and consuming home grown fruit and vegetables	0.1	0.2
Drinking groundwater and consuming home grown eggs	0.1	0.3
Drinking groundwater and consuming home grown meat	0.1	0.3
Drinking groundwater and consuming home grown eggs and meat	0.2	0.3
Acceptable Risk (based on Australian health guidance)	**≤1**	**≤1**

Notes:

1 The 2 values listed are for the situation where cattle eat fodder that is not irrigated by the groundwater that contains PFAS and for the situation where cattle eat fodder that is irrigated by groundwater. The higher value has been used in the combination scenarios.

Zone 5

Table 10.11: Calculated Risks – Zone 5

Receptor/Exposure Pathway	Threshold Risk (HI/RI) Adults	Children
Individual exposure pathways		
Ingestion of groundwater for drinking	0.2	0.3
Incidental ingestion of groundwater during use of water for farming purposes	0.002	0.009
Incidental ingestion of groundwater during use of water for domestic purposes	0.002	0.009
Consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater	0.006	0.003
Consumption of home grown eggs which may contain PFAS due to the chickens drinking groundwater	0.04	0.1
Consumption of home grown meat which may contain PFAS due to stock watering using groundwater[1]	0.02/0.05	0.05/0.1
Combination exposure scenarios		
Drinking groundwater and consuming home grown fruit and vegetables	0.2	0.3
Drinking groundwater and consuming home grown eggs	0.2	0.4
Drinking groundwater and consuming home grown meat	0.25	0.4
Drinking groundwater and consuming home grown eggs and meat	0.3	0.5
Acceptable Risk (based on Australian health guidance)	**≤1**	**≤1**

Notes:

1 The 2 values listed are for the situation where cattle eat fodder that is not irrigated by the groundwater that contains PFAS and for the situation where cattle eat fodder that is irrigated by groundwater. The higher value has been used in the combination scenarios.

Zone 6

Table 10.12: Calculated Risks – Zone 6

Receptor/Exposure Pathway	Threshold Risk (HI/RI) Adults	Threshold Risk (HI/RI) Children
Individual exposure pathways		
Ingestion of groundwater for drinking	0.1	0.2
Incidental ingestion of groundwater during use of water for farming purposes	0.001	0.006
Incidental ingestion of groundwater during use of water for domestic purposes	0.001	0.006
Consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater	0.003	0.002
Consumption of home grown eggs which may contain PFAS due to the chickens drinking groundwater	0.02	0.06
Consumption of home grown meat which may contain PFAS due to stock watering using groundwater[1]	0.01/0.03	0.03/0.08
Combination exposure scenarios		
Drinking groundwater and consuming home grown fruit and vegetables	0.1	0.2
Drinking groundwater and consuming home grown eggs	0.1	0.3
Drinking groundwater and consuming home grown meat	0.1	0.3
Drinking groundwater and consuming home grown eggs and meat	0.15	0.4
Acceptable Risk (based on Australian health guidance)	**≤1**	**≤1**

Notes:

1 The 2 values listed are for the situation where cattle eat fodder that is not irrigated by the groundwater that contains PFAS and for the situation where cattle eat fodder that is irrigated by groundwater. The higher value has been used in the combination scenarios.

These results indicate the following for Zones 2, 3, 5 and 6:

- Risks for each of the following individual exposure pathways are acceptable (based on the guidance from national health authorities):
  - ingestion of groundwater for drinking (and all household uses of water)
  - incidental ingestion of groundwater during use of water for farming purposes
  - incidental ingestion of groundwater during outdoor domestic uses of water
  - consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater
  - consumption of home grown eggs which may contain PFAS due to chickens drinking groundwater
  - consumption of home grown meat which may contain PFAS due to stock watering using groundwater and consumption of fodder by the cattle where that fodder is irrigated with the relevant groundwater.
- Risks resulting from combining drinking groundwater with all or some of the pathways based on consuming home grown produce which may be impacted by PFAS are acceptable based on Australian health guidance.

10.3 Swimming/recreating in Callide Creek

Along with considering the extraction and use of groundwater at the properties downgradient of Callide Power Station, it is also important to consider potential for exposure to PFAS in surface water in Callide Creek, if used for swimming or other recreational activities.

The photos in **Figure 10.1** show that the creek may often be quite still, resulting in rapid growth of algae and aquatic plants making it less pleasant as an area for swimming. At other times, when water is released from Lake Callide, this would not be the case.

The risks due to use of surface water for swimming and recreating have been assessed using the Australian recreational water quality guidelines (NHMRC 2008, 2019).

Recreational water quality guidelines are based on the assumption that people could ingest up to 0.2 L (i.e. 200 mL) of water when they swim (NHMRC 2008). This is a high end estimate based on recommendations from the World Health Organisation that people consume around 0.05 L (i.e. 50 mL) of water per hour while they are swimming and that they might swim for a number of hours on a particular day.

This means that recreational water quality guidelines are calculated by multiplying the drinking water guideline by 10 to convert the value from one based on drinking 2 L of water per day to one based on incidentally ingesting 0.2 L of water per day while swimming. For PFOS+PFHxS, it is assumed people swim or recreate in the water body o 150 days per year (i.e. almost every second day).

The NHMRC guidance is under review as the World Health Organisation recently updated their guidance (WHO 2021). The new WHO guidance indicates that ingestion is likely to be around 0.1 L of water when swimming not 0.2 L which means, in the future, recreational water quality guidelines may be determined by multiplying the drinking water guideline by 20. This means the approach adopted here is conservative.

Section 9.3.1 shows that the maximum concentrations of the key PFAS were less than the relevant recreational water quality guideline. This means the concentrations in upstream and downstream locations along Callide Creek are acceptable for recreation based on Australian health guidance.

No further assessment is, therefore, required for swimming/recreating in Callide Creek.

10.4 Food Standards trigger points – fish/seafood

10.4.1 Approach

There were a number of species discussed in **Section 9.4** for which the PFOS concentrations were above the FSANZ trigger point in the screening risk assessment. A detailed/refined assessment is, therefore, required.

The detailed/refined assessment needs to consider:

- how likely people are to be able to catch species that would be desirable to eat on a regular basis

- how this impacts on the way the FSANZ trigger point has been calculated (i.e. whether there is any adjustment that can be made).

The Food Standards Code[7] provides guidance on the presence of a range of chemicals (naturally occurring ones, agricultural chemicals or food processing chemicals) or microorganisms in the Australian food supply. The limits outlined in this code are legal requirements. The calculation includes consideration of the normal amount that people eat for each particular food type as well as the acceptable intake of a chemical.

There are no limits in the code for PFAS.

Food Standards Australia and New Zealand (FSANZ) has, however, determined trigger points for the levels of PFAS that can be in different food types without likelihood of harm. These values are not legal limits. They have been determined using a conservative exposure scenario and are provided to inform environmental assessments.

FSANZ has provided the detail about how they were calculated. These details about how this calculation was undertaken allows the trigger point to be adjusted to provide a value that is more relevant for the location of interest, where required.

Adjustments to the national guidelines from FSANZ can be undertaken based on a more appropriate understanding of aspects such as:

- how much fish people actually eat over a year or a lifetime (i.e. average instead of high end value)
- how much fish people could catch in a location (i.e. species people could eat, size of fish in line with size limits, would there be enough fish to catch every day of the week all year round)
- how popular fishing is in an area
- if there is other guidance that applies to eating fish.

The health based screening criteria for consumption of fish developed by FSANZ, in regard to PFAS concentrations, are based on the following assumptions:

- body weight of a small child (2-6 years old) (19 kg)[8]
- high end child consumer (P90) (i.e. a child consumes 73 g (0.073 kg) of fish every day)
- toxicity reference value (TRV) for PFOS + PFHxS (0.02 µg/kg/d) (FSANZ 2017c).

This means the trigger point of 5.2 µg/kg for the concentration of PFOS+PFHxS in fish is protective for a preschool child (i.e. 3-4 year old based on data from the Australian Bureau of Statistics) who eats 73 g of fish every day of the year throughout their childhood.

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[7] https://www.foodstandards.gov.au/code/Pages/default.aspx

[8] FSANZ uses a different body weight for a small child compared to that normally used in contaminated land investigations. FSANZ uses 19 kg and this was used in the calculation of the FSANZ trigger points but contaminated land investigations use 15 kg based on guidance in the ASC NEPM.

It is appropriate to use these types of assumptions to calculate a conservative generic criteria to use to screen data in the first instance. This allows monitoring results to be easily classified to indicate sites that need no further evaluation.

National guidelines can, however, be adjusted based on a better understanding of fish consumption patterns to make them more site specific.

Information collected by FSANZ to understand consumption rates in Australia comes from phone surveys which ask people what they have eaten over the last couple of days (i.e. when survey is undertaken). These data are then used to indicate normal daily ingestion rates over the longer term.

The information about fish consumption indicates that only a small proportion of children eat fish on any given day – around 7% (FSANZ 2017c). Focusing on those children, the average amount of fish those children ate was 28-34 g per day and the 90th percentile amount was 60-72 g per day (i.e. high end value). As noted, the value used in the calculation of the FSANZ trigger point was 73 g/day.

For adults surveyed by FSANZ, the average amount people ate (for the people who ate fish on the day) was 50-56 g per day and the 90th percentile amount was 119-143 g per day. These findings provide robust values that can be considered when adjusting national guidelines.

Another matter that may allow a national guideline to be adjusted is whether FSANZ has issued other guidance unrelated to PFAS which may be relevant. In the case of eating fish, FSANZ has another advisory stating that everyone in Australia should limit their consumption of fish to 2-3 meals per week. This advisory is based on ensuring the intake of mercury is at acceptable levels[9]. Mercury occurs naturally in fish and levels depend on the species and the location. Given that this is national guidance for the entire population, the assumption that people eat 2-3 meals per week instead of every day can be considered in site specific assessments based on this example from FSANZ.

Guidance from the USEPA also indicates that this adjustment approach for addressing site specific situations is appropriate[10]. Examples of how they use this guidance to set guidelines for specific locations or specific species is shown at the following websites:

- https://www.epa.gov/choose-fish-and-shellfish-wisely
- https://www.epa.gov/fish-tech

Therefore, it is considered to be permissible and appropriate to adjust guidelines like these FSANZ trigger points for PFAS to make a risk assessment more site specific/realistic. As a result, the FSANZ trigger point has been adjusted for this assessment based on exposure parameters that are more relevant for this location.

[9] http://www.foodstandards.gov.au/consumer/chemicals/mercury/Pages/default.aspx
[10] https://www.epa.gov/fish-tech/epa-guidance-developing-fish-advisories

10.4.2 Adjusted trigger points

The calculation by FSANZ used the following equation:

$$Guideline\ value\ (\mu g\ per\ kg) = \frac{toxicity\ reference\ value\ (\mu g\ per\ kg\ bw\ per\ day) * \ body\ weight\ (kg)}{fish\ ingestion\ rate\ (kg\ per\ day)}$$

There are a number of adjustments that can be considered for this detailed/refined assessment including:

- Number of meals per week
- Use of average as well as high end amounts of fish eaten per meal
- Focus on adults as well as children.

The first set of adjustments focuses on the use of average ingestion rates and considers adults as well as children. The adjusted parameter values are listed in **Table 10.13** and adjusted trigger points are listed in **Table 10.14**.

Table 10.13: Adjusted parameter values for use in trigger point calculation (FSANZ 2017c)

Parameter	Parameter Value	Comment
Toxicity reference value (µg/kg/d)	0.02	Value used in generic guideline for PFOS + PFHxS
Child Relevant Parameters		
Fish Ingestion Rate (kg/day) – P90 (i.e. high end consumer)	0.073	Value used in generic guideline
Fish Ingestion Rate (kg/day) – Mean for consumers	0.024	Value from FSANZ survey data to allow modification based on site-specific information
Body Weight (kg)	19	Value used in generic guideline
Adult Relevant Parameters		
Fish Ingestion Rate (kg/day) – P90 (i.e. high end consumer)	0.123	Value from FSANZ survey data to allow modification based on site-specific information
Fish Ingestion Rate (kg/day) – Mean for consumers	0.045	Value from FSANZ survey data to allow modification based on site-specific information
Body Weight (kg)	70	Standard assumption in Australia

When these parameters are used in these calculations, the following adjusted trigger points can be determined.

Table 10.14: Proposed adjusted trigger points for fish consumption – based on average consumption and values for adults

Proposed adjustment	Trigger point (mg/kg)	Trigger point (µg/kg)
Current generic national trigger point	0.0052	5.2
Child		
Average	0.016	16
Adult		
P90	0.011	11
Mean	0.031	31

All of the adjusted trigger points listed in **Table 10.14** still assume that a person will eat fish from Callide Creek every day all year round.

The second set of adjustments are based on adjusting how many meals of fish caught in Callide Creek a person might eat per week. The number of meals per week can be adjusted as it is unlikely that there are sufficient fish of sufficient size for people to fish regularly or all year round within Callide Creek.

Tables 10.15 and **10.16** provide adjusted exposure parameters and trigger points assuming people consume fish from Callide Creek 3 times per week (i.e. FSANZ recommended maximum consumption rate based on mercury levels) and 1 time per week (i.e. likely maximum consumption rate based on nature of creek/habitat and species availability).

Table 10.15: Recommended parameter values adjusted for realistic exposure frequencies (FSANZ 2017c)

Parameter	Parameter Value	Comment
Toxicity reference value (µg/kg/d)	0.02	Value used in generic guideline for PFOS + PFHxS
Child Relevant Parameters		
Fish Ingestion Rate (kg/day) – P90 (i.e. high end consumer)	0.031	Value used in generic guideline but adjusted for 3 meals per week instead of 7
Fish Ingestion Rate (kg/day) – P90 (i.e. high end consumer)	0.010	Value used in generic guideline but adjusted for 1 meal per week instead of 7
Fish Ingestion Rate (kg/day) – average	0.010	Value from FSANZ survey data to allow modification based on site-specific information – adjusted for 3 meals per week
Fish Ingestion Rate (kg/day) – average	0.003	Value from FSANZ survey data to allow modification based on site-specific information – adjusted for 1 meal per week
Body Weight (kg)	19	Value used in generic guideline
Adult Relevant Parameters		
Fish Ingestion Rate (kg/day) – P90 (i.e. high end consumer)	0.052	Value from FSANZ survey data to allow modification based on site-specific information – adjusted for 3 meals per week
Fish Ingestion Rate (kg/day) – P90 (i.e. high end consumer)	0.018	Value from FSANZ survey data to allow modification based on site-specific information – adjusted for 1 meal per week
Fish Ingestion Rate (kg/day) – average	0.019	Value from FSANZ survey data to allow modification based on site-specific information – adjusted for 3 meals per week
Fish Ingestion Rate (kg/day) – average	0.006	Value from FSANZ survey data to allow modification based on site-specific information – adjusted for 1 meal per week
Body Weight (kg)	70	Standard assumption in Australia

Table 10.16: Proposed adjusted trigger points based on exposure frequencies

Proposed adjustment	Trigger point (mg/kg)	Trigger point (µg/kg)
Current generic national trigger point	0.0052	5.2
3 meals per week		
Child (P90)	0.012	12
Child (average)	0.038	38
Adult (P90)	0.027	27
Adult (average)	0.074	74
1 meal per week		
Child (P90)	0.038	38
Child (average)	0.127	127
Adult (P90)	0.078	78
Adult (average)	0.233	233

These chemicals are known to be routinely present in aquatic systems in urban areas due to their historic widespread use in household products as well as at industrial sites (as discussed in **Section**

5). It is not straightforward to remove such chemicals from waterways when they are sourced from diffuse sources around homes and, in such circumstances, it is normal practice to provide dietary advice to ensure people who fish in the area can make appropriate choices.

It is noted that:

- Consumption of fish by people is an environmental value that is considered relevant for Callide Creek.
- There are limited species present in Callide Creek that are targeted by recreational fishers or that could grow to legal size.
- The size of the creek means that, even for fish that are relevant for size and fisher preference, the number of fish that could be present in the creek would limit how many people could obtain fish from the creek for routine/regular consumption.
- A range of jurisdictions (state, national and international) establish conservative screening guidelines for indicating when fish may be contaminated to a level requiring action and then adjust those conservative guidelines using waterbody specific information to provide site specific guidance to ensure people have appropriate local information for decision making.

Relevant adjustments to the national FSANZ trigger point for fish give an adjusted trigger point of around 40 µg/kg using the standard parameters used by FSANZ with only an adjustment to 1 meal per week instead of 7 meals per week (i.e. child and P90 consumption). This value is also relevant for a child eating average amounts of fish for 3 meals per week.

All samples collected for species relevant for consumption by people are at or below this adjusted trigger point, so no further assessment is required.

10.5 Uncertainties

10.5.1 General

The ASC NEPM requires risk assessments to include consideration of the uncertainties present in any such assessment. Uncertainties are present because not every aspect of interest can be measured in an investigation or because the state of knowledge is limited (NEPC 1999 amended 2013b).

Uncertainty in any assessment refers to a lack of knowledge (that could be better refined through the collection of additional data or conduct of additional studies) and is an important aspect of the risk assessment process. An assessment of uncertainty is usually a qualitative process relating to the selection and rejection of specific data, estimates or scenarios within the risk assessment. In general, to compensate for uncertainty, conservative assumptions are often made that result in an overestimate rather than an underestimate of risk.

In general, the uncertainties and limitations of any risk assessment can be classified into the following categories, where uncertainties relevant to each have been addressed within the report (as noted):

- Sampling and analysis (see **Section 10.5.2**)
- Exposure assessment (see **Section 10.5.3**)

- Toxicity assessment (see **Section 7.8**)
- Other PFAS (see **Section 10.5.4**).

10.5.2 Sampling and analysis

Groundwater and surface water sampling has occurred at the site targeting both upgradient and downgradient locations plus areas within the Callide Power Station site. Multiple rounds of both groundwater and surface water data have been collected over a number of years. The data available are considered relevant and appropriate for this assessment of risk.

10.5.3 Exposure assessment

The quantification of exposure has adopted a number of conservative assumptions. The values adopted for the purpose of quantifying exposure are point values that are derived from a wide range of physiological or behavioural values that are better defined using a distribution. It is overly complex to present the assessment based on distributions hence the point values identified provide an approximation of RME.

A number of approaches and assumptions have been adopted in this assessment that are considered conservative – i.e. they result in an overestimate rather than an underestimate of risk. Such approaches and assumptions include:

- use of the maximum groundwater /surface water concentration from a single location in a zone to calculate risks across the whole zone for all exposure pathways.
- use of maximum concentration measured in fish/seafood to assess potential risks from their consumption.

10.5.4 Other PFAS

General

This assessment has focused on the PFAS that are considered key within national guidance – i.e. PFOS, PFHxS and PFOA (HEPA 2020). The presence of other PFAS has been considered in this uncertainty section to confirm that conclusions based on the key PFAS do not change when the other PFAS are included.

Groundwater – human health

The screening assessment for groundwater (human health) is shown in **Table 10.17**.

Table 10.17: Screening risk assessment – groundwater – other PFAS – human health

Detected PFAS	Maximum Concentration – upgradient (µg/L)	Maximum Concentration – downgradient (µg/L)	Screening criteria (µg/L) – recreational	Screening criteria (µg/L) – drinking
Chemicals in Australian Guidance				
PFOS+PFHxS	0.388	0.826	2	0.07
PFOA	0.0175	0.0105	10	0.56
Additional review of other detected individual PFAS				
PFBS	0.2170	0.0767		
PFPeS	0.15	0.06		
PFHpS	0.0063	0.0158		

Detected PFAS	Maximum Concentration – upgradient (µg/L)	Maximum Concentration – downgradient (µg/L)	Screening criteria (µg/L) – recreational	Screening criteria (µg/L) – drinking
Chemicals in Australian Guidance				
6:2 FTS	0.05	0.3140		
PFBA	0.9540	0.048		
PFPeA	2.24	0.017		
PFHxA	0.9260	0.1320		
PFHpA	0.18	0.0032		
PFNA	0.0007	ND		
SUM of PFOS like	0.8113	1.2925	2	0.07
SUM of PFOA like	4.3182	0.2107	10	0.56

Notes:
Screening criteria used here are from **Table 7.2**
ND = not detected

This screening assessment indicates that, while a range of different PFAS were detected, the primary PFAS present at concentrations higher than guidelines at downgradient monitoring wells were PFOS and PFHxS (i.e. >60% of sum of all PFOS like individual PFAS). As a result, the detailed assessment of PFOS+PFHxS concentrations is appropriate.

Surface water – human health

The screening assessment for surface water (human health) is shown in **Table 10.18**.

Table 10.18: Screening risk assessment – surface water – other PFAS – human health

Detected PFAS	Maximum concentration upstream of the power station (µg/L)	Maximum Concentration downstream of the power station (µg/L)	Screening criteria (µg/L) – recreation	Screening criteria (µg/L) – drinking
Chemicals in Australian Guidance				
PFOS+PFHxS	0.597	0.12	2	0.07
PFOA	0.0984	0.002	10	0.56
Additional review of other detected individual PFAS				
PFBS	0.188	0.0111		
PFPeS	0.0528	0.0113		
PFHpS	0.0214	0.0019		
6:2 FTS	0.24	0.01		
8:2 FTS	0.013	ND		
PFBA	0.8190	0.022		
PFPeA	3.02	0.0265		
PFHxA	1.28	0.0138		
PFHpA	0.706	0.0052		
PFNA	0.0189	ND		
PFDA	0.0013	ND		
PFDoDA	ND	0.0011		
SUM of PFOS like	1.1122	0.1543	2	0.07
SUM of PFOA like	5.9436	0.0706	10	0.56

Notes:
Screening criteria used here are from **Table 7.2**

This screening assessment indicates that, while a range of different PFAS were detected, the primary PFAS present at concentrations higher than guidelines at downstream monitoring locations were PFOS and PFHxS (i.e. >75% of sum of all PFOS like individual PFAS). As a result, a detailed assessment of PFOS+PFHxS concentrations is appropriate.

Section 11. Refined assessment – ecological

11.1 General

Section 9.3.2 provides a screening assessment of the potential for individual PFAS in Callide Creek to have effects by comparing the concentrations found in the creek to national water quality guidelines from the PFAS NEMP (HEPA 2020).

The findings of the screening assessment were:

- PFOA and PFOA like chemicals were not at concentrations above water quality guideline values protective of ecosystems assuming so do not require further refined assessment.
- PFOS and some of the PFOS like chemicals were reported at levels above both the 95% and 99% species protection value, so further refined assessment is required.

It is important to note that the 99% species protection guideline value only applies to PFAS that have the potential to bioaccumulate. Chemicals like PFOS and PFHxS are known to have potential to bioaccumulate.

Chemicals like PFBS, PFPeA, 8:2 FTS and 6:2 FTS, which have also been detected in surface water downstream of Callide Power Station (see **Section 11.5**), are known to not have potential to bioaccumulate. For these chemicals, only the 95% species protection guideline value is relevant.

Therefore, the chemicals that require consideration in this refined assessment are:

- PFOS, PFHxS in relation to bioaccumulation
- PFOS, PFHxS, PFBS and 6:2 FTS in relation to direct toxicity.

The most appropriate approach for assessing risks in relation to bioaccumulation for PFOS is biota sampling directly from the waterway of interest to see if bioaccumulation is actually occurring. This has been undertaken for this site as discussed in **Section 9.4.3**.

As noted, PFOS was almost the only PFAS detected in the biota samples. There was 1 sample that reported PFHxS at the limit of reporting. This means that, even though PFHxS or PFHpS have potential to bioaccumulate, there were insufficient levels of these 2 chemicals present in Callide Creek to accumulate in the fish and other species to levels above the limits of reporting. No further assessment is, therefore, required in relation to bioaccumulation of PFHxS or PFHpS.

This refined assessment has, therefore, focused on:

- PFOS – bioaccumulation and direct toxicity
- PFBS – direct toxicity
- PFHxS – direct toxicity
- 6:2 FTS – direct toxicity.

11.2 Direct ecotoxicity to aquatic organisms

11.2.1 General

The focus of this section is the potential for direct ecotoxicity for aquatic organisms. This aspect is normally addressed using the 95% species protection guideline values for PFOS (and other PFAS where relevant).

11.2.2 Refined assessment

To address potential for direct ecotoxicity, the 95% species protection guideline value was applied to the data in **Section 9.3.2** for the key PFAS (i.e. surface water results for Callide Creek). The value listed in the PFAS NEMP for this guideline value is 0.13 µg/L (HEPA 2020).

Appendix D provides a detailed discussion of the issues with the development of guidelines for PFOS, the new draft guideline for PFOS released for discussion in 2023 and the new data and software that now exist. This discussion provides support for adopting the updated draft PFOS 95% species protection guideline value published in 2023 to assess whether direct ecotoxicity is of concern at this site.

Therefore, the more appropriate value to adopt for this assessment is 0.48 µg/L for PFOS (and PFOS like chemicals). The maximum concentrations of PFOS and PFHxS are below this value – i.e. the results are in compliance with the guideline value.

This updated draft value is considered appropriate for use in this assessment as it is considered conservative based on the following:

- Canadian guideline for ecosystem protection is 6.8 µg/L
- USEPA guideline for ecosystem protection is 8.4 µg/L
- When new data and new software are applied to the dataset for PFOS in Australia, the draft value is likely to increase – potentially as high as 1 µg/L.

As a result, it is expected that there would be no direct ecotoxicity effects in Callide Creek and Lake Callide (i.e. downstream of the power station) due to the presence of these PFAS as the maximum concentrations for PFOS and PFHxS are below 0.48 µg/L.

The maximum concentrations of PFBS and 6:2 FTS downstream of the power station are also well below this value so there would be no direct ecotoxicity effects in Callide Creek and Lake Callide due to the presence of these PFAS.

11.3 Dietary guideline for birds

11.3.1 Approach

The guidelines adopted in the PFAS NEMP (HEPA 2020) for screening were those developed by Environment Canada (Environment Canada 2018).

Just as for the human health guidelines, it is important to understand how such criteria were determined to interpret what these results may mean for this creek and whether there is potential for adjustment to address site-specific matters.

The dietary guideline for birds from Canada is based on the following assumptions:

- results from long term studies of toxicity of PFOS for 3 bird species (mallard duck, northern bobwhite quail and Japanese quail – these are the species of birds used in pesticide assessments, so they are the ones for which tests have been developed and which are kept for such purposes)

- most sensitive toxicity result was a lowest observed effect dose of 772 µg/kg bw/d for the northern bobwhite
- uncertainty factor of 100 was applied to this result giving a toxicity reference value (TRV) of 7.7 µg/kg bw/d
- This TRV was then adjusted for the maximum ratio of food intake to body weight in their database to address potential for exposure – 0.94 kg food/kg body weight (result for Wilson's storm-petrel – this means that it is assumed that a bird eats almost its entire body weight every day of its life)
- This gives the dietary guideline of 0.0082 mg/kg ww (Environment Canada 2018) based on the calculation as follows – 7.7/0.94 = 8.2 µg/kg ww (in the fresh food as consumed by the bird) i.e. 0.0082 mg/kg ww.

The PFAS NEMP has chosen to apply this guideline to the sum of PFOS+PFHxS but it is based on PFOS toxicity data only – i.e. it has been assumed that PFHxS has similar toxicity to PFOS for birds.

11.3.2 Refined assessment

Food ingestion rate to body weight ratio

The information about ratio of food intake to body weight used in this calculation comes from the CCME Protocol for the Derivation of Canadian Tissue Residue Guidelines for the Protection of Wildlife that Consume Aquatic Biota (CCME 1998).

In this guidance document, Table 1 gives the ratio of food intake to body weight for a wide range of bird species. The food intake to body weight ratios vary from 0.1 kg food/kg body weight (i.e. diet corresponds to 10% of body weight per day) to 0.94 kg food/kg body weight (i.e. diet corresponds to 94% of body weight per day). The guideline calculation used the highest value (0.94) to be conservative which is appropriate for a generic national guideline.

This range is quite large. This makes sense, given that it is obvious some bird species expend a lot of energy in their normal activities and require more food to provide that energy, while other species are not as energetic in their behaviour and so don't require as much energy each day to undertake their normal activities.

The average food intake to body weight ratio for the data in this table is 0.33 and the median ratio is 0.31 which indicates that consuming 30% of their body weight per day is common for birds (CCME 1998). The table of values in this Canadian guidance indicates that this ratio ranged from 0.2 to 0.4 for birds like ducks while for raptors it ranged from 0.1 to 0.2. For gull species, it ranged from 0.2 to 0.6. There was 1 species of kingfisher for which data were available for which the ratio was 0.5.

The species with the highest food intake to body weight ratios were 2 species of storm petrels. These are marine birds that migrate significant distances. The Wilsons Storm Petrel is found throughout the world including in Australia. It is known to migrate between Australia and Japan. It breeds in Antarctica.[11].

All other species (>25 species) in the Canadian guidance have food intake to body weight ratios of 0.5 or less.

Callide Creek is approximately 100 km inland. This means that ocean going/marine bird species such as storm petrels are not likely to be present in this area. The food intake to body weight ratio for such birds is, therefore, likely to be quite high for birds in this area.

The dietary guideline for birds can be adjusted based on changing the food intake to body weight ratio to make the guideline more relevant for the bird species that may be present in this area. As a result, the dietary guideline has been recalculated using 2 values for the food intake to body weight ratio – 0.3 and 0.5. These values are taken from the average/median for all species in the Canadian guidance and the value relevant for kingfishers has been used as a high end estimate for the types of birds that are likely in this location.

Using the TRV adopted for the PFAS NEMP calculations and a food intake to body weight ratio of either 0.3 or 0.5, gives adjusted dietary guidelines relevant for birds of:

- 15 µg/kg ww (i.e. 7.7/0.5)
- 26 µg/kg ww (i.e. 7.7/0.3)

These values still assume the birds only source dietary items from Callide Creek.

Toxicity reference values

There is a particular issue in regard to the Environment Canada guidelines. The guidance in Canada recommends:

- use of an uncertainty factor of 100 when calculating the toxicity reference value for a bird when the TRV is used to calculate a dietary guideline.
- use of an uncertainty factor of 2 when calculating a TRV for a bird when it is used in calculating a soil guideline.

This means Environment Canada used a TRV of 7.7 µg/kg bw/d to calculate dietary guidelines for birds and a TRV of 386 µg/kg bw/d to calculate soil guidelines for PFOS protective for birds. Both of these values were based on the same study which gave a lowest observed effect dose of 772 µg/kg bw/d using the northern bobwhite quail (Environment Canada 2017).

This discrepancy in the approaches recommended by Environment Canada was discussed in depth in some of the supporting documents for the draft PFAS NEMP version 3 but no recommendation was made about the approach to be preferred in Australia for dealing with this discrepancy[12]. Australia can make a different choice about the use of uncertainty factors as this is a technical policy decision based on incorporating an acknowledgement that there are limitations in the

[11] http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=1034
[12] https://consult.dcceew.gov.au/nemp-pfas

available information which must be covered in some way. This choice is for each country/jurisdiction to make for themselves.

Site-specific risk assessments across Australia have adopted a range of values for the TRV for birds including:

- 7.7 µg/kg bw/d
- 77 µg/kg bw/d
- 386 µg/kg bw/d.

APVMA (the Australian pesticide regulator) uses an uncertainty factor (i.e. APVMA use the term assessment factor) of 10 to apply to endpoints in studies looking at the acute toxicity of a pesticide to birds (i.e. LD50 values) (see Appendix A of (APVMA 2019)). They use an uncertainty factor of 1 for studies looking at chronic toxicity in birds where the endpoint is a no observed effect level (NOEL). EFSA also recommends applying an assessment factor of 10 to an LD50 value to estimate a chronic toxicity value for a risk assessment but using a NOEL as is without any adjustment (EFSA 2009).

Based on these approaches for pesticides, it could be argued that the TRV should be 772 µg/kg bw/d (i.e. no uncertainty factor applied).

Given that the value adopted for the northern bobwhite quail was a lowest observed effect level (LOEL) rather than a NOEL, an uncertainty factor would normally be adopted. A value of 10 for this factor would be an overestimate when the use of a 10 fold factor to convert LD50 values to an estimate of NOEL is normal practice. However, there is no specific guidance about the conversion of LOELs to NOELs for bird studies, so an uncertainty factor of 10 has been adopted for this assessment – in line with recommended approaches for human health protective uncertainty factors.

This gives a TRV of 77 µg/kg bw/d for use in this assessment.

If this value is adopted for the calculation of an adjusted dietary guideline, then the adjusted dietary guidelines for birds would be:

- 82 µg/kg ww using the food intake to body weight ratio of 0.94 (i.e. as per Canadian approach)
- 150-250 µg/kg ww using the more relevant food intake to body weight ratios of 0.3 or 0.5 to generate a guideline more relevant for this location.

Site specific matters

There are a number of site-specific matters that are also relevant for discussion in this refined assessment including:

- Callide Creek is not the only waterway in the area.
- There are 2 large lakes/dams in the vicinity of the creek – Lake Callide (AB1) and Kroombit Dam (AB9).
- Birds are more likely to collect dietary items from these larger waterbodies.

- PFOS was not detected in almost any samples taken from Lake Callide or from Kroombit Dam – 1 of the samples collected from Lake Callide for the human health assessment – reported a concentration of 2 µg/kg ww. This value is in compliance with the Environment Canada developed dietary guideline – i.e. 8.2 µg/kg ww.
- The average concentration of PFOS for all the samples collected within Callide Creek is 10 µg/kg ww using all the biota data (i.e. human health samples and ecosystem samples) and assuming a concentration of 1 µg/kg ww for all samples where the result was non-detect (i.e. less than the limit of reporting).

Findings

The diet of birds in any environment will always be a mix of food items from various locations within their home range.

In this case, birds that consume aquatic diets will take most of their diet from organisms taken in the dams just due to ease of access, visibility etc. They may also take organisms from Callide Creek. Regardless, they will not catch the organisms with the highest PFOS concentrations every day. They will catch some with PFOS at various concentrations and some which do not have any detectable PFOS. Therefore, using the average concentration reported for this whole dataset in this refined assessment is appropriate. The refined assessment is provided in **Table 11.1**.

Table 11.1: Refined risk assessment for birds

Key chemical	Average concentration (µg/kg ww)
PFOS concentration in aquatic organisms that birds may eat	10
PFAS NEMP dietary guideline value	8.2
Adjusted dietary guideline values	
Adjusted for food ingestion rate to body weight ratio = 0.5	15
Adjusted for food ingestion rate to body weight ratio = 0.3	25
Adjusted for TRV	82
Adjusted for TRV and food ingestion rate to body weight ratio = 0.5	150
Adjusted for TRV and food ingestion rate to body weight ratio = 0.3	250

This refined assessment shows that the average concentration of PFOS in fish and invertebrates that might be consumed by birds in this area is approximately the same as the national dietary guideline for birds and is in compliance with all other adjusted dietary guidelines as described.

As a result, no effects in birds due to PFOS exposure in their diet where that is composed of organisms taken from Callide Creek and the various dams in the area are expected, so no further assessment is required. This assessment assumes they obtain their entire diet from Callide Creek, Lake Callide and Kroombit Dam. It is possible they will consume aquatic organisms from other waterways across the region which may have lower levels of PFAS.

11.4 Dietary guideline for mammals

11.4.1 Approach

The dietary guideline listed in the PFAS NEMP for the protection of mammals was that developed by Environment Canada (Environment Canada 2018). As discussed in **Section 11.3** for birds, it is important to understand how such criteria were determined to interpret what these results may mean for this creek.

The dietary guideline for mammals developed by Environment Canada was based on the following assumptions:

- results from 9 studies of toxicity of PFOS to 4 species (monkeys, rabbits, mice and rats – these are the species used to assess toxicity for people but as they are mammals for which data are available they are also commonly used for assessing wildlife)
- toxicity reference values (TRVs) were determined based on the dose that caused no effects even for the most sensitive type of effect (i.e. no observed effect level (NOEL))
- an uncertainty factor of 100 was applied to the NOEL (the NOEL is divided by the uncertainty factor to get the TRV)
- TRVs for this range of studies were 0.0011 to 0.112 mg/kg bw/d
- The most sensitive TRV (i.e. 0.0011 mg/kg bw/d) was then adjusted for the maximum ratio of food intake to body weight in their database – 0.24 kg food/kg body weight (result for American mink from another Canadian guidance document – i.e. the organism consumes 24% of its body weight each day (CCME 1998))
- This gives the dietary guideline of 0.0046 mg/kg ww based on the calculation as follows – 1.1/0.24 = 4.6 µg/kg ww (in the fresh food as consumed by the mammal) i.e. 0.0046 mg/kg ww.

The PFAS NEMP has chosen to apply this guideline to the sum of PFOS+PFHxS but it is based on PFOS toxicity data only. There is limited information but it indicates PFHxS has similar toxicity to PFOS for mammals.

11.4.2 Refined assessment

Toxicity data

In considering this guideline in more detail, consideration of what effects were used to generate the no observed effect dose is relevant. The listed TRVs incorporated a NOEL or LOEL dose and a 100 fold uncertainty factor. Therefore, the NOELs/LOELs were 0.110 to 11.2 mg/kg bw/d.

These studies were designed to assess toxicity of these chemicals to people. As such even small changes in body weight, liver weight or blood chemistry are considered relevant. However, many of these types of effects are not ones that are considered ecologically relevant for use in assessing potential effects on wildlife. Ecologically relevant effects are those that impact on the populations of these organisms rather than individual animals. Small changes in body weight, liver weight or blood chemistry are unlikely to impact on the survival of a population of wildlife. Impacts on mortality, growth and reproduction (including effects on young) are more important for this assessment of wildlife species.

The specifics of each of the studies are difficult to find as the Environment Canada document did not include sufficient referencing.

Using the draft ATSDR toxicological profile for perfluoroalkyls (ATSDR 2018), the following can be noted about the types of effects that have been seen generally in studies with rats, mice and rabbits:

- Rats – increased liver weight, changes in serum cholesterol (LOEL – 2-3 mg/kg bw/d)
- Rats – effects on survival of young and changes in body weight of young, developmental delays (NOEL – 0.1-0.3 mg/kg bw/d)
- Rabbits – similar range of effects with developmental effects in young above 2 mg/kg bw/d (NOEL)
- Mice – similar effects to rats (on survival of young and changes in body weight of young, developmental delays) (NOEL – 0.1-3 mg/kg bw/d)

No effects on survival of young were observed for doses less than 1 mg/kg bw/d in the various species (ATSDR 2018, 2021).

For the study in monkeys, again detailed information is limited, however, a NOEL of 0.75 mg/kg bw/d appears to be relevant for use for wildlife (OECD 2002).

Using this more refined understanding of these studies, a more appropriate toxicity reference value can be determined.

It can be assumed that a NOEL of 0.1 mg/kg bw/d could be used as this value is 10 times lower than the dose that caused no impacts on survival of young for a limited range of species. An uncertainty factor of 10 can then be applied to this value to generate a TRV based on reproductive and development effects. It is noted that an uncertainty factor of 10 is still larger than that required by the APVMA when using data from long term studies in the assessment of risks from pesticides so this approach remains very conservative (see Appendix A of (APVMA 2019)).

Using these values gives a toxicity reference value of 0.01 mg/kg bw/d for use in this assessment and an adjusted dietary guideline of 42 µg/kg ww using the food intake to body weight ratio of 0.24.

Food ingestion rate/body weight ratio

Given that there is limited information about the types of mammals likely to be feeding on organisms from Callide Creek or the dams, it is not appropriate to adjust the food ingestion rate/body weight ratio used in the Canadian dietary guideline for this assessment.

Site specific matters

There are a number of site-specific matters that are also relevant for discussion in this refined assessment including:

- Callide Creek is not the only waterway in the area.
- There are 2 large lakes/dams in the vicinity of the creek – Lake Callide (AB1) and Kroombit Dam (AB9).

- Mammals that consume aquatic organisms may be more likely to collect dietary items from these larger waterbodies.
- PFOS was not detected in almost any samples taken from Lake Callide or from Kroombit Dam – 1 of the samples collected from Lake Callide for the human health assessment – reported a concentration of 2 µg/kg ww. This value is in compliance with the Environment Canada developed dietary guideline for mammals – i.e. 4.6 µg/kg ww.
- The average concentration of PFOS for all the samples collected within Callide Creek is 10 µg/kg ww using all the biota data (i.e. human health samples and ecosystem samples) and assuming a concentration of 1 µg/kg ww for all samples where the result was non-detect (i.e. less than the limit of reporting).

Findings

The diet of mammals in any environment will always be a mix of food items from various locations within their home range.

In this case, mammals that consume aquatic diets will take most of their diet from organisms taken in the dams just due to ease of access, visibility etc. They may also take organisms from Callide Creek at times. Regardless, they will not catch the organisms with the highest PFOS concentrations every day. They will catch some organisms with PFOS at various concentrations and some which do not have any detectable PFOS. Therefore, using the average concentration reported for this whole dataset in this refined assessment is appropriate.

The refined assessment is provided in **Table 11.2**.

Table 11.2: Refined risk assessment for mammals

Key chemical	Average concentration (µg/kg ww)
PFOS concentration in aquatic organisms that mammals may eat	10
PFAS NEMP dietary guideline value	4.6
Adjusted dietary guideline value	
Adjusted for TRV	42

This refined assessment shows that the average concentration of PFOS in fish and invertebrates that might be consumed by mammals in this area is above the national dietary guideline for mammals but is in compliance with the adjusted dietary guideline based on a more appropriate consideration of the toxicity data in regard to wildlife and Australian guidance on the use of toxicity data in such assessments.

As a result, no effects in mammals due to exposure to PFOS in their diet where that is composed of organisms taken from Callide Creek and the various dams in the area are expected. This assessment assumes they obtain their entire diet from Callide Creek, Lake Callide and Kroombit Dam only. It is possible they will consume aquatic organisms from other waterways across the region which may have lower levels of PFAS.

11.5 Uncertainties

General

This assessment has focused on the PFAS that are considered key within national guidance – i.e. PFOS, PFHxS and PFOA (HEPA 2020).

In regard to risks to birds and mammals, the biota sampling by Hydrobiology confirmed that focusing on these key PFAS was appropriate as essentially only PFOS was detected in any of the tissue samples (there was 1 sample where PFHxS was detected at the limit of reporting).

The presence of other PFAS has been considered in this uncertainty section for surface water to confirm that conclusions for based on the key PFAS do not change when the other PFAS are included.

The screening assessment for surface water (ecological) is shown in **Table 11.3**.

Table 11.3: Screening risk assessment – surface water – other PFAS – ecological

Detected PFAS	Maximum concentration upstream of the power station (µg/L)	Maximum Concentration downstream of the power station (µg/L)	Screening criteria – ecological (95% species protection) (µg/L)	Screening criteria – ecological (99% species protection) (µg/L)
Chemicals in Australian Guidance				
PFOS	0.303	0.0606	0.13	0.00023
PFHxS	0.294	0.0594		
PFOA	0.0984	0.002	220	19
Additional review of other detected individual PFAS				
PFBS	0.188	0.0111		
PFPeS	0.0528	0.0113		
PFHpS	0.0214	0.0019		
6:2 FTS	0.24	0.01		
8:2 FTS	0.013	ND		
PFBA	0.8190	0.022		
PFPeA	3.02	0.0265		
PFHxA	1.28	0.0138		
PFHpA	0.706	0.0052		
PFNA	0.0189	ND		
PFDA	0.0013	ND		
PFDoDA	ND	0.0011		
SUM of PFOS like	1.1122	0.1543	0.13	0.00023
SUM of PFOA like	5.9436	0.0706	220	19

Notes:

Screening criteria used here are from **Table 8.2**

This screening assessment indicates that, while a range of different PFAS were detected, the primary PFAS present at concentrations higher than guidelines in Callide Creek downstream of the power station were PFOS and PFHxS (or the sum of PFOS like chemicals). As a result, a detailed assessment based on PFOS+PFHxS concentrations in the surface waters downstream of the power station has been appropriate as shown in **Section 11.2**. It is expected that there would be no direct ecotoxicity effects in Callide Creek and Lake Callide due to the presence of these other PFAS as the maximum concentrations for all of the PFOS like chemicals individually (and for the sum of PFOS like chemicals) are below 0.48 µg/L in the downstream sampling locations (i.e. locations relevant for this assessment) and the maximum concentrations for all of the PFOA like chemicals individually (and for the sum) are below 19 µg/L.

Section 12. Conclusions

This HHERA has been prepared making use of extensive data collected by EPIC Environmental and it has focused on the area downgradient of the power station site. It has evaluated all the uses of groundwater or surface water expected in rural areas to provide information to allow refinement of community advice, if appropriate.

Evaluation of potential for risks to people has been undertaken using the approaches recommended in national guidance provided in the ASC NEPM (supported by the PFAS NEMP) and by enHealth, and FSANZ (enHealth 2012a; FSANZ 2017a; HEPA 2020; NEPC 1999 amended 2013a, 1999 amended 2013b).

In regard to ecological risks, the environmental values determined by EPIC arising from the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (i.e. Water EPP) have been considered in this HHERA as well as the relevant Australian water quality guidelines (or other relevant guidelines for other media) (ANZG 2018; HEPA 2020).

On the basis of the available data and the assessment undertaken in this report, the following can be concluded:

Human Health

- Risks for each of the individual exposure pathways are acceptable in all zones (based on the guidance from national health authorities). These pathways include:
    - ingestion of groundwater for drinking (and all household uses of water)
    - incidental ingestion of groundwater during use of water for farming purposes
    - incidental ingestion of groundwater during outdoor domestic uses of water
    - consumption of home grown fruit/vegetables which may contain PFAS due to irrigation by groundwater
    - consumption of home grown eggs which may contain PFAS due to chickens drinking groundwater
    - consumption of home grown meat which may contain PFAS due to stock watering using groundwater and consumption of fodder by the cattle where that fodder is irrigated with the relevant groundwater.
- Risks resulting from combining drinking groundwater with all or some of the pathways involving consumption of home grown produce are acceptable based on Australian health guidance for all zones except for the most impacted areas within Zone 1.
- Zone 1 has the highest concentration of PFOS+PFHxS. In this zone, if multiple exposure pathways for home grown produce (i.e. home grown eggs + home grown fruit & vegetables + home grown meat or home grown fruit & vegetables + home grown meat) are combined with using groundwater at the property as the sole source of drinking water, the risk to individuals would be slightly elevated when compared to the national guidelines for the locations with the highest concentrations (i.e. 0.3-0.4 µg/L). Based on the data available, it is understood that no individual household is exposed via the combination of all the possible exposures.
- It is understood that properties are being supplied with an alternate source of drinking water so use of groundwater as the sole source of drinking water is not occurring.

- For Zone 4, there was only 1 groundwater supply bore available for monitoring in this zone. The results for this bore were in compliance with the drinking water guideline for PFOS+PFHxS. Risks are, therefore, negligible and no further assessment was required for this zone.
- Risks due to exposures to people using Callide Creek for swimming/recreation are acceptable.
- Risks due to exposure to PFAS via consumption of fish caught in Lake Callide are acceptable based on the conservative national FSANZ trigger point.
- Risks due to exposure to PFAS via consumption of fish caught in Callide Creek are acceptable based on adjusted guidelines in line with the practical limitations on catch size and frequency of fishing.

It is important to note that the combination calculations (as per **Table 10.8a**) are based on the maximum concentrations reported and assume that people living/working on those properties will:

- use the groundwater as their sole source of drinking water and for all farming and/or domestic activities where incidental ingestion could occur
- consume 100% of eggs from chickens kept at the property
- consume 35% of meat from livestock kept at the property which are given groundwater to drink and that eat fodder that has been irrigated with groundwater
- consume 35% of fruit and vegetables from produce grown at the property and irrigated with groundwater.

It is understood that this combination is unlikely to have occurred.

Ecological

- No direct ecotoxicity effects from exposure to PFAS on aquatic species in Callide Creek and Lake Callide are expected.
- No effects in birds are expected due to consuming aquatic organisms from Callide Creek or Lake Callide that may contain PFOS.
- No effects in mammals are expected due to consuming aquatic organisms from Callide Creek or Lake Callide that may contain PFOS.

Other matters

The following points are also noted:

- This assessment has been based on the maximum reported concentrations for any sample type in each zone.
- While the site is likely to contribute to the levels of PFAS in Callide Creek, the site investigation shows that Callide Power Station is not the sole source of these chemicals to these waterways.
- For uptake of the chemicals into meat or eggs, the concentrations modelled assuming 100% PFOS is present have been used in the risk calculations as this is the worst case calculation.
- For uptake into meat, the combination scenario uses the risks based on the stock drinking groundwater and eating fodder that has been irrigated using the groundwater.
- There are no maximum residue levels for PFAS in meat/eggs (i.e. legally enforceable limits).

- FSANZ, however, has published trigger points to indicate when food may need more detailed investigation. The concentrations modelled in this assessment are generally in compliance with these trigger points.

This assessment shows that, based on a site-specific evaluation of risk, the concentrations of PFOS and PFHxS (and other PFAS) in groundwater or surface water do not pose an unacceptable risk to people when that water is accessed/used on properties in the off-site area downgradient of Callide Power Station based on national guidance for health risk assessment.

The levels of PFAS in groundwater or surface water also do not pose an unacceptable risk to ecosystems in and around Callide Creek based on national guidance for ecological risk assessment.

Section 13. References

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Appendix A Types of PFAS analysis

Standard PFAS Analysis

Standard PFAS analysis is the analysis method that is the most developed and that is now available at most commercial laboratories in Australia. Standard PFAS analysis reports concentrations of around 25 to 30 individual PFAS via a technique known as isotope dilution. This analysis method is well established, and as noted above, offered by the majority of commercial laboratories in Australia.

One of the potential issues with any type of PFAS analysis (or any type of analysis for environmental contaminants, in general) is the potential for variability in results between laboratories. This has been addressed for PFAS by the Australian Government National Measurement Institute (NMI). They have provided assessments of the proficiency of laboratories to undertake PFAS analysis since around 2015/2016.

Proficiency programs are designed to test the performance of the participating laboratories to provide an independent check of the quality and comparability of PFAS measurements in Australia. The most recent reports are those for work undertaken in 2023[13].

Standard PFAS analysis results are, therefore, routinely relied upon for PFAS investigation, risk assessment and remediation work across Australia.

TOP Assay

The PFAS family is much larger than these 25-30 substances and so, while the standard analytical suite allows measurement of the substances that are expected to be present most commonly and at the highest concentration, there remains a question as to whether the others matter.

It is expected that the substances in the standard analytical suite are the most important in regard to potential risks and it has been shown that some of the other substances may transform into the 3 key ones over time which supports the focus on the 3 key PFAS.

However, researchers developed an assay to target precursors – the PFAS chemicals that break down into PFOS, PFHxS or PFOA. This is the TOP assay or total organic precursors assay(Houtz & Sedlak 2012). The method makes use of the same type of analysis as the standard analytical suite but includes a pretreatment step where the sample is subject to strong oxidation (potassium persulfate and sodium hydroxide and heat). This is designed to convert relevant PFAS not normally measured in the standard suite into the critical PFAS we measure using the standard suite (e.g. PFOS, PFOA or PFHxS and others). The assay requires analysis of the original sample and then the sample after the pretreatment step (i.e. strong oxidation step). It is the difference between the 2 sets of results that informs as to whether there are significant amounts of precursors present in the samples or not.

This assay is most useful for fingerprinting PFAS sources or for use during remediation projects to ensure treatment plants are appropriately sized. It gives an indication of the load of fluorinated chemicals that might be present and need to be removed via any proposed treatment process.

[13] https://www.industry.gov.au/publications/proficiency-test-reports-2023

The TOP assay is less developed than the standard analytical suite but is offered by many of the commercial laboratories in Australia. It can be a problematic method particularly for soil, sediment or biota samples as it can be difficult to get good reproducibility.

A validation program for TOP assay was undertaken in Australia (Ventia 2019). The results of this study noted:

- The amount of oxidant recommended in the original method (and the number of cycles of oxidation) is not usually sufficient to meet the quality requirements specified in the NEMP, so laboratories need to increase the dose of oxidant, the number of cycles and/or the temperature for the pre-treatment in line with this validation study (HEPA 2020).
- The results for the sulfonates (PFOS, PFHxS etc) should always be similar in the TOP assay (i.e. same levels in analysis of original sample and in oxidised sample). If there are large differences in the results, this indicates an issue with the analysis.
- The results for the longer chain carboxylic acids (i.e. those with 10 or more carbons (i.e. PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA)) should also be similar in original sample and in oxidised sample. If they are not, then this may indicate some issue with the analysis.

This report (Ventia 2019) also notes:

"The products of TOP assay do not necessarily represent environmental endpoints of PFAS degradation. The assay uses a strong oxidation with hydroxyl radicals that would be harsher than the expected conditions of both abiotic and biotic break down in the environment. Degradation can include not only oxidation but also hydrolytic processes acting on precursor compounds. For example, the metabolic endpoint of sulfonamide break down in the environment would be the sulfonic acid rather than a perfluorocarboxylic acid but the conversion that occurs in the TOP assay is to the perfluorocarboxylic acid."

Further work has been undertaken by NMI to assess the proficiency of laboratories to use this TOP assay for analysing PFAS in water (NMI 2020). All participating laboratories used much higher amounts of oxidant and allowed the oxidation to occur for much longer times than originally proposed when this method was first designed (Houtz & Sedlak 2012).

The results from the TOP assay are not commonly used to assess potential risks in standard PFAS environmental investigations around Australia. Queensland Health has confirmed that TOP assay results are not required for the purpose of assessing public health risks for human health risk assessment using biota data.[14] This is because:

- the strong oxidisers used in the laboratory are not present in the natural environment
- the oxidation step primarily converts precursors into carboxylic acid based standard/key PFAS.

[14] https://www.qld.gov.au/__data/assets/pdf_file/0032/68684/pfas-fish-sampling-protocol.pdf

In the natural environment, some of the other PFAS chemicals measured in the TOP assay would break down to PFOS like chemicals. This means the TOP assay results can give an incorrect picture in regard to risks.

TOP assay results may be useful for:

- sizing remedial equipment
- where strong oxidisers are to be used during remediation of water or soil containing PFAS
- fingerprinting PFAS sources.

It's also important to note that the precursors and the PFAS in the standard analytical suite do not have much difference in molecular weight (for each size of carbon chain) so if the concentration measured in the TOP assay increases a small amount it is indicative of only small amounts of precursor compounds which would be unlikely to change the conclusions around risk.

It is acknowledged that some PFAS degrade in the environment quicker than others, and TOP assay may provide an indication of the degradation potential and future environmental concentrations for these PFAS. However, the PFAS with a higher degradation potential are smaller PFAS or PFAS with functional groups that allow ready hydrolysis or biodegradation which means:

- they are not "persistent" in the same way as PFOS, PFHxS, PFOA or other longer chain chemicals
- they are not likely to be bioaccumulative
- they are not 1 of the 3 key PFAS that are of most concern (PFOS, PFOA and PFHxS).

This means the risks posed by these other PFAS are less important than those for PFOS, PFOA, PFHxS because the concentrations are smaller and these chemicals do not qualify as persistent, bioaccumulative and toxic (PBT) as they do not persist in the environment.

As noted above, the guidelines for PFAS in the PFAS NEMP are for results from the standard PFAS analytical suite and not for results from TOP assay analysis. There are no guidelines available in Australia or internationally based on the results from TOP assay.

TOF Analysis

The third analysis method that is available is total organic fluorine (TOF) analysis. TOF analysis measures the total concentration of fluorine in an environmental sample, including PFAS and non-PFAS chemicals. It does not distinguish between chemicals that may be of environmental concern and those that may not be of concern or even those that may be naturally occurring. TOF analysis is only available at a few commercial laboratories in Australia and there are no current or historical proficiency test/validation programs underway for this method.

This method is primarily useful when designing treatment processes to ensure they are adequately sized as it gives an idea of the load of fluorinated chemicals that might be present.

TOF analysis involves oxidising the sample at approximately 1,000ºC under humid conditions. The carbon fluorine bonds in the chemicals are broken under these conditions and the fluorine is emitted from the sample as hydrogen fluoride (HF) gas which is dissolved in solution and the fluoride ions are then measured. As indicated in the PFAS NEMP, this method measures both organic and inorganic fluoride.

Each laboratory must incorporate some method to correct the results to remove the HF generated from naturally occurring fluoride in soils which will always be present (i.e. inorganic fluoride). It has been indicated that this is corrected for by the analysing laboratories, but the methods used by both laboratories in Australia differ. Given this, the intra laboratory repeatability of TOF analysis is currently not clear.

The method also does not provide a way to separate HF formed by oxidation of PFAS from HF formed due to oxidation of other synthetic chemicals containing fluorine – this includes a wide range of pharmaceuticals and other compounds. This means it can provide a false picture of the how much PFAS is present. For this reason, the PFAS NEMP indicates that this method must be used in addition to the standard analysis, rather than on its own.

The very high toxicity of HF does make this a method of concern in a laboratory. While the equipment used is likely to limit the amount of HF produced and its potential to escape into the laboratory, it is still preferred to avoid methods that involve the production of chemicals like HF.

As noted for the TOP assay, the oxidation method used to generate fluoride ions from these chemicals is not something that could ever occur under environmental conditions, so the results from the TOF analysis will always be a significant overestimate of the potential PFAS present.

As noted above, there are no guidelines available in Australia or internationally for the results of TOF analysis.

Appendix B Site assessment data

Epic File: BC200153.03
Site: Callide Power Station
Client: CS Energy
Report Date 12-Jan-24

Epic Environmental Pty Ltd
Level 17, 95 North Quay, Brisbane QLD 4000

Table T1: Groundwater and Surface Water Analytical Results - PFAS

Sample Date	Laboratory Sample Number	Company	Sample Number	Location	Material Type	Analysis	Total Organic Fluorine (TOF) (µg/L)	Perfluoroalkyl Sulfonic Acids (PSA) (µg/L) PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFDS	PFOS & PFHxS	Perfluoroalkyl Carboxylic Acids (PCA) (µg/L) PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnDA	PFDoDA	PFTrDA	PFTeDA	Perfluoroalkyl Sulfonamides (µg/L) FOSA	MeFOSA	EtFOSA	MeFOSE	EtFOSE	MeFOSAA	EtFOSAA	Fluorotelomer Sulfonic Acids (FSA) (µg/L) 4:2 FTS	6:2 FTS	8:2 FTS	10:2 FTS	Total PFAS (µg/L) Total PFAS	Sum of TOP C_4 - C_{14} Carboxylates and C_4 - C_8 Sulfonates	Sum of TOP C_4 - C_{14} as Fluorine
PFAS NEMP Freshwater - 99% Species Protection (high conservation value systems)							-	-	-	-	-	**0.0002**	-	-	-	-	-	-	**19**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS NEMP Freshwater - 95% Species Protection (slightly to moderately disturbed systems)							-	-	-	-	-	**0.1300**	-	-	-	-	-	-	**220**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS NEMP Health Based Guidance Values - Drinking Water							-	-	-	-	-	-	-	**0.0700**	-	-	-	-	**0.56**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS NEMP Health Based Guidance Values - Recreational Water							-	-	-	-	-	-	-	**2.0000**	-	-	-	-	**10.0**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Laboratory Level of Reporting (µg/L)) - Standard Analysis							20-500	0.001	0.001	0.001	0.001	0.0001	0.001	0.0010	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.001	0.005	0.001	0.001	0.005	-	-
Laboratory Level of Reporting (µg/L)) - TOPA							-	0.002	0.002	0.002	0.002	0.0020	0.002	0.0020	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.002	0.005	0.005	0.005	0.005	0.002	0.002	0.005	0.005	0.005	0.005	0.002	0.002	0.002
Groundwater																																							
03-Nov-20	EB2029263069	-	MW01	Onsite - North-western Boundary (Upgradient)	Groundwater	Standard	<20	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	**0.003**	**0.0051**	**0.0019**	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	**0.0400**	<0.002	<0.002	**0.0500**	-	-
03-Nov-20	EB2029263069	-	MW01	Onsite - North-western Boundary (Upgradient)	Groundwater	TOPA	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01	**0.012**	**0.0140**	**0.003**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	**0.0290**	**0.0290**	**0.019**
07-Apr-22	EB2209861001	-	MW01	Onsite - North-western Boundary (Upgradient)	Groundwater	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0081	<0.0016	**0.0019**	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	**0.0019**	-	-
04-Nov-22	EB2232870016	-	MW01	Onsite - North-western Boundary (Upgradient)	Groundwater	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0014	<0.0008	<0.0008	<0.0040	**0.0022**	**0.0031**	**0.0008**	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	**0.0061**	-	-
02-Mar-23	EB2306934016	-	MW01	Onsite - North-western Boundary (Upgradient)	Groundwater	Standard	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0005	<0.0002	<0.0020	<0.0005	**0.0018**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	**0.0010**	<0.001	<0.001	**0.0028**	-	-
19-Jan-21	EB2101853004	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	<20	**0.0397**	**0.0343**	**0.186**	**0.008**	**0.2060**	<0.0008	**0.3920**	<0.0220	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	**0.4740**	-	-
19-Jan-21	EB2101853004	-	MW68	Offsite - Adjacent to WSCA	Groundwater	TOPA	-	**0.0460**	**0.029**	**0.199**	**0.006**	**0.2130**	<0.002	**0.4120**	**0.0200**	**0.017**	**0.1320**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	**0.6620**	**0.6620**	**0.419**
20-Feb-21	EB2104890018	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0526**	**0.0427**	**0.226**	**0.0118**	**0.3320**	<0.0032	**0.5580**	**0.0124**	**0.0089**	**0.0124**	**0.0032**	**0.0105**	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	**0.0420**	**0.0300**	<0.003	**0.7840**	-	-
08-Apr-21	EB2109607004	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0445**	**0.0456**	**0.224**	**0.0097**	**0.2970**	<0.0008	**0.5210**	<0.0020	<0.0011	**0.0008**	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	**0.0020**	<0.001	<0.001	**0.6240**	-	-
17-May-21	EB2114060004	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0461**	**0.0386**	**0.222**	**0.0113**	**0.2890**	<0.0020	**0.5110**	<0.0020	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	**0.0010**	<0.001	<0.001	**0.6080**	-	-
28-May-21	EB2115500007	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0569**	**0.0318**	**0.234**	**0.0114**	**0.2980**	<0.0008	**0.5320**	<0.0020	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	**0.0050**	<0.001	<0.001	**0.6370**	-	-
23-Oct-21	EB2130810024	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0493**	**0.0334**	**0.244**	**0.0126**	**0.2740**	<0.0008	**0.5180**	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	**0.0060**	<0.001	<0.001	**0.6190**	-	-
17-Dec-21	EB2137227013	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0507**	**0.0466**	**0.207**	**0.0105**	**0.2850**	<0.0032	**0.4920**	<0.0159	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	**0.6000**	-	-
19-Jan-22	EB2202169032	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0535**	**0.0407**	**0.222**	**0.0122**	**0.2980**	<0.0016	**0.5200**	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	**0.6260**	-	-
30-Mar-22	EB2209243017	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0767**	**0.06**	**0.367**	**0.0154**	**0.4590**	<0.0008	**0.8260**	<0.0040	<0.0008	**0.0030**	<0.0008	<0.0015	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	**0.9810**	-	-
08-Jul-22	EB2220051029	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0640**	**0.0474**	**0.215**	**0.0158**	**0.2880**	<0.0005	**0.5030**	<0.0080	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	**0.6300**	-	-
02-Nov-22	EB2232870005	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0475**	**0.0392**	**0.232**	**0.0118**	**0.2840**	<0.0008	**0.5160**	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	**0.6140**	-	-
03-Mar-23	EB2306934025	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0490**	**0.0354**	**0.21**	**0.012**	**0.3040**	<0.0005	**0.5140**	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	**0.6100**	-	-
07-Jun-23	EB2318365021	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0478**	**0.0404**	**0.247**	**0.0111**	**0.3370**	<0.0016	**0.5840**	<0.0796	**0.0027**	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	**0.6860**	-	-
07-Sep-23	EB2328001014	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0543**	**0.0406**	**0.239**	**0.008**	**0.2890**	<0.0005	**0.5280**	<0.0078	<0.0016	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	**0.6310**	-	-
11-Dec-23	EB2339753027	-	MW68	Offsite - Adjacent to WSCA	Groundwater	Standard	-	**0.0455**	**0.031**	**0.223**	**0.0082**	**0.3390**	<0.0005	**0.5620**	<0.0081	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0040	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	**0.6470**	-	-
05-Mar-21	EB2106358008	-	MW69	Downstream (0.5km)	Groundwater	Standard	<400	<0.0032	<0.0032	**0.0165**	<0.0032	**0.0954**	<0.0032	**0.1120**	**0.0187**	**0.0127**	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0079	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	**0.1430**	-	-
05-Mar-21	EB2108581003	-	MW69	Downstream (0.5km)	Groundwater	TOPA	-	<0.009	<0.009	**0.014**	<0.009	**0.0860**	<0.009	**0.1000**	<0.04	**0.014**	**0.0950**	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.023	<0.009	<0.023	<0.023	<0.023	<0.023	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	**0.2090**	**0.2090**	**0.136**
07-Apr-21	EB2109607005	-	MW69	Downstream (0.5km)	Groundwater	Standard	-	**0.0016**	**0.0017**	**0.0155**	<0.0016	**0.0944**	<0.0016	**0.1100**	<0.0210	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	**0.1130**	-	-
16-May-21	EB2114060001	-	MW69	Downstream (0.5km)	Groundwater	Standard	-	**0.0008**	<0.0008	**0.0077**	<0.0008	**0.0297**	<0.0008	**0.0374**	<0.0020	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	**0.0010**	<0.001	<0.001	**0.0392**	-	-

Epic File: BC200153.03
Site: Callide Power Station
Client: CS Energy
Report Date 12-Jan-24

Epic Environmental Pty Ltd
Level 17, 95 North Quay, Brisbane QLD 4000

Table T1: Groundwater and Surface Water Analytical Results - PFAS

Sample Date	Laboratory Sample Number	Company	Sample Number	Location	Material Type	Analysis	Total Organic Fluorine (TOF) (µg/L)	Perfluoroalkyl Sulfonic Acids (PSA) (µg/L)							Perfluoroalkyl Carboxylic Acids (PCA) (µg/L)											Perfluoroalkyl Sulfonamides (µg/L)							Fluorotelomer Sulfonic Acids (FSA) (µg/L)				Total PFAS (µg/L)		
								PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFDS	PFOS & PFHxS	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnDA	PFDoDA	PFTrDA	PFTeDA	FOSA	MeFOSA	EtFOSA	MeFOSE	EtFOSE	MeFOSAA	EtFOSAA	4:2 FTS	6:2 FTS	8:2 FTS	10:2 FTS	Total PFAS	Sum of TOP C_4 - C_{14} Carboxylates and C_4 - C_8 Sulfonates	Sum of TOP C_4 - C_{14} as Fluorine
PFAS NEMP Freshwater - 99% Species Protection (high conservation value systems)							-	-	-	-	-	0.0002	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS NEMP Freshwater - 95% Species Protection (slightly to moderately disturbed systems)							-	-	-	-	-	0.1300	-	-	-	-	-	-	220	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS NEMP Health Based Guidance Values - Drinking Water							-	-	-	-	-	-	-	0.0700	-	-	-	-	0.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PFAS NEMP Health Based Guidance Values - Recreational Water							-	-	-	-	-	-	-	2.0000	-	-	-	-	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Laboratory Level of Reporting (µg/L)) - Standard Analysis							20-500	0.001	0.001	0.001	0.001	0.0001	0.001	0.0010	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.001	0.005	0.001	0.001	0.005	-	-
Laboratory Level of Reporting (µg/L)) - TOPA							-	0.002	0.002	0.002	0.002	0.0020	0.002	0.0020	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.002	0.005	0.005	0.005	0.005	0.002	0.002	0.005	0.005	0.005	0.005	0.002	0.002	0.002
Surface Water																																							
19-Jan-21	EB2101853007	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	<20	<0.0032	<0.0008	0.0037	<0.0008	<0.0036	<0.0008	0.0037	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0037	-	-
19-Jan-21	EB2102849007	-	SW02	Callide Creek adjacent to SSCA	Surface Water	TOPA	-	0.0020	<0.002	0.004	<0.002	0.0040	<0.002	0.0080	<0.01	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	0.0120	0.0120	0.007
08-Apr-21	EB2109607002	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0021	0.0018	0.0086	<0.0005	0.0032	<0.0005	0.0118	<0.0020	<0.0025	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0162	-	-
18-May-21	EB2114060013	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
20-May-21	EB2114060037	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0016	<0.0016	0.0034	<0.0016	<0.0016	<0.0016	0.0034	<0.0078	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0034	-	-
28-May-21	EB2115500006	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0016	<0.0016	0.0022	<0.0016	<0.0016	<0.0016	0.0022	0.0046	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0068	-	-
19-Oct-21	EB2130810049	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0030	<0.0014	0.0094	<0.0014	<0.0034	<0.0014	0.0094	<0.0072	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0036	<0.0014	<0.004	<0.004	<0.004	<0.004	<0.0014	<0.0014	<0.001	<0.001	<0.001	<0.001	0.0124	-	-
01-Dec-21	EB2135860004	CS Energy	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0027	<0.0020	0.0134	<0.0008	0.0059	<0.0008	0.0193	<0.004	<0.0008	<0.0015	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0220	-	-
09-Dec-21	EB2137227015	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0015	<0.0010	<0.0045	<0.0008	0.0020	<0.0008	0.0020	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0020	-	-
14-Dec-21	EB2137227008	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
16-Dec-21	EB2137227009	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
18-Jan-22	EB2202169007	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
31-Mar-22	EB2209243026	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	<0.0032	<0.0032	0.0044	<0.0032	<0.0032	<0.0032	0.0044	<0.0158	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0079	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	0.0044	-	-
06-Jul-22	EB2220051014	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0036	<0.0015	0.0095	<0.0005	<0.0003	<0.0005	0.0095	<0.0080	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0040	<0.0005	<0.001	<0.004	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0131	-	-
26-Oct-22	EB2232600014	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0024	<0.0016	0.0027	<0.0016	<0.0016	<0.0016	0.0027	<0.0080	<0.0016	<0.0016	<0.0020	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0051	-	-
28-Feb-23	EB2306934008	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0072	0.0043	0.0225	<0.0005	0.0059	<0.0005	0.0284	<0.0080	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.001	<0.001	<0.001	<0.001	0.0399	-	-
12-Jun-23	EB2318365044	-	SW02	Callide Creek adjacent to SSCA	Surface Water	Standard	-	0.0058	<0.0005	0.0019	<0.0005	0.0004	<0.0005	0.0023	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0081	-	-
04-Nov-20	EB2029263060	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	<20	0.0016	0.0007	0.0037	<0.0005	0.0012	<0.0005	0.0049	<0.0720	<0.0025	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0072	-	-
04-Nov-20	EB2029263060	-	SW12	Callide Creek adjacent to ESCA	Surface Water	TOPA	-	<0.002	<0.002	0.006	<0.002	<0.002	<0.002	0.0060	<0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	0.0060	0.0060	0.004
20-Jan-21	EB2101853014	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	<20	0.0009	0.0008	0.0025	<0.0008	0.0014	<0.0008	0.0039	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0056	-	-
20-Jan-21	EB2102849014	-	SW12	Callide Creek adjacent to ESCA	Surface Water	TOPA	-	<0.002	<0.002	0.005	<0.008	<0.002	<0.002	0.0050	<0.01	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	0.0070	0.0070	0.004
18-May-21	EB2114060014	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0016	<0.0016	0.003	<0.0016	<0.0016	<0.0016	0.0030	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0030	-	-
20-May-21	EB2114060036	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
28-May-21	EB2115500004	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	0.0019	<0.0016	0.004	<0.0016	0.0018	<0.0016	0.0058	<0.0020	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0077	-	-
19-Oct-21	EB2130810047	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0032	<0.0032	0.0099	<0.0032	<0.0032	<0.0032	0.0099	<0.0160	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	0.0099	-	-
12-Nov-21	EB2133062009	CS Energy	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	0.0032	<0.0032	0.0176	<0.0032	0.0058	<0.0032	0.0234	<0.016	<0.0032	0.0038	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	0.0304	-	-
18-Jan-22	EB2202169008	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
31-Mar-22	EB2209243027	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0040	<0.0005	0.003	<0.0005	<0.0014	<0.0005	0.0030	<0.0158	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0079	<0.0005	<0.008	<0.008	<0.001	<0.008	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0032	-	-
07-Jul-22	EB2220051023	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0022	<0.0019	0.0082	<0.0008	<0.0030	<0.0008	0.0082	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0082	-	-
26-Oct-22	EB2232600017	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0159	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	<0.0032	-	-
28-Feb-23	EB2306934007	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	0.0162	0.0113	0.0615	<0.0008	0.0106	<0.0008	0.0721	<0.0200	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	0.0011	<0.0008	<0.0100	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.1010	-	-
07-Jun-23	EB2318365045	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0005	<0.0005	<0.0012	<0.0005	<0.0002	<0.0008	<0.0002	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0002	-	-
04-Sep-23	EB2328001038	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	0.0111	0.0096	0.0556	<0.0007	0.0078	<0.0005	0.0634	<0.0081	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0841	-	-
05-Dec-23	EB2339753008	-	SW12	Callide Creek adjacent to ESCA	Surface Water	Standard	-	<0.0115	0.0086	0.0594	0.0019	0.0181	<0.0005	0.0775	<0.0080	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0880	-	-
26-Mar-21	EB2109622003	CS Energy	SW17	Dunn Creek (Downstream of R2)	Surface Water	Standard	-	0.0042	0.0023	0.0177	<0.0015	0.0145	<0.0005	0.0322	<0.0260	<0.0175	<0.0115	0.0085	0.0035	0.0008	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0515	-	-
07-Jul-21	EB2119293012	-	SW17	Dunn Creek (Downstream of R2)	Surface Water	Standard	-	0.0030	<0.0016	0.0026	<0.0016	0.0030	<0.0016	0.0056	0.0065	0.0045	<0.0016	0.0038	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0234	-	-
01-Dec-21	EB2135860007	CS Energy	SW17	Dunn Creek (Downstream of R2)	Surface Water	Standard	-	0.0093	0.0052	0.0286	<0.0020	0.0185	<0.0008	0.0471	<0.004	0.0308	0.0171	0.0062	0.0022	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.1180	-	-
19-Jan-22	EB2202169021	-	SW17	Dunn Creek (Downstream of R2)	Surface Water	Standard	-	0.0152	0.0072	0.0328	<0.0008	0.0116	<0.0008	0.0444	<0.0140	0.014	<0.0075	<0.0008	<0.0015	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0808	-	-
10-Mar-22	EB2207080001	CS Energy	SW17	Dunn Creek (Downstream of R2)	Surface Water	Standard	-	<0.0055	<0.0042	0.0183	<0.0032	<0.0055	<0.0032	0.0183	<0.0160	<0.0061	0.0061	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	0.0244	-	-
20-Jan-21	EB2101853013	-	SW20	Background - Lake Callide	Surface Water	Standard	<20	<0.0005	<0.0005	<0.0005	<0.0005	<0.0004	<0.0005	<0.0002	<0.0020	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0002	-	-
20-Jan-21	EB2102849013	-	SW20	Background - Lake Callide	Surface Water	TOPA	-	<0.002	<0.002	<0.002	<0.004	<0.002	<0.002	<0.002	<0.01	0.002	0.0030	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	0.0050	0.0050	0.003
19-Oct-21	EB2130810050	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0160	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	<0.0032	-	-
18-Jan-22	EB2202169010	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0020	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
31-Mar-22	EB2209243022	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
06-Jul-22	EB2220051015	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0009	<0.0005	<0.0005	<0.0005	<0.0002	<0.0005	<0.0002	<0.0080	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0040	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0016	-	-
26-Oct-22	EB2232600011	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
28-Feb-23	EB2306934005	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0008	<0.0008	<0.0010	<0.0008	<0.0008	<0.0008	<0.0008	<0.0200	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0100	<0.0008	<0.010	<0.010	<0.010	<0.010	<0.0008	<0.0008	<0.001	0.0100	<0.001	<0.001	0.0100	-	-
10-Jun-23	EB2318365046	-	SW20	Background - Lake Callide	Surface Water	Standard	-	0.0029	<0.0005	<0.0005	<0.0005	<0.0002	<0.0005	<0.0002	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0039	<0.0016	<0.004	<0.004	<0.001	<0.004	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0029	-	-
11-Dec-23	EB2339753010	-	SW20	Background - Lake Callide	Surface Water	Standard	-	<0.0016	<0.0005	<0.0005	<0.0005	<0.0006	<0.0005	<0.0005	<0.0081	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	-	-
19-Jan-21	EB2101853002	-	SW22	Downstream (4.2km)	Surface Water	Standard	<20	0.0014	0.0012	0.0117	<0.0005	0.0069	<0.0005	0.0186	<0.0300	<0.0015	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0212	-	-
19-Jan-21	EB2102849002	-	SW22	Downstream (4.2km)	Surface Water	TOPA	-	<0.002	<0.002	0.012	<0.002	0.0080	<0.002	0.0200	<0.01	<0.002	0.0050	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.005	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	<0.005	<0.005	<0.005	<0.005	0.0250	0.0250	0.016
08-Apr-21	EB2109607001	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	0.0017	0.0016	0.0145	<0.0005	0.0110	<0.0005	0.0255	<0.0760	<0.0032	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	0.0020	<0.001	<0.001	0.0308	-	-
18-May-21	EB2114060015	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0016	<0.0016	0.0184	<0.0016	0.0163	<0.0016	0.0347	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0347	-	-
20-May-21	EB2114060038	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	0.0016	0.0016	0.0185	<0.0016	0.0195	<0.0016	0.0380	<0.0160	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0412	-	-
28-May-21	EB2115500003	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	0.0024	0.0019	0.0162	<0.0016	0.0131	<0.0016	0.0293	<0.0020	0.0022	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0358	-	-
22-Oct-21	EB2130810051	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	0.0017	<0.0015	0.0138	<0.0015	<0.0057	<0.0015	<0.0195	<0.0076	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0038	<0.0015	<0.004	<0.004	<0.004	<0.004	<0.0015	<0.0015	<0.002	<0.002	<0.002	<0.002	0.0155	-	-
12-Nov-21	EB2133062010	CS Energy	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0032	<0.0032	<0.0032	<0.0032	0.0038	<0.0032	0.0038	<0.016	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	0.0038	-	-
01-Dec-21	EB2135860005	CS Energy	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0015	<0.0008	0.0115	<0.0015	0.0118	<0.0008	0.0233	<0.004	<0.0020	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0233	-	-
18-Jan-22	EB2202169009	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0008	<0.0008	0.0029	<0.0008	0.0036	<0.0008	0.0065	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0015	<0.0020	<0.001	<0.001	<0.001	<0.001	0.0065	-	-
31-Mar-22	EB2209243029	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0025	<0.0018	0.0139	<0.0007	0.0122	<0.0007	0.0261	<0.0036	<0.0007	<0.0010	<0.0007	<0.0010	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0018	<0.0007	<0.002	<0.002	<0.002	<0.002	<0.0007	<0.0007	<0.001	<0.001	<0.001	<0.001	0.0261	-	-
06-Jul-22	EB2220051016	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0019	<0.0014	0.0155	<0.0008	0.0156	<0.0008	0.0311	<0.0038	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0311	-	-
26-Oct-22	EB2232600010	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	0.0048	0.0008	0.0174	<0.0005	0.0074	<0.0005	0.0248	<0.0020	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0008	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0304	-	-
07-Mar-23	EB2306934041	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0016	<0.0016	0.0122	<0.0016	0.0160	<0.0016	0.0282	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0397	<0.0016	<0.040	<0.040	<0.040	<0.040	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0282	-	-
07-Jun-23	EB2318365047	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0005	0.0011	0.0163	<0.0005	0.0134	<0.0005	0.0297	<0.0078	<0.0016	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0039	<0.0016	<0.004	<0.004	<0.001	<0.004	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0308	-	-
04-Sep-23	EB2328001039	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0016	<0.0011	0.0166	<0.0005	0.0163	<0.0005	0.0329	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0329	-	-
05-Dec-23	EB2339753007	-	SW22	Downstream (4.2km)	Surface Water	Standard	-	<0.0185	<0.0015	0.0187	<0.0005	0.0149	<0.0005	0.0336	<0.0080	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0336	-	-
16-Mar-21	EB2107351002	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.01	<0.1	0.03	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.0300	-	-
07-Jul-21	EB2119293005	-	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0030	<0.0016	0.0056	<0.0016	<0.0040	<0.0016	0.0056	<0.0080	<0.0030	0.0042	0.0026	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0124	-	-
19-Oct-21	EB2130810064	-	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	0.0035	<0.0015	0.0106	<0.0015	0.0076	<0.0015	0.0182	0.0240	0.0272	0.0122	0.0083	0.0029	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0038	<0.0015	<0.004	<0.004	<0.004	<0.004	<0.0015	<0.0015	<0.002	<0.002	<0.002	<0.002	0.0963	-	-
22-Oct-21	EB2130810063	-	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0080	<0.0080	0.0152	<0.0080	<0.0089	<0.0080	<0.0241	<0.0400	0.0136	0.0128	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	<0.008	<0.008	<0.008	0.0416	-	-
26-Oct-21	EB2130810065	-	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0080	<0.0080	0.008	<0.0080	<0.0081	<0.0080	<0.0161	<0.0400	0.0168	0.0136	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	<0.008	<0.008	<0.008	0.0384	-	-
12-Nov-21	EB2133062001	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	0.0032	<0.0032	0.0074	<0.0032	0.0045	<0.0032	0.0119	<0.016	0.0256	0.0189	0.0077	0.0042	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	0.0715	-	-
02-Dec-21	EB2135860011	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	0.0034	<0.0025	0.0134	<0.0008	0.0099	<0.0008	0.0233	0.0370	0.0726	0.0320	0.0174	0.0077	<0.0015	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.1930	-	-
10-Mar-22	EB2207080002	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0080	<0.0080	<0.0080	<0.0080	0.0144	<0.0080	0.0144	<0.0400	0.0336	0.0216	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	<0.008	<0.008	<0.008	0.0696	-	-
04-Jul-22	EB2220051043	-	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0032	<0.0032	0.0032	<0.0032	<0.0035	<0.0032	0.0032	<0.0158	0.0212	0.0133	<0.0067	0.0063	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0758	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.004	<0.003	<0.003	0.0440	-	-
06-Jul-22	EB2220051003	-	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	0.0031	<0.0022	<0.0096	<0.0015	<0.0108	<0.0015	<0.0015	<0.0770	0.0343	0.0197	<0.0097	<0.0054	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0385	<0.0015	<0.004	<0.004	<0.004	<0.004	<0.0015	<0.0015	<0.002	<0.002	<0.002	<0.002	0.0571	-	-
22-Jul-22	EB2221968002	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0800	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0160	<0.0400	<0.0160	<0.040	<0.040	<0.040	<0.040	<0.0160	<0.0160	<0.016	<0.016	<0.016	<0.016	<0.0160	-	-
01-Dec-22	EB2236118008	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	0.0027	<0.0016	0.0075	<0.0016	0.0032	<0.0016	0.0107	0.0141	0.0981	0.0307	0.0086	0.003	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.1680	-	-
05-Jan-23	EB2300551001	CS Energy	SW33	Northern Railway Crossing - Culvert near MW75	Surface Water	Standard	-	<0.0074	<0.0074	0.0074	<0.0074	<0.0074	<0.0074	0.0074	<0.0370	0.0437	0.0266	0.0104	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0074	<0.0185	<0.0074	<0.018	<0.018	<0.018	<0.018	<0.0074	<0.0074	<0.007	<0.007	<0.007	<0.007	0.0881	-	-
16-Mar-21	EB2107351001	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0300	<0.02	0.1	<0.02	0.1500	<0.02	0.2500	0.2000	0.88	0.5300	0.3	0.06	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.0900	<0.05	<0.05	2.3400	-	-
07-Jul-21	EB2119293006	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0425	0.0496	0.24	0.0102	0.1190	<0.0079	0.3590	0.8190	3.02	1.3800	0.706	0.0984	0.0189	<0.0079	<0.0079	<0.0079	<0.0079	<0.0197	<0.0079	<0.020	<0.020	<0.020	<0.020	<0.0079	<0.0079	<0.008	0.1120	<0.008	<0.008	6.6200	-	-
19-Oct-21	EB2130810066	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0248	0.0168	0.126	<0.0089	0.1550	<0.0080	0.2810	0.4900	1.43	0.7710	0.314	0.0928	0.02	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	0.1530	<0.011	<0.008	3.5900	-	-
22-Oct-21	EB2130810067	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0232	0.0144	0.0992	<0.0080	0.1130	<0.0080	0.2120	0.2680	0.807	0.4750	0.213	0.0632	0.0136	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	0.1160	<0.008	<0.008	2.2000	-	-
26-Oct-21	EB2130810068	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0264	0.016	0.12	<0.0080	0.1460	<0.0080	0.2660	0.1540	0.566	0.3990	0.175	0.0552	0.0104	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	0.0390	<0.008	<0.008	1.7100	-	-
12-Nov-21	EB2133062002	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0272	0.0163	0.104	0.0058	0.1130	<0.0032	0.2170	0.1560	0.506	0.3650	0.179	0.0445	0.0125	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	0.0420	0.0050	<0.003	1.5800	-	-
02-Dec-21	EB2135860010	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0283	0.0188	0.114	0.0075	0.0994	<0.0016	0.2130	0.3370	0.78	0.3540	0.187	0.0449	0.0102	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	0.0140	<0.002	<0.002	2.0000	-	-
09-Dec-21	EB2137227014	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0354	0.0411	0.221	0.0108	0.1420	<0.0032	0.3630	0.4500	1.34	0.6570	0.288	0.0718	0.0099	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	0.0100	<0.003	<0.003	3.2800	-	-
16-Dec-21	EB2137227011	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0414	0.0395	0.25	0.0134	0.1460	<0.0032	0.3960	0.4940	1.53	0.7470	0.346	0.0818	0.0102	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	0.0090	<0.003	<0.003	3.7100	-	-
19-Jan-22	EB2202169018	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0521	0.0528	0.358	0.0143	0.1230	<0.0016	0.4810	0.6800	1.88	0.8420	0.504	0.0981	<0.0016	<0.0020	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	0.0140	<0.002	<0.002	4.6200	-	-
10-Mar-22	EB2207080003	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	<0.0320	<0.0320	0.0928	<0.0320	0.1310	<0.0320	0.2240	0.2080	0.794	0.3810	0.179	0.0416	<0.0320	<0.0320	<0.0320	<0.0320	<0.0320	<0.0800	<0.0320	<0.080	<0.080	<0.080	<0.080	<0.0320	<0.0320	<0.032	0.1060	<0.032	<0.032	1.9300	-	-
04-Jul-22	EB2220051042	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0146	0.0117	0.0781	<0.0040	0.0575	<0.0016	0.1360	0.1010	0.243	0.1580	0.0935	0.0244	0.0043	<0.0016	<0.0016	<0.0157	<0.0157	<0.0394	<0.0016	<0.039	<0.039	<0.004	<0.004	<0.0016	<0.0016	<0.002	0.0210	<0.002	<0.002	0.8070	-	-
06-Jul-22	EB2220051002	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0228	0.0158	0.104	<0.0058	0.0622	<0.0005	0.1660	0.0966	0.256	0.1780	0.0963	0.0325	0.0044	<0.0005	<0.0005	<0.0032	<0.0032	<0.0080	<0.0005	<0.001	<0.001	<0.001	<0.008	<0.0005	<0.0005	<0.001	0.0270	0.0020	<0.001	0.8980	-	-
22-Jul-22	EB2221968001	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	<0.0275	<0.0090	0.0592	<0.0080	0.1010	<0.0080	0.1600	0.0768	0.246	0.1490	0.0872	0.0328	0.0088	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	<0.081	<0.080	<0.008	0.7610	-	-
21-Oct-22	EB2231628001	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	<0.0310	0.0195	0.142	0.0101	0.1950	<0.0032	0.3370	0.1590	0.364	0.2400	0.136	0.0656	0.0094	<0.0032	<0.0032	<0.0032	<0.0032	<0.0079	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	0.2400	0.0360	<0.003	1.6200	-	-
25-Oct-22	EB2232600004	-	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.1880	0.026	0.19	<0.0113	0.1580	<0.0113	0.3480	0.2040	0.436	0.3740	0.195	0.0633	<0.0113	<0.0113	<0.0113	<0.0113	<0.0113	<0.0282	<0.0113	<0.028	<0.028	<0.028	<0.028	<0.0113	<0.0113	<0.011	0.2320	0.0680	<0.011	2.1300	-	-
01-Dec-22	EB2236118007	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	0.0043	0.0157	0.0968	0.0059	0.0827	<0.0016	0.1800	0.1320	0.484	0.2400	0.12	0.0378	0.0054	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	0.0800	0.0130	<0.002	1.3200	-	-
05-Jan-23	EB2300551002	CS Energy	SW34	Northern Railway Crossing - Culvert near MW74	Surface Water	Standard	-	<0.0235	0.0243	0.145	0.0092	0.1640	<0.0008	0.3090	0.2730	0.745	0.3850	0.237	0.0826	0.0168	0.0013	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	0.0960	0.0070	<0.001	2.1900	-	-
19-May-21	EB2114060027	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
21-Oct-21	EB2130810069	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0079	<0.0160	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
24-Jan-22	EB2202169057	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	<0.0020	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
31-Mar-22	EB2209243025	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0039	<0.0008	<0.0008	<0.0008	<0.0010	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
07-Jul-22	EB2220051022	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	<0.0009	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
26-Oct-22	EB2232600013	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	0.0295	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	0.004	0.0035	<0.002	<0.002	<0.002	<0.002	0.0370	-	-
28-Feb-23	EB2306934006	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0008	-	-
10-Jun-23	EB2318365048	-	SW36	Downstream - Dunn Creek	Surface Water	Standard	-	0.0026	<0.0005	<0.0005	<0.0005	<0.0002	<0.0005	<0.0002	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0026	-	-
19-May-21	EB2114060019	-	SW37	Upstream - Northwestern Corner	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	0.0026	<0.0016	0.0026	0.0089	0.0037	0.0038	0.0045	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0235	-	-
21-Oct-21	EB2130810070	-	SW37	Upstream - Northwestern Corner	Surface Water	Standard	-	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0400	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0200	<0.0080	<0.020	<0.020	<0.020	<0.020	<0.0080	<0.0080	<0.008	<0.008	<0.008	<0.008	<0.0080	-	-
31-Mar-22	EB2209243019	-	SW37	Upstream - Northwestern Corner	Surface Water	Standard	-	<0.0015	<0.0008	<0.0010	<0.0008	<0.0027	<0.0008	<0.0008	<0.0080	0.0053	0.0046	<0.0024	<0.0010	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0099	-	-
06-Jul-22	EB2220051004	-	SW37	Upstream - Northwestern Corner	Surface Water	Standard	-	<0.0032	<0.0032	<0.0032	<0.0032	<0.0064	<0.0032	<0.0032	<0.0159	<0.0083	<0.0055	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0032	<0.0080	<0.0032	<0.008	<0.008	<0.008	<0.008	<0.0032	<0.0032	<0.003	<0.003	<0.003	<0.003	<0.0032	-	-
03-Nov-22	EB2232870013	-	SW37	Upstream - Northwestern Corner	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0045	0.0027	0.0019	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0046	-	-
19-May-21	EB2114060018	-	SW39	Onsite - Northwestern Dam	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
19-Oct-21	EB2130810071	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	<0.0016	<0.0016	0.0171	<0.0016	0.0155	<0.0016	0.0326	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0326	-	-
26-Oct-21	EB2130810072	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
18-Jan-22	EB2202169011	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	0.0023	0.0024	0.029	0.0012	0.0356	<0.0008	0.0646	<0.0039	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0705	-	-
31-Mar-22	EB2209243030	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	<0.0017	0.0018	0.0227	0.0012	0.0418	<0.0007	0.0645	<0.0036	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0018	<0.0007	<0.002	<0.002	<0.002	<0.002	<0.0007	<0.0007	<0.001	<0.001	<0.001	<0.001	0.0675	-	-
06-Jul-22	EB2220051019	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	0.0082	0.0025	0.0281	<0.0014	0.0606	<0.0005	0.0887	<0.0080	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0016	<0.0016	<0.0040	<0.0005	<0.004	<0.004	<0.001	<0.004	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0994	-	-
26-Oct-22	EB2232600012	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	0.0030	<0.0008	0.032	0.0014	0.0434	<0.0008	0.0754	<0.0040	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0798	-	-
07-Jun-23	EB2318365049	-	SW40	Jambin Dakenba Road	Surface Water	Standard	-	0.0036	0.0025	0.0267	0.0013	0.0216	<0.0005	0.0483	<0.0078	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0016	<0.0016	<0.0016	<0.0039	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.001	<0.001	<0.001	<0.001	0.0557	-	-
21-Oct-21	EB2130810073	-	SW41	Callide Wier	Surface Water	Standard	-	<0.0016	<0.0016	<0.0055	<0.0016	<0.0119	<0.0016	<0.0055	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	<0.0016	-	-
24-Jan-22	EB2202169056	-	SW41	Callide Wier	Surface Water	Standard	-	<0.0210	<0.0016	0.0042	<0.0016	0.0064	<0.0016	0.0106	<0.0080	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0106	-	-
05-Apr-22	EB2209861010	-	SW41	Callide Wier	Surface Water	Standard	-	0.0016	<0.0016	0.0103	<0.0016	0.0236	<0.0016	0.0339	<0.0079	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0355	-	-
07-Jul-22	EB2220051024	-	SW41	Callide Wier	Surface Water	Standard	-	<0.0060	<0.0024	0.0191	<0.0010	0.0242	<0.0008	0.0433	<0.0038	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0019	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0433	-	-
02-Nov-22	EB2232870004	-	SW41	Callide Wier	Surface Water	Standard	-	<0.0100	<0.0025	0.0207	<0.0011	0.0242	<0.0005	0.0449	<0.0020	0.0046	<0.0005	<0.0020	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0008	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0495	-	-
06-Mar-23	EB2306934038	-	SW41	Callide Wier	Surface Water	Standard	-	0.0047	<0.0015	0.0164	<0.0010	0.0339	<0.0005	0.0503	<0.0159	<0.0032	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0079	<0.0005	<0.008	<0.008	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0550	-	-
12-Jun-23	EB2318365050	-	SW41	Callide Wier	Surface Water	Standard	-	0.0021	0.0022	0.023	0.0011	0.0217	<0.0005	0.0447	<0.0078	<0.0016	<0.0016	<0.0016	<0.0005	<0.0005	<0.0005	<0.0016	<0.0016	<0.0016	<0.0005	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.001	<0.001	<0.001	<0.001	0.0501	-	-
08-Dec-23	EB2339753009	-	SW41	Callide Wier	Surface Water	Standard	-	0.0022	<0.0015	0.0109	<0.0005	0.0152	<0.0005	0.0261	<0.0080	<0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0283	-	-
19-Oct-21	EB2130787002	-	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0156	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0031	<0.0078	<0.0031	<0.008	<0.008	<0.008	<0.008	<0.0031	<0.0031	<0.003	<0.003	<0.003	<0.003	<0.0031	-	-
26-Oct-21	EB2130787003	-	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	0.0059	<0.0020	0.0116	<0.0016	0.0089	<0.0016	0.0205	<0.0080	0.0049	<0.0037	0.0024	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0337	-	-
12-Nov-21	EB2133062005	CS Energy	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	<0.0030	<0.0016	0.0021	<0.0016	0.0045	<0.0016	0.0066	<0.008	<0.0030	0.0022	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0088	-	-
02-Dec-21	EB2135860009	CS Energy	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	0.0084	0.0046	0.0242	<0.0025	0.0180	<0.0008	0.0422	0.0220	0.0265	0.0138	0.0052	0.002	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.1250	-	-
07-Jul-22	EB2220051041	-	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	0.0062	<0.0033	0.0164	<0.0008	<0.0064	<0.0008	0.0164	<0.0398	<0.0021	<0.0017	<0.0016	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0199	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0226	-	-
01-Nov-22	EB2232870002	-	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	0.0104	<0.0040	0.0172	<0.0008	<0.0062	<0.0008	0.0172	<0.0040	<0.0030	<0.0025	<0.0025	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0020	<0.0008	<0.002	<0.002	<0.002	<0.002	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	0.0276	-	-
01-Dec-22	EB2236118004	CS Energy	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	0.0067	0.0022	0.0136	<0.0016	0.0021	<0.0016	0.0157	<0.0080	0.0018	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	<0.002	<0.002	<0.002	0.0264	-	-
05-Jan-23	EB2300551008	CS Energy	SW42	Dunn Creek (Downstream of SW17)	Surface Water	Standard	-	<0.0100	0.0024	0.0118	<0.0005	0.0052	<0.0005	0.0170	<0.0070	<0.0060	<0.0030	0.0044	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	0.0244	-	-
22-Jul-22	EB2221964003	CS Energy	SW50	BS3 Clean Water Drain North	Surface Water	Standard	-	0.0514	0.0343	0.203	0.0163	0.3030	<0.0016	0.5060	0.0827	0.257	0.1930	0.0843	0.0504	0.0112	<0.0016	<0.0016	<0.0016	<0.0016	<0.0399	<0.0016	<0.040	<0.040	<0.040	<0.040	<0.0016	<0.0016	<0.002	0.0450	<0.016	<0.002	1.3300	-	-
01-Dec-22	EB2236118006	CS Energy	SW50	BS3 Clean Water Drain North	Surface Water	Standard	-	0.0726	0.0517	0.294	0.0214	0.3010	<0.0016	0.5950	0.1520	0.573	0.3170	0.144	0.0672	0.0112	<0.0016	<0.0016	<0.0016	<0.0016	<0.0040	<0.0016	<0.004	<0.004	<0.004	<0.004	<0.0016	<0.0016	<0.002	0.0230	<0.002	<0.002	2.0300	-	-
22-Jul-22	EB2221964004	CS Energy	SW51	BS3 Clean Water Drain East	Surface Water	Standard	-	<0.0060	<0.0008	<0.0025	<0.0008	<0.0030	<0.0008	<0.0008	<0.0394	<0.0079	<0.0020	<0.0025	<0.0015	<0.0008	<0.0008	<0.0008	<0.0079	<0.0079	<0.0197	<0.0008	<0.020	<0.020	<0.020	<0.020	<0.0008	<0.0008	<0.001	<0.001	<0.001	<0.001	<0.0079	-	-
21-Oct-22	EB2231621003	CS Energy	SW51	BS3 Clean Water Drain East	Surface Water	Standard	-	<0.0008	<0.0008	<0.0008	<0.0008	<0.0009	<0.0008	<0.0008	0.0059	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0078	<0.0078	<0.0078	<0.0194	<0.0078	<0.019	<0.019	<0.019	<0.019	<0.0078	<0.0078	<0.001	<0.001	<0.001	<0.001	<0.0078	-	-

NOTES:

1	Analyte exceeds the PFAS NEMP Freshwater 99% Species Protection
1	Analyte exceeds the PFAS NEMP Freshwater 95% Species Protection
1	Analyte exceeds the PFAS NEMP Health Based - Drinking Water
1	Analyte exceeds the PFAS NEMP Health Based - Recreational Water

Sample number				AB1-AA-WB	AB1-CS-WB	AB1-NH-EP	AB1-MS-WB	AB1-PR-EP	AB1-CQ-EP	AB1-OL-EP	AB1-TT-EP	AB1-MA-EP
Date sampled				4/02/2023	4/02/2023	4/02/2023	4/02/2023	2/02/2023	4/02/2023	4/02/2023	4/02/2023	4/02/2023
Species				Ambassis agassizii	Craterocephalus stercusmuscarum	Neosilurus hyrtlii	Macrobrachium sp.	Porochilus rendahli	Cherax quadricarinatus	Oxyeleotris lineolata	Tandanus tandanus	Macquaria ambigua
Common name				Agassiz's perchlet	Flyspecked Hardyhead	Hyrtl's Catfish	Freshwater prawn	Rendahl's Catfish	Crayfish	Sleepy cod	Eeltail Catfish	Yellowbelly
Site				AB1	AB1	AB1	AB1	AB1	AB1	AB1	AB1	AB1
System				Callide Creek U/S	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S
Condition				Control	Control	Control	Control	Control	Control	Control	Control	Control
Assessment				Ecological health	Ecological health	Human health	Ecological health	Human health	Human health	Human health	Human health	Human health
Tissue analysed				Whole body	Whole body	Edible portion	Whole body	Edible portion	Edible portion	Edible portion	Edible portion	Edible portion
	Unit	LOR	Screening criteria									
Weight	g	0.1	-	7.9	13	141	3.4	7.7	63	535	238	1150
Arsenic	mg/kg	0.05	-	0.2	0.21	0.07	0.55	0.05	0.5	0.06	0.12	0.06
Barium	mg/kg	0.1	-	6.1	7.4	<0.1	30.4	0.7	47.5	<0.1	0.2	<0.1
Boron	mg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chromium	mg/kg	0.05	-	0.79	0.18	<0.05	0.15	2.44	2.41	<0.05	<0.05	<0.05
Copper	mg/kg	0.1	20/2*	1.2	0.6	0.3	23.8	1.2	15.7	1.1	0.7	0.3
Molybdenum	mg/kg	0.05	-	0.1	<0.05	<0.05	<0.05	0.35	0.33	<0.05	<0.05	<0.05
Selenium	mg/kg	0.05	1/2*	0.25	0.17	0.22	0.22	0.16	0.07	0.17	0.26	0.44
Strontium	mg/kg	0.1	-	95.6	93.6	0.8	121	54.3	134	0.6	1.9	0.5
Uranium	mg/kg	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Sample number				AB1-AA-WB	AB1-CS-WB	AB1-NH-EP	AB1-MS-WB	AB1-PR-EP	AB1-CQ-EP	AB1-OL-EP	AB1-TT-EP	AB1-MA-EP
Vanadium	mg/kg	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	mg/kg	0.5	40/15*	48.6	66.7	12.4	44.5	39.5	15.3	7.2	6.1	10.1
Perfluorobutane sulfonic acid (PFBS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoropentane sulfonic acid (PFPeS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorohexane sulfonic acid (PFHxS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroheptane sulfonic acid (PFHpS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Linear	µg/kg	1	-	<1	<1	<1	<1	2	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Branched	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS)	µg/kg	1	-	<1	<1	<1	<1	2	<1	<1	<1	<1
Perfluorodecane sulfonic acid (PFDS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorobutanoic acid (PFBA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Perfluoropentanoic acid (PFPeA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorohexanoic acid (PFHxA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	µg/kg	1	11.2**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorononanoic acid (PFNA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorodecanoic acid (PFDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroundecanoic acid (PFUnDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1

Sample number				AB1-AA-WB	AB1-CS-WB	AB1-NH-EP	AB1-MS-WB	AB1-PR-EP	AB1-CQ-EP	AB1-OL-EP	AB1-TT-EP	AB1-MA-EP
Perfluorododecanoic acid (PFDoDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotridecanoic acid (PFTrDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotetradecanoic acid (PFTeDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorooctane sulfonamide (FOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of PFAS	µg/kg	1	-	<1	<1	<1	<1	2	<1	<1	<1	<1
Sum of PFHxS and PFOS	µg/kg	1	1.4/4.6/8.2***	<1	<1	<1	<1	2	<1	<1	<1	<1
Lithium	mg/kg	0.2	-	<0.2	<0.2	<0.2	----	<0.2	<0.2	<0.2	<0.2	<0.2
Thorium	mg/kg	0.01	-	<0.01	<0.01	<0.01	----	<0.01	<0.01	<0.01	<0.01	<0.01

Sample number				AB1-AA-WB	AB1-CS-WB	AB1-NH-EP	AB1-MS-WB	AB1-PR-EP	AB1-CQ-EP	AB1-OL-EP	AB1-TT-EP	AB1-MA-EP
Fluoride	mg/kg	0.2	-	----	----	<0.2	----	----	----	<0.2	<0.2	<0.2

Sample number				AB2-LC-EP	AB2-CS-WB	AB2-MP-WB	AB2-CQ-EP	AB2-CQ-RB	AB2-TT-EP	AB3-LC-EP	AB3-LC-RB	AB3-AA-WB
Date sampled				30/01/2023	31/01/2023	31/01/2023	31/01/2023	30/01/2023	30/01/2023	30/01/2023	30/01/2023	31/01/2023
Species				Lates calcarifer	Craterocephalus stercusmuscarum	Macrobrachium sp.	Cherax quadricarinatus	Cherax quadricarinatus	Tandanus tandanus	Lates calcarifer	Lates calcarifer	Ambassis agassizii
Common name				Barramundi	Flyspecked Hardyhead	Freshwater prawn	Crayfish	Crayfish	Eeltail Catfish	Barramundi	Barramundi	Agassiz's perchlet
Site				AB2	AB2	AB2	AB2	AB2	AB2	AB3	AB3	AB3
System				Lake Callide	Lake Callide	Lake Callide	Lake Callide	Lake Callide	Lake Callide	Lake Callide	Lake Callide	Lake Callide
Condition				Test	Test	Test	Test	Test	Test	Test	Test	Test
Assessment				Human health	Ecological health	Ecological health	Human health	Human health	Human health	Human health	Human health	Ecological health
Tissue analysed				Edible portion	Whole body	Whole body	Edible portion	Rest of body	Edible portion	Edible portion	Rest of body	Whole body
	Unit	LOR	Screening criteria									
Weight	g	0.1	-	11200	6	1.3	10	10	85	10600	10600	8
Arsenic	mg/kg	0.05	-	0.08	0.22	----	0.28	0.27	0.16	0.09	0.06	0.16
Barium	mg/kg	0.1	-	0.1	5.5	----	2.3	2.1	0.7	<0.1	<0.1	3.8
Boron	mg/kg	5	-	<5	<5	----	<5	<5	<5	<5	<5	<5
Chromium	mg/kg	0.05	-	<0.05	0.26	----	0.13	0.14	6.85	<0.05	<0.05	0.22
Copper	mg/kg	0.1	20/2*	0.4	0.6	----	8.1	7.1	1.6	0.4	0.3	0.8
Molybdenum	mg/kg	0.05	-	<0.05	<0.05	----	<0.05	<0.05	0.77	<0.05	<0.05	0.05
Selenium	mg/kg	0.05	1/2*	0.16	0.14	----	0.08	0.08	0.15	0.2	0.18	0.26
Strontium	mg/kg	0.1	-	1.1	104	----	24.9	24.5	2	0.9	0.6	93.5
Uranium	mg/kg	0.01	-	<0.01	<0.01	----	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/kg	0.5	-	<0.5	<0.5	----	<0.5	<0.5	1.8	<0.5	<0.5	<0.5
Zinc	mg/kg	0.5	40/15*	5.6	82.6	----	18.8	16.9	6.7	5.7	5.1	41.3
Perfluorobutane sulfonic acid (PFBS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1

Sample number				AB2-LC-EP	AB2-CS-WB	AB2-MP-WB	AB2-CQ-EP	AB2-CQ-RB	AB2-TT-EP	AB3-LC-EP	AB3-LC-RB	AB3-AA-WB
Perfluoropentane sulfonic acid (PFPeS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorohexane sulfonic acid (PFHxS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroheptane sulfonic acid (PFHpS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Linear	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Branched	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorodecane sulfonic acid (PFDS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorobutanoic acid (PFBA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Perfluoropentanoic acid (PFPeA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorohexanoic acid (PFHxA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	µg/kg	1	11.6**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorononanoic acid (PFNA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorodecanoic acid (PFDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroundecanoic acid (PFUnDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorododecanoic acid (PFDoDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotridecanoic acid (PFTrDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotetradecanoic acid (PFTeDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorooctane sulfonamide (FOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2

Sample number				AB2-LC-EP	AB2-CS-WB	AB2-MP-WB	AB2-CQ-EP	AB2-CQ-RB	AB2-TT-EP	AB3-LC-EP	AB3-LC-RB	AB3-AA-WB
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of PFAS	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sum of PFHxS and PFOS	µg/kg	1	1.4/4.6/8.2***	<1	<1	<1	<1	<1	<1	<1	<1	<1
Lithium	mg/kg	0.2	-	<0.2	<0.2	----	<0.2	----	<0.2	<0.2	----	<0.2
Thorium	mg/kg	0.01	-	0.018	<0.01	----	<0.01	----	0.022	<0.01	----	<0.01
Fluoride	mg/kg	0.2	-	<0.2		----		----	<0.2	<0.2	----	----

Sample number				AB3-CS-WB	AB3-MS-WB	AB3-CQ-EP	AB4-AT-WB	AB4-AA-WB	AB4-CS-WB	AB4-PR-EP	AB4-OL-EP	AB4-TT-EP
Date sampled				31/01/2023	31/01/2023	31/01/2023	2/02/2023	2/02/2023	2/02/2023	2/02/2023	2/02/2023	2/02/2023
Species				Craterocephalus stercusmuscarum	Macrobrachium sp.	Cherax quadricarinatus	Atyidae	Ambassis agassizii	Craterocephalus stercusmuscarum	Porochilus rendahli	Oxyeleotris lineolata	Tandanus tandanus
Common name				Flyspecked Hardyhead	Freshwater prawn	Crayfish	Freshwater shrimp	Agassiz's perchlet	Flyspecked Hardyhead	Rendahl's Catfish	Sleepy cod	Eeltail Catfish
Site				AB3	AB3	AB3	AB4	AB4	AB4	AB4	AB4	AB4
System				Lake Callide	Lake Callide	Lake Callide	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S
Condition				Test	Test	Test	Test	Test	Test	Test	Test	Test
Assessment				Ecological health	Ecological health	Human health	Ecological health	Ecological health	Ecological health	Human health	Human health	Human health
Tissue analysed				Whole body	Whole body	Edible portion	Whole body	Whole body	Whole body	Edible portion	Edible portion	Edible portion
	Unit	LOR	Screening criteria									
Weight	g	0.1	-	27	16	121	1.9	3	2.2	2.4	5.1	112
Arsenic	mg/kg	0.05	-	0.22	0.42	0.4	----	----	0.51	----	----	0.16
Barium	mg/kg	0.1	-	2.4	4.4	1.3	----	----	12.9	----	----	<0.1
Boron	mg/kg	5	-	<5	<5	<5	----	----	<5	----	----	<5
Chromium	mg/kg	0.05	-	1.4	0.45	0.22	----	----	0.12	----	----	<0.05
Copper	mg/kg	0.1	20/2*	0.6	17.6	13	----	----	0.7	----	----	0.2
Molybdenum	mg/kg	0.05	-	0.18	0.07	0.05	----	----	<0.05	----	----	<0.05
Selenium	mg/kg	0.05	1/2*	0.2	0.18	0.09	----	----	0.18	----	----	0.12
Strontium	mg/kg	0.1	-	52.1	106	17.6	----	----	109	----	----	0.5
Uranium	mg/kg	0.01	-	<0.01	<0.01	<0.01	----	----	<0.01	----	----	<0.01
Vanadium	mg/kg	0.5	-	<0.5	<0.5	<0.5	----	----	<0.5	----	----	<0.5
Zinc	mg/kg	0.5	40/15*	53.8	24.6	20	----	----	96.5	----	----	5.2
Perfluorobutane sulfonic acid (PFBS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoropentane sulfonic acid (PFPeS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorohexane sulfonic acid (PFHxS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	1

Sample number				AB3-CS-WB	AB3-MS-WB	AB3-CQ-EP	AB4-AT-WB	AB4-AA-WB	AB4-CS-WB	AB4-PR-EP	AB4-OL-EP	AB4-TT-EP
Perfluoroheptane sulfonic acid (PFHpS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Linear	µg/kg	1	-	<1	<1	<1	3	7	<1	14	1	3
Perfluorooctane sulfonic acid (PFOS) - Branched	µg/kg	1	-	<1	<1	<1	<1	3	<1	2	<1	1
Perfluorooctane sulfonic acid (PFOS)	µg/kg	1	-	<1	<1	<1	3	10	<1	16	1	4
Perfluorodecane sulfonic acid (PFDS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorobutanoic acid (PFBA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Perfluoropentanoic acid (PFPeA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorohexanoic acid (PFHxA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	µg/kg	1	11.2**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorononanoic acid (PFNA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorodecanoic acid (PFDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluoroundecanoic acid (PFUnDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Perfluorododecanoic acid (PFDoDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotridecanoic acid (PFTrDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotetradecanoic acid (PFTeDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorooctane sulfonamide (FOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2

Sample number				AB3-CS-WB	AB3-MS-WB	AB3-CQ-EP	AB4-AT-WB	AB4-AA-WB	AB4-CS-WB	AB4-PR-EP	AB4-OL-EP	AB4-TT-EP
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of PFAS	µg/kg	1	-	<1	<1	<1	3	10	<1	16	1	5
Sum of PFHxS and PFOS	µg/kg	1	1.4/4.6/8.2***	<1	<1	<1	3	10	<1	16	1	5
Lithium	mg/kg	0.2	-	<0.2	<0.2	<0.2	----	----	----	----	<0.2	<0.2
Thorium	mg/kg	0.01	-	<0.01	<0.01	<0.01	----	----	----	----	<0.01	<0.01
Fluoride	mg/kg	0.2	-	----	----	6.3	----	----	----	----		<0.2

Sample number				AB5-AA-WB	AB5-PR-EP	AB7-AT-WB	AB7-AA-WB	AB7-CS-WB	AB8-AA-WB	AB8-CS-WB	AB8-NH-EP	AB8-MA-EP
Date sampled				2/02/2023	2/02/2023	3/02/2023	3/02/2023	3/02/2023	1/02/2023	1/02/2023	1/02/2023	1/02/2023
Species				Ambassis agassizii	Porochilus rendahli	Atyidae	Ambassis agassizii	Craterocephalus stercusmuscarum	Ambassis agassizii	Craterocephalus stercusmuscarum	Neosilurus hyrtlii	Macquaria ambigua
Common name				Agassiz's perchlet	Rendahl's Catfish	Freshwater shrimp	Agassiz's perchlet	Flyspecked Hardyhead	Agassiz's perchlet	Flyspecked Hardyhead	Hyrtl's Catfish	Yellowbelly
Site				AB5	AB5	AB7	AB7	AB7	AB8	AB8	AB8	AB8
System				Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S	Callide Creek D/S
Condition				Test	Test	Test	Test	Test	Test	Test	Test	Test
Assessment				Ecological health	Human health	Ecological health	Ecological health	Ecological health	Ecological health	Ecological health	Human health	Human health
Tissue analysed				Whole body	Edible portion	Whole body	Whole body	Whole body	Whole body	Whole body	Edible portion	Edible portion
	Unit	LOR	Screening criteria									
Weight	g	0.1	-	0.9	39	1.2	1.4	0.6	15	17	13	154
Arsenic	mg/kg	0.05	-	----	0.06	----	----	----	0.15	0.2	<0.05	0.06
Barium	mg/kg	0.1	-	----	1.2	----	----	----	6	5.6	0.3	1
Boron	mg/kg	5	-	----	<5	----	----	----	<5	<5	<5	<5
Chromium	mg/kg	0.05	-	----	1.76	----	----	----	0.48	0.25	<0.05	<0.05
Copper	mg/kg	0.1	20/2*	----	1	----	----	----	0.6	0.5	0.3	0.4
Molybdenum	mg/kg	0.05	-	----	0.24	----	----	----	0.09	0.05	<0.05	<0.05
Selenium	mg/kg	0.05	1/2*	----	0.1	----	----	----	0.13	0.11	0.21	0.52
Strontium	mg/kg	0.1	-	----	55.5	----	----	----	82.6	79.6	7.6	27
Uranium	mg/kg	0.01	-	----	<0.01	----	----	----	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/kg	0.5	-	----	<0.5	----	----	----	<0.5	<0.5	<0.5	<0.5

Sample number				AB5-AA-WB	AB5-PR-EP	AB7-AT-WB	AB7-AA-WB	AB7-CS-WB	AB8-AA-WB	AB8-CS-WB	AB8-NH-EP	AB8-MA-EP
Zinc	mg/kg	0.5	40/15*	----	49.2	----	----	----	40.2	50	14.1	9.8
Perfluorobutane sulfonic acid (PFBS)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluoropentane sulfonic acid (PFPeS)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluorohexane sulfonic acid (PFHxS)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluoroheptane sulfonic acid (PFHpS)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Linear	µg/kg	1	-	35	42	28	66	30	82	64	7	4
Perfluorooctane sulfonic acid (PFOS) - Branched	µg/kg	1	-	5	2	3	18	10	7	4	1	1
Perfluorooctane sulfonic acid (PFOS)	µg/kg	1	-	40	44	31	84	40	89	68	8	5
Perfluorodecane sulfonic acid (PFDS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorobutanoic acid (PFBA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Perfluoropentanoic acid (PFPeA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorohexanoic acid (PFHxA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	µg/kg	1	11.2**	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluorononanoic acid (PFNA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluorodecanoic acid (PFDA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluoroundecanoic acid (PFUnDA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
Perfluorododecanoic acid (PFDoDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotridecanoic acid (PFTrDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Perfluorotetradecanoic acid (PFTeDA)	µg/kg	2	-	<2	<2	<2	<2	<6	<2	<2	<2	<2

Sample number				AB5-AA-WB	AB5-PR-EP	AB7-AT-WB	AB7-AA-WB	AB7-CS-WB	AB8-AA-WB	AB8-CS-WB	AB8-NH-EP	AB8-MA-EP
Perfluorooctane sulfonamide (FOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/kg	5	-	<5	<5	<5	<5	<6	<5	<5	<5	<5
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/kg	2	-	<2	<2	<2	<2	<6	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/kg	2	-	<2	<2	<2	<2	<6	<2	<2	<2	<2
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/kg	2	-	<2	<2	<2	<2	<6	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<2	<1	<1	<1	<1
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sum of PFAS	µg/kg	1	-	40	44	31	84	40	89	68	8	5
Sum of PFHxS and PFOS	µg/kg	1	1.4/4.6/8.2***	40	44	31	84	40	89	68	8	5
Lithium	mg/kg	0.2	-	----	<0.2	----	----	----	<0.2	<0.2	<0.2	<0.2
Thorium	mg/kg	0.01	-	----	<0.01	----	----	----	<0.01	<0.01	<0.01	<0.01
Fluoride	mg/kg	0.2	-	----	----	----	----	----	----	----	----	3.5

Sample number				AB8-MA-RB	AB9-AA-WB	AB9-NH-EP	AB9-MS-WB	AB9-TT-EP	AB2-LC-DU
Date sampled				30/01/2023	1/02/2023	1/02/2023	1/02/2023	1/02/2023	30/01/2023
Species				Macquaria ambigua	Ambassis agassizii	Neosilurus hyrtlii	Macrobrachium sp.	Tandanus tandanus	Lates calcarifer
Common name				Yellowbelly	Agassiz's perchlet	Hyrtl's Catfish	Freshwater prawn	Eeltail Catfish	Barramundi
Site				AB8	AB9	AB9	AB9	AB9	AB2
System				Callide Creek D/S	Lake Kroombit	Lake Kroombit	Lake Kroombit	Lake Kroombit	Lake Callide
Condition				Test	Reference	Reference	Reference	Reference	Test
Assessment				Human health	Ecological health	Human health	Ecological health	Human health	Human health
Tissue analysed				Rest of body	Whole body	Edible portion	Whole body	Edible portion	Edible portion
	Unit	LOR	Screening criteria						
Weight	g	0.1	-	154	19	15	4.3	12.5	11200
Arsenic	mg/kg	0.05	-	0.06	0.17	<0.05	0.33	<0.05	0.07
Barium	mg/kg	0.1	-	0.2	1.6	<0.1	19.2	0.2	<0.1
Boron	mg/kg	5	-	<5	<5	<5	<5	<5	<5
Chromium	mg/kg	0.05	-	<0.05	0.09	0.6	0.42	<0.05	<0.05
Copper	mg/kg	0.1	20/2*	0.4	0.5	0.4	16.7	0.3	0.3
Molybdenum	mg/kg	0.05	-	<0.05	<0.05	0.07	0.06	<0.05	<0.05
Selenium	mg/kg	0.05	1/2*	0.49	0.2	0.14	0.22	0.12	0.18
Strontium	mg/kg	0.1	-	6.2	41.6	1	78.4	0.5	0.8
Uranium	mg/kg	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/kg	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	mg/kg	0.5	40/15*	7.5	34.9	11.5	29.8	7	4.9
Perfluorobutane sulfonic acid (PFBS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluoropentane sulfonic acid (PFPeS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluorohexane sulfonic acid (PFHxS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluoroheptane sulfonic acid (PFHpS)	µg/kg	1	-	<1	<1	<1	<1	<1	<1

Sample number				AB8-MA-RB	AB9-AA-WB	AB9-NH-EP	AB9-MS-WB	AB9-TT-EP	AB2-LC-DU
Perfluorooctane sulfonic acid (PFOS) - Linear	µg/kg	1	-	4	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Branched	µg/kg	1	-	2	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS)	µg/kg	1	-	6	<1	<1	<1	<1	<1
Perfluorodecane sulfonic acid (PFDS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
Perfluorobutanoic acid (PFBA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5
Perfluoropentanoic acid (PFPeA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
Perfluorohexanoic acid (PFHxA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	µg/kg	1	11.2**	<1	<1	<1	<1	<1	<1
Perfluorononanoic acid (PFNA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluorodecanoic acid (PFDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluoroundecanoic acid (PFUnDA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
Perfluorododecanoic acid (PFDoDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
Perfluorotridecanoic acid (PFTrDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
Perfluorotetradecanoic acid (PFTeDA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
Perfluorooctane sulfonamide (FOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/kg	5	-	<5	<5	<5	<5	<5	<5
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1	<1
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2

Sample number				AB8-MA-RB	AB9-AA-WB	AB9-NH-EP	AB9-MS-WB	AB9-TT-EP	AB2-LC-DU
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2	<2
Sum of PFAS	µg/kg	1	-	6	<1	<1	<1	<1	<1
Sum of PFHxS and PFOS	µg/kg	1	1.4/4.6/8.2***	6	<1	<1	<1	<1	<1
Lithium	mg/kg	0.2	-	----	<0.2	<0.2	<0.2	<0.2	-
Thorium	mg/kg	0.01	-	----	<0.01	<0.01	0.022	<0.01	-
Fluoride	mg/kg	0.2	-	----	----	----	----	----	-

Sample number				AB3-CS-DU	AB9-NH-DU	AB1-MA-DU	AB1-MA-TR	AB1-NH-TR
Date sampled				30/01/2023	30/01/2023	30/1/2023	30/1/2023	30/01/2023
Species				Craterocephalus stercusmuscarum	Neosilurus hyrtlii	Macquaria ambigua	Macquaria ambigua	Neosilurus hyrtlii
Common name				Flyspecked Hardyhead	Hyrtl's Catfish	Yellowbelly	Yellowbelly	Hyrtl's Catfish
Site				AB3	AB9	AB1	AB1	AB1
System				Lake Callide	Lake Kroombit	Callide Creek U/S	Callide Creek U/S	Callide Creek U/S
Condition				Test	Reference	Control	Control	Control
Assessment				Ecological health	Human health	Human health	Human health	Human health
Tissue analysed				Whole body	Edible portion	Edible portion	Edible portion	Edible portion
	Unit	LOR	Screening criteria					
Weight	g	0.1	-	27	15	1150	-	-
Arsenic	mg/kg	0.05	-	0.24	<0.05	0.05	< 2	< 2
Barium	mg/kg	0.1	-	2.8	0.2	<0.1	< 10	< 10
Boron	mg/kg	5	-	<5	<5	<5	< 10	< 25
Chromium	mg/kg	0.05	-	1.44	0.55	<0.05	< 5	< 5

Sample number				AB3-CS-DU	AB9-NH-DU	AB1-MA-DU	AB1-MA-TR	AB1-NH-TR
Copper	mg/kg	0.1	20/2*	0.6	0.4	0.3	< 5	< 5
Molybdenum	mg/kg	0.05	-	0.2	0.07	<0.05	< 5	< 5
Selenium	mg/kg	0.05	1/2*	0.21	0.13	0.4	< 2	< 2
Strontium	mg/kg	0.1	-	61.3	5.9	0.4	< 10	< 10
Uranium	mg/kg	0.01	-	<0.01	<0.01	<0.01	< 10	< 10
Vanadium	mg/kg	0.5	-	<0.5	<0.5	<0.5	< 10	< 10
Zinc	mg/kg	0.5	40/15*	54.3	15.6	9.3	7.8	10
Perfluorobutane sulfonic acid (PFBS)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluoropentane sulfonic acid (PFPeS)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorohexane sulfonic acid (PFHxS)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluoroheptane sulfonic acid (PFHpS)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Linear	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS) - Branched	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorooctane sulfonic acid (PFOS)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorodecane sulfonic acid (PFDS)	µg/kg	2	-	<2	<2	<2	<2	<2
Perfluorobutanoic acid (PFBA)	µg/kg	5	-	<5	<5	<5	<5	<5
Perfluoropentanoic acid (PFPeA)	µg/kg	2	-	<2	<2	<2	<2	<2
Perfluorohexanoic acid (PFHxA)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluoroheptanoic acid (PFHpA)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorooctanoic acid (PFOA)	µg/kg	1	11.2**	<1	<1	<1	<1	<1

Sample number				AB3-CS-DU	AB9-NH-DU	AB1-MA-DU	AB1-MA-TR	AB1-NH-TR
Perfluorononanoic acid (PFNA)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorodecanoic acid (PFDA)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluoroundecanoic acid (PFUnDA)	µg/kg	1	-	<1	<1	<1	<1	<1
Perfluorododecanoic acid (PFDoDA)	µg/kg	2	-	<2	<2	<2	<2	<2
Perfluorotridecanoic acid (PFTrDA)	µg/kg	2	-	<2	<2	<2	<2	<2
Perfluorotetradecanoic acid (PFTeDA)	µg/kg	2	-	<2	<2	<2	<2	<2
Perfluorooctane sulfonamide (FOSA)	µg/kg	5	-	<5	<5	<5	<5	<5
N-Methyl perfluorooctane sulfonamide (MeFOSA)	µg/kg	5	-	<5	<5	<5	<5	<5
N-Ethyl perfluorooctane sulfonamide (EtFOSA)	µg/kg	2	-	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2
N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	µg/kg	2	-	<2	<2	<2	<2	<2
N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1
N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	µg/kg	1	-	<1	<1	<1	<1	<1
4:2 Fluorotelomer sulfonic acid (4:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2

Sample number				AB3-CS-DU	AB9-NH-DU	AB1-MA-DU	AB1-MA-TR	AB1-NH-TR
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2
10:2 Fluorotelomer sulfonic acid (10:2 FTS)	µg/kg	2	-	<2	<2	<2	<2	<2
Sum of PFAS	µg/kg	1	-	<1	<1	<1	<1	<1
Sum of PFHxS and PFOS	µg/kg	1	1.4/4.6/8.2***	<1	<1	<1	<1	<1
Lithium	mg/kg	0.2	-	-	-	-	-	-
Thorium	mg/kg	0.01	-	-	-	-	-	-
Fluoride	mg/kg	0.2	-	-	-	-	-	-

* Crustacean GEL/ Fish GEL. Units mg/kgbw/day.

** Human health screening value. Units µg/kgbw/day.

***Human health screening value/Mammalian diet/ Avian diet. Units µg/kgbw/day.

Appendix C Summary of toxicity for PFAS

PFOS and PFOA

Properties and Uses

PFAS are a family of man-made fluorine-containing chemicals that do not occur naturally in the environment. The have unique properties to make materials stain- and stick-resistant because they repel oil, grease and water. PFAS are often described as being "ubiquitous in the environment". They have been widely used in man-made products such as surface protection products (e.g. carpet and clothing treatments) and coatings for cardboard and packaging. Some PFAS are or were also historically used in fire-fighting foams (ATSDR 2021).

There are hundreds of different PFAS; the most common and well-studied compounds are PFOS and PFOA as these PFAS were manufactured at the highest rate. PFOS is a completely fluorinated compound with eight carbons and a sulfonate group. PFOA is a completely fluorinated compound with 7 carbons and a carboxyl functional group. Both PFOS and PFOA are metabolically and environmentally stable (i.e. persistent), bioaccumulative and toxic (PBT). Perfluoroalkyl carboxylates and sulfonates are made up of a long perfluorocarbon tail that is both hydrophobic and oleophobic, and a charged end that is hydrophilic (ATSDR 2021).

In addition, many of the PFAS compounds break down to give PFOS or PFOA when released into the environment. Degradation stops at PFOS and PFOA which is why these compounds are commonly found to have accumulated in organisms. These compounds are mobile in soil and leach into groundwater (ATSDR 2021).

Exposure

<u>Oral</u>

PFOS and PFOA are readily absorbed via the oral route of exposure. The bioavailability of both PFAS is estimated to be >93% within 24 hours (based on studies with rats).

<u>Dermal</u>

When a receptor comes into direct contact with impacted soil or water, exposure is often assumed to occur via incidental ingestion and dermal contact. However, there is scientific evidence to suggest that the dermal absorption of PFOS and PFOA is limited in comparison to the ingestion pathway.

The dermal absorption of a chemical depends on the area of skin in contact with the impacted media/chemical, the concentration of chemical in the media, the duration of contact with the media, how tightly the chemical is bound into the media and the ability of the chemical to penetrate the skin. Anionic surfactants (e.g. PFOS/PFOA), are generally thought to penetrate the whole skin poorly. Experimental values (Scala et. al. 1968) confirm that even at the highest surfactant concentrations studied (0.03 M or 1%), non-detectable concentrations of ionic surfactants passed through the skin in the first two hours of exposure. Diffusion curves were observed to be non–linear (exponential), with surfactant able to be measured on the underside of the skin 4 hours following exposure.

Dermal exposures of rats to ammonium PFOA have been shown to produce systemic (e.g., liver, immunotoxicity) effects in animals confirming that the absorption of PFOA by animal skin is possible, however, estimates of the rates of dermal absorption in humans or animals have not been reported. In addition, experimental studies with rat, mouse and human skin indicate that rat and mouse skin may be more permeable to PFOA than human skin. As would be expected, given the physicochemical properties of PFOS and PFOA, dermal permeability was sensitive to pH and was higher when the skin was buffered at pH 2.5 ($5.5x10^{-2}$ cm/hour) compared to pH 5.5 ($4.4x10^{-5}$ cm/hour), well above the pKa for the terminal carboxylic acid of PFOA. This suggests that permeability of the unionized acid is greater than that of the dissociated anion (ATSDR 2021) (noting that at environmental pH, PFOS, PFOA and PFHxS will be in the ionised form (i.e. dissociated anion) in natural waters).

Following application of the ammonium salt of PFOA to isolated human or rat epidermis, approximately 0.048% of the dose was absorbed across human epidermis and 1.44% was absorbed across rat epidermis. The estimated dermal penetration coefficient was $9.49x10^{-7}$ cm/hour in the isolated human epidermis and $3.25x10^{-5}$ cm/hour in the isolated rat epidermis (ATSDR 2021).

Default dermal permeability coefficients for PFOS and PFOA are not available (RAIS). This may be because the measurement of the n-octanol / water partition (a critical parameter for estimating the dermal permeability co-efficient) is impossible for PFOS and PFOA using the standard methodology as these chemicals form a separate layer when mixed with hydrocarbons and water (ATSDR 2021).

In summary, the existing evidence in the scientific literature indicates that the dermal absorption of PFAS following direct contact is limited in comparison to the ingestion pathway so it will not be included in this assessment.

Vapour Inhalation

PFOS and PFOA are not volatile at environmental pH (they exist as an anion), hence vapour inhalation exposures have not been considered further in this HHERA.

Distribution

Unlike other compounds that have PBT (i.e. persistent, bioaccumulative and toxic) characteristics (e.g. organochlorine pesticides, PCBs or dioxins), PFOS and PFOA are highly water soluble and bioaccumulate by attaching to proteins in the blood rather than accumulating in lipids (USEPA 2017). It has been shown that 99.7% of these chemicals in humans and 97.3% of these chemicals in rats and monkeys are bound to the albumin. Following oral exposure in rats, PFOS is found mainly in the blood, liver, lungs and kidneys. PFOA is found mainly in the blood, liver, testis, spleen, lungs, kidney and brain. In post mortem human studies, most of the PFOS is found in the lungs, kidneys, liver and blood. Most of the PFOA has been found in the lungs, kidneys, liver, blood and bone.

Both PFOS and PFOA bind to the fatty acid binding protein in the liver (although PFOS is more strongly bound than PFOA). Both chemicals also have a medium to high binding affinity for other proteins including the human serum thyroid hormone transport protein, transthyretin, low density lipoproteins and / or alpha-globulins. Transporters, including organic anion transporters, and likely to be involved in the absorption, distribution and excretion of PFOS and PFOA. PFOS and PFOA are able to cross the placenta and have been found in breast milk.

Metabolism and Excretion

There is no evidence (from studies with rats and monkeys) that PFOS and PFOA are metabolised in the body. This is in line with the limited ability to break down these chemicals within the environment more generally (i.e. via photolysis, hydrolysis or biodegradation).

Excretion primarily occurs via the kidneys (in the urine) in rats. PFOA is also excreted in the bile and may be subject to extensive enterohepatic recirculation. Lactation and menstruation are also relevant routes of excretion in women and mice.

The elimination half-life for PFOS is 5.4 years in humans compared to 121, 48 and 37 days in monkeys, rats and mice respectively. Half-lives are generally consistent between males and females.

The elimination half-life for PFOA is 2.3 to 3.8 years in humans compared to 20.8, 11.5 and 15.6 days in monkeys, rats and mice respectively. A marked sex difference is observed for PFOA in rats with males showing slower elimination which may be linked to difference in expression of organic anion transporters in the kidneys. Significant sex related differences have not been demonstrated in monkeys or humans, however, it is noted that this may be due to study design.

Health Effects – PFOS

The database relating to the toxicity of PFOS in animals includes acute and short term studies with mice, rats and monkeys, sub-chronic studies with rats and monkeys, chronic studies with rats and reproductive / developmental studies with mice, rats and rabbits. The critical effects identified from these studies and used by international agencies to develop TRVs include the following:

- Rats: mortality, increased liver weights, decreased body weight, decreased body weight gain, decreased serum cholesterol, increased alanine aminotransferase, hepatocellular hypertrophy and hepatocellular vacuolation, delayed eye-opening, reduced pup viability and weight / weight gain, reduced gestation length
- Monkeys: mortality, reduced body weight gain, increased liver weight and liver histopathological changes and reduced serum cholesterol
- Rabbits: lower maternal body weight gain (with no corresponding effect on food ingestion rate), lower foetal weight and abortions
- Mice: increased relative liver weight, reduced serum triglycerides, increased foetal liver weight, delayed eye-opening; reduced SBRC plaque forming cell response, impaired learning and memory and increased apoptosis in hippocampal cells.

Data from epidemiological studies with occupationally exposed workers at 3M manufacturing facilities (Alabama, USA and Belgium), communities exposed to contaminated drinking water (USA) and general populations (USA, UK and Scandinavia) are also available. It is noted that concentrations of PFAS in occupationally exposed workers are 100 to 1,000-fold higher than those in the general populations. Despite this, epidemiology studies have generally failed to draw conclusive links between exposure to PFOS and adverse health effects. Associations between exposure to PFOS and the following health effects have been suggested:

- Changes in serum lipid levels e.g. increase total cholesterol levels
- Changes in serum liver enzymes levels
- Kidney disease

- Effects on fertility, pregnancy and birth outcomes
- Effects on thyroid and immune function.

Overall, the evidence from the epidemiological studies for adverse effects on humans following PFOS exposure is inconsistent (i.e. 1 study reports an effect and another study reports that the effect did not occur). In addition, the biological significance of some of the observed effects has been questioned (i.e. just because an effect is observed it does not mean it is, or will lead to, an adverse effect) and there is the potential that observed effects may be due to confounding factors e.g. exposure to other contaminants, diet or lifestyle.

Health Effects – PFOA

The database relating to the toxicity of PFOA in animals includes acute and short term studies with mice, rats and monkeys, sub-chronic studies with monkeys, chronic studies with mice, rats and monkeys and reproductive / developmental studies with mice and rats. The critical effects identified from these studies and used by international agencies to develop TRVs include the following:

- Rats: increased liver weights, decreased body weight, decreased body weight gain, significant increases in Leydig cell adenomas, hepatocellular adenomas and pancreatic acinar cell tumours, decreased sexual maturation in offspring
- Monkeys: decreased heart and brain weights, mortality, liver toxicity, body weight effects
- Mice: decreased maternal weight gain, increased late foetal mortality, decreased pup weight, increase in developmental defects and neonatal mortality, decreased preweaning growth rate, delayed eye-opening, stunted mammary development in pups and immunotoxicity.

Similar to PFOS, data are available from epidemiological studies with occupationally exposed workers at 3M manufacturing facilities, communities exposed to contaminated drinking water and the general population. It is noted that concentrations of PFAS in occupationally exposed workers are 100 to 1,000-fold higher than those in the general populations. Despite this, epidemiology studies have generally failed to draw conclusive links between exposure to PFOA and adverse health effects. Associations between exposure to PFOA and the following health effects have been suggested:

- Endocrine effects (e.g. elevated thyroxine levels and increased risk of thyroid disease, diabetes mellitus and early onset menopause)
- Changes in serum lipid levels
- Effects on fertility, pregnancy, lactation and decreased birthweight
- Effects on immune function
- Cardiovascular disease
- Cancer.

Similar to the information for PFOS, the evidence for adverse effects on humans following PFOA exposure from the epidemiological studies is inconsistent (i.e. 1 study reports an effect and another study reports that the effect did not occur). However, the epidemiological studies do suggest that PFOA may be positively associated with levels of cholesterol, low-density lipoprotein and triglycerides in the serum. The actual mechanisms by which these effects occur have not been determined.

Interestingly, the positive association between PFOA and elevated levels of cholesterol and triglycerides in human blood is inconsistent with the findings from animal toxicity studies (cholesterol goes down in animals and up in people). These effects are also the reverse of what would be expected for a chemical that activates the receptor of interest (i.e. PPARα) (which PFOA has been shown to do).

There are two main complicating factors with attempting to correlate PFOA effects in animals with effects in people:

- The large interspecies variation in toxicokinetics (specifically elimination half-life), which is estimated to be years in a human but only hours to days in rats, mice and monkeys
- The activation of PPARα by PFOA, and the difference in the potential for activation of this receptor in rats and humans. i.e. this receptor is present in both rats and humans, however, it is thought to be considerably more active in rats than humans. This may be the reason some effects (e.g. liver cancer) are seen in rats but not humans.

Classification – PFOS

EFSA and USEPA have concluded that PFOS is not genotoxic based on negative findings in *in vitro* and *in vivo* tests (EFSA Panel on Contaminants in the Food Chain et al. 2020; FSANZ 2017d; USEPA 2016c).

USEPA updated their consideration of the potential for PFOS to cause cancer in 2023 (USEPA 2023c). The classification is now that PFOS is likely to be carcinogenic to people based on animal and human data. Recently, International Agency for Research on Cancer (IARC) published an update to their classification of PFOS[15]. The details of the classification have not been made publicly available as yet. IARC have now classified PFOS as Group 2B – possibly carcinogenic to people. These updates do not mean that the mechanism of action of PFOS has changed to a non-threshold one just that the groups consider there is more evidence that there is a link between exposure and some types of cancer.

Other reviews of this aspect of the toxicity of PFOS have reported that there was inadequate evidence of carcinogenicity in human and animal studies and PFOS should be classified as *not classifiable as to its carcinogenicity to humans (Group 3)* (Arrieta-Cortes et al. 2017).

With respect to the overall information available relating to the potential for exposure to PFOS to cause cancer:

- The literature evidence is often contradictory (or vague), even within the same reference
- Associations with kidney, testicular, liver and bladder cancers have been reported for workers in epidemiological studies, however, these studies may include a small number of participants, high occupational exposure and confounding factors (e.g. the study may not be controlled for other cancer causing exposures such as smoking)
- Some observed effects attributed to causing cancer are reversible, hence are not necessarily adverse. In addition, associations are not causations.

[15] https://monographs.iarc.who.int/agents-classified-by-the-iarc/

As noted above, there are two general groups of carcinogens (NEPC 1999 amended 2013e):

- Genotoxic carcinogens – ones that directly cause damage/changes in DNA and for which, in theory, any level of exposure could result in a response but still low exposure results in low risk
- Non-genotoxic carcinogens, for which there is a threshold below which exposure is not expected to result in adverse health effects (i.e. low exposure below threshold results in no risk).

Classification – PFOA

In July 2016, IARC classified PFOA as Group 2B: *Possibly carcinogenic to humans* (IARC 2016). The following is a summary of the information provided in the IARC monograph:

- The epidemiological literature for cancer and PFOA is relatively small and considers 3 different types of populations – workers exposed in chemical plants producing or using PFOA, high exposure communities (e.g. where contamination of water supplies has occurred) and the general population (i.e. background exposures).
- Two studies have found an increased risk of cancer of the testis. The evidence in these studies was considered credible and unlikely to be explained by bias or confounding, however, the numbers were small.
- There were 4 studies that investigated the potential for PFOA to cause kidney cancer. The evidence for kidney cancer was considered credible, however, chance, bias and confounding could not be ruled out.
- Some positive associations were observed for bladder, thyroid, prostate, liver and pancreatic cancer, however, the results were inconsistent and based on small numbers, and the overall evidence was concluded to be inadequate.
- PFOA was found to increase the incidence of testicular adenomas (benign tumours) in rats in two studies, and increase the incidence of hepatocellular and pancreatic adenomas in a single study. PFOA was also found to promote cancer of the liver in two studies with rats and two studies with rainbow trout.
- Due to the reabsorption of PFOA in the kidney, the body burden of PFOA is much greater in people than that in experimental animals.
- PFOA is not DNA-reactive, therefore, there is strong evidence that PFOA is not a direct genotoxic carcinogen. There is moderate evidence that PFOA is not an indirect genotoxic carcinogen.
- The liver is a well-established target for toxicity in rats and mice. Potential mechanisms include activation of PPARα and cytotoxicity (i.e. cell damage). The human relevance of these findings cannot be excluded based on the available information.

The International Agency for Research on Cancer (IARC) concluded that there was *limited evidence* in humans and experimental animals for the carcinogenicity of PFOA. Overall, PFOA was classified as *possible carcinogenic to humans (Group 2B)* (IARC 2016). Recently, IARC published an update to their classification of PFOA[16]. The details of the classification have not been made publicly available as yet. IARC have now classified PFOA as Group 1 – carcinogenic to people.

USEPA updated their consideration of the potential for PFOA to cause cancer in 2023 (USEPA 2023a). The classification is now that PFOA is likely to be carcinogenic to people based on animal and human data – i.e. same classification as PFOS.

These updates do not mean that the mechanism of action of PFOA has changed to a non-threshold one just that the groups consider there is more evidence that there is a link between exposure and some types of cancer.

Summary

There are 2 general groups of carcinogens (NEPC 1999 amended 2013e):

- Genotoxic carcinogens for which, in theory, any level of exposure could result in a response as the chemical has the ability to interact directly with DNA (low dose = low risk)
- Non-genotoxic carcinogens, for which there is a threshold below which exposure is not expected to result in adverse health effects (low dose below threshold = no risk).

PFAS do not possess the chemical / physical properties typically associated with direct genotoxicity and this is supported by an understanding of the mode of action. IARC note that there is strong evidence that PFOA cannot act via direct genotoxic mechanisms. Some studies that have looked at cancer in the liver note that this is likely to be linked to liver damage and so, without liver damage, carcinogenic effects also do not occur (IARC 2017).

Overall, the weight of evidence is that, *if they are carcinogenic*, PFOS / PFOA act via a threshold mode of action (DeWitt 2015). Therefore, the use of threshold toxicity reference value (TRV) for the assessment of PFAS is considered appropriate.

Toxicity Reference Values

On the basis that PFOS and PFOA are not considered to be non-threshold chemicals, they have been assessed based on a threshold approach in this HHERA. The following threshold chronic values are available from Level 1 Australian and International sources (**Table C1**):

[16] https://monographs.iarc.who.int/agents-classified-by-the-iarc/

Table C1: Summary of Toxicity Information for PFOS and PFOA

Source	PFOS TRV (µg/kg/d)	Basis / Comments	PFOA TRV (µg/kg/d)	Basis / Comments
Australian				
ADWG (NHMRC 2011 updated 2022)	0.02	HBGV based on PBPK modelling for 4 selected pivotal toxicity studies (1 with monkeys and 3 with rats). The final HBGV was derived based on a POD (HED) of 0.6 µg/kg/day associated with decreased pup body weight in a two-generation reproductive toxicity study with rats and an UF of 30 (10 for intraspecies variability and 3 for interspecies variability). HBGVs calculated for the other studies were in the range 0.02 to 0.1 µg/kg/day.	0.16	HBGV based on PBPK modelling for 3 selected pivotal toxicity studies (1 with monkeys, 1 with rats and 1 with mice). The final HBGV was derived based on a POD (HED) of 4.9 µg/kg/day associated with foetal toxicity in a reproductive/developmental toxicity study on mice and an UF of 30 (10 for intraspecies variability and 3 for interspecies variability). HBGVs calculated for the other studies were in the range 0.43 to 0.92 µg/kg/day.
Food Standards Australia New Zealand (FSANZ) (FSANZ 2017b)	0.02		0.16	
International				
WHO Drinking Water Guidelines (WHO 2022)	No guideline value	In 2022, WHO published a DRAFT guideline for PFOS based on a relevant limit of reporting. They determined that the toxicity data was not sufficiently robust to support the calculation of a guideline value. The limit of reporting they recommended was 0.1 µg/L.	No guideline value	In 2022, WHO published a DRAFT guideline for PFOS based on a relevant limit of reporting. They determined that the toxicity data was not sufficiently robust to support the calculation of a guideline value. The limit of reporting they recommended was 0.1 µg/L.
United Kingdom Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT 2006b, 2006a, 2009, 2014)	0.3	Provisional TDI based on a POD (NOAEL) of 30 µg/kg/day associated with decreased serum T3 levels in a 26-week study with cynomolgus monkeys and an UF of 100 for inter- and intra-species variability.	1.5	Provisional TDI based of a POD of 300 µg/kg/day associated with hepatic effects in a number of studies in rats and mice and an UF of 200 (10 for inter- and intra-species variability and 2 for uncertainties relating to internal dose kinetics).
European Food Safety Authority (EFSA 2008)	0.15	TDI based on a POD (NOAEL) of 30 µg/kg/day associated with changes in serum lipids and thyroid hormones in a 26-week study with cynomolgus monkey and a UF of 200. The UF comprised by factor of 100 adopted by the UK COT for inter- and intra-species variability as well as an additional UF of 2 to account for the	1.5	TDI based on a POD ($BMDL_{10}$) of 300 µg/kg/day associated with a 10% increase in effects on the liver from studies in rats and mice and an UF of 200 (10 for inter- and intra-species variability and 2 for uncertainties relating to internal dose kinetics).

Source	PFOS TRV (µg/kg/d)	Basis / Comments	PFOA TRV (µg/kg/d)	Basis / Comments
		relatively short duration of the key study and internal dose kinetics.		
European Food Safety Authority (Knutsen et al. 2018)	*0.013 µg/kg bw/week (0.0019 µg/kg bw/day)* *DRAFT*	*Epidemiological studies showed evidence for immune system effects, increased levels of serum cholesterol, potential for impacts on liver enzymes, low birth weight. This assessment determined that effects on cholesterol were critical and these were used to develop the TRV. NOEC for serum PFOS centred around 0.0018 µg/kg/day converted to per week to give 0.013 µg/kg/week*	*0.006 µg/kg/week (0.0009 per day)*	*Epidemiological studies showed evidence for immune system effects, increased levels of serum cholesterol, potential for impacts on liver enzymes, low birth weight. This assessment determined that effects on cholesterol were critical and these were used to develop the TRV. NOEC for serum PFOS for changes in serum cholesterol at around 0.0008 µg/kg/day converted to per week to give 0.006 µg/kg/week*
European Food Safety Authority (EFSA Panel on Contaminants in the Food Chain (CONTAM Panel) et al. 2020)	*0.008 µg/kg bw/week (0.0011 µg/kg bw/day)* *DRAFT*	*Value established for sum of PFOS, PFOS, PFNA and PFHxS* *Epidemiological studies showed evidence for immune system effects, increased levels of serum cholesterol, potential for impacts on liver enzymes, low birth weight. This assessment determined that effects on the immune system were critical and these were used to develop the TRV. The assessment took the NOAEC serum concentration from studies in young children, converted the serum concentration to a value for the mother during breastfeeding that would result in the NOAEC in the child using PBPK modelling. This was then converted to a weekly intake with no additional safety factors.*		
European Food Safety Authority (EFSA Panel on Contaminants in the Food Chain et al. 2020)	0.0044 µg/kg bw/week (0.0006 µg/kg bw/day)	Final value established for sum of PFOS, PFOS, PFNA and PFHxS – now in use in Europe. Epidemiological studies showed evidence for immune system effects, increased levels of serum cholesterol, potential for impacts on liver enzymes, low birth weight. This assessment determined that effects on the immune system were critical and these were used to develop the TRV. The assessment took the NOAEC serum concentration from studies in young children, converted the serum concentration to a value for the mother during breastfeeding that would result in the NOAEC in the child using PBPK modelling. This was then converted to a weekly intake with no additional safety factors.		
United States Environmental Protection Agency (USEPA 2016b, 2016a) (Final)	0.02	RfD based on PBPK modelling on for data from 6 subchronic, developmental / neurodevelopmental and reproductive toxicity studies with rats for which measured serum PFOS concentrations were available. Critical effects included increased levels of alanine aminotransferase and blood urea nitrogen, decreased pup body weight and survival rate and increased motor activity / decreased habituation. The adopted UF varied depending on the study and were in the range 30	0.02	RfD based on PBPK modelling on for data from a number of studies with rats, monkeys and mice for which measured serum PFOS concentrations were available. 6 primary studies were selected and critical effects included increased liver and kidney weight (rats), decreased pup body weight (mice) and developmental and immunotoxic effects (mice). The adopted UF varied depending on the study and were in the range 30 to 300. Candidate RfDs were in the range 0.02 to 0.15 µg/kg/day.

Source	PFOS TRV (µg/kg/d)	Basis / Comments	PFOA TRV (µg/kg/d)	Basis / Comments
		to 100. Candidate RfDs were in the range 0.02 to 0.05 µg/kg/day.		
United States Environmental Protection Agency (USEPA 2022a, 2022d)	*0.0000079 µg/kg bw/day* *DRAFT*	*This guideline was based on presumed impacts on the immune system in children.*	*0.0000015 µg/kg bw/day* *DRAFT*	*This guideline was based on presumed impacts on the immune system in children.*
United States Environmental Protection Agency (USEPA 2023c, 2023a)	--	In 2023, USEPA determined a drinking water guideline for PFOS based on a relevant limit of reporting. They determined that PFOS has the potential to cause cancer and their guidance requires that the drinking water goal for such chemicals must be that they are not detectable. The limit of reporting they recommended was 0.004 µg/L which gives a TRV of 0.0001 µg/kg bw/day.	--	In 2023, USEPA determined a drinking water guideline for PFOA based on a relevant limit of reporting. They determined that PFOA has the potential to cause cancer and their guidance requires that the drinking water goal for such chemicals must be that they are not detectable. The limit of reporting they recommended was 0.004 µg/L which gives a TRV of 0.0001 µg/kg bw/day.
Agency for Toxic Substances and Disease Registry (ATSDR 2015) (based on Draft 2014 USEPA Guidance)	*0.03* *DRAFT*	*MRL based on a POD (NOAEL) of 2.52 µg/kg/day associated with increased absolute liver weight in a 26-week study with cynomolgus monkeys and a UF of 90 (3 for interspecies differences, 10 for intraspecies differences and 3 for deficiencies in the database).*	*0.02* *DRAFT*	*MRL based on a POD (HED) of 1.54 µg/kg/day associated with increased absolute liver weight in a 26-week study with cynomolgus monkeys and a UF of 90 (3 for interspecies differences, 10 for intraspecies differences and 3 for deficiencies in the database).*
Agency for Toxic Substances and Disease Registry (ATSDR 2018)	*0.002 PFOS* *0.02 PFHxS* *DRAFT*	*Used similar information as per previous assessments but added a 10 fold factor for potential for immune system impacts which were becoming clearer*	*0.003 PFOA* *0.003 PFNA* *DRAFT*	*Used similar information as per previous assessments but added a 10 fold factor for potential for immune system impacts which were becoming clearer*
Agency for Toxic Substances and Disease Registry (ATSDR 2021)	0.002 PFOS 0.02 PFHxS	Used similar information as per previous assessments but added a 10 fold factor for potential for immune system impacts which were becoming clearer	0.003 PFOA 0.003 PFNA	Used similar information as per previous assessments but added a 10 fold factor for potential for immune system impacts which were becoming clearer
Danish Ministry for the Environment (Danish	0.03	TDI based on a POD ($BMDL_{10}$) of 33 µg/kg/day associated with hepatotoxicity (liver toxicity) in a chronic toxicity/carcinogenicity study with rats	0.1	TDI based on a POD ($BMDL_{10}$ converted to a HED) of 3 µg/kg/day associated with hepatotoxicity (liver toxicity) in a chronic toxicity/carcinogenicity study with rats and

Source	PFOS TRV (µg/kg/d)	Basis / Comments	PFOA TRV (µg/kg/d)	Basis / Comments
Ministry of the Environment 2015)		and an UF of 1,230 (3 for possible differences in pharmacodynamics, 41 for differences in pharmacokinetics and 10 for intraspecies differences).		an UF of 30 (10 for intraspecies variation and 3 for interspecies differences).
Minnesota Department of Health (MDH 2009a, 2009b)	0.08	TRV based on a POD (HED) of 2.5 µg/kg/day associated with decreased cholesterol and changes in thyroid hormones in rats and a UF of 30.	0.08	TRV based on a POD (HED) of 2.3 µg/kg/day associated with decreased cholesterol and changes in thyroid hormones in monkeys and a UF of 30.
Minnesota Department of Health (MDH 2018, 2019b, 2019a)	0.003 (PFOS) 0.0097 (PFHxS)	TDI (PFOS) based on immune system effects, low birth weight and other effects in rats with an uncertainty factor of 100 and conversion to a human equivalent dose TDI (PFHxS) based on thyroid effects in rats with an uncertainty factor of 300 and conversion to a human equivalent dose	0.018	TDI based on low birth weight, impaired bone growth and liver effects in mice with an uncertainty factor of 300 and conversion to a human equivalent dose
German Drinking Water Commission (GDWC 2006)	0.1	TRV based on a POD of 25 µg/kg/day which was the lowest POD for rats from a range of studies with rats and monkeys. The adopted UF was 300.	0.1	TRV based on a NOAEL of 100 µg/kg/day which was the lowest POD from a range of studies reviewed by the USEPA. The adopted UF was 1,000.

Notes:

Grey italics indicates guidance published as draft for consultation.

BMDL = Benchmark Dose Level, HBGV = Health Based Guideline Value, HED = Human Equivalent Dose, MRL = Minimal Risk Level, NOAEL = No Observed Adverse Effect Level, PBPK = Physiologically Based Pharmacokinetic, POD = Point of Departure, RfD = Reference Dose, TDI = Tolerable Daily Intake, UF = Uncertainty Factor.

Table C1 indicates that available finalised TRVs for PFOS range from 0.0001 to 0.15 µg/kg/day (i.e. a range of 1,500). Available finalised TRVs for PFOA range from 0.0001 to 1.5 µg/kg/day (i.e. a range of 15,000).

The differences between the available TRVs are mainly due to the following:

- Selection of the critical study and the point of departure (POD) from the available toxicity studies.
- Use (or not) of PBPK modelling.
- Differences in the PBPK modelling to convert between serum concentrations and daily intakes.
- Application of different uncertainty factors (UFs). The application of significantly different UFs by various agencies is largely due to the toxicokinetics related issues (i.e. clearance), as well as the application of additional UFs because the available studies were less than lifetime for the estimated POD

In April 2017, FSANZ released TRVs for PFOS, PFOA and PFHxS in the form of TDIs (called HBGVs) (FSANZ 2017d). The FSANZ TRVs are the final values for use in Australia and hence the TRVs for PFOS and PFOA from this guidance are the ones adopted in this HHERA:

- PFOS: 0.02 µg/kg/day
- PFOA: 0.16 µg/kg/day.

Since the work by FSANZ was completed in 2017, several international agencies have published updated toxicological reviews for these chemicals as shown in **Table C1**.

The US ATSDR published updates to their toxicological profile for PFAS in 2018, 2020 and 2021. The final version of the update was published in May 2021 and included toxicity reference values for PFOA, PFOS, PFHxS and PFNA (ATSDR 2021). These values are listed in **Table C2**. These newly derived guidelines are lower (i.e. more stringent) than the Australian TDIs.

Table C2: TRV for PFAS – ATSDR (2021)

Chemical	TRV (µg/kg/day)
PFOA	0.003
PFOS	0.002
PFHxS	0.02
PFNA	0.003

In September 2020, the European Food Safety Authority released a toxicity profile for PFOS, PFOA, PFNA and PFHxS (EFSA Panel on Contaminants in the Food Chain et al. 2020). A tolerable weekly intake of 0.0044 µg/kg bw/week for the sum of PFOS, PFOA, PFNA and PFHxS was determined based on effects on the immune system. The value is provided in **Table C3**. This newly derived guideline is lower (i.e. more stringent) than the Australian TDIs.

Table C3: TRV for PFAS – EFSA (2020)

Chemical	TRV
PFOA+PFOS+PFNA+PFHxS	0.0044 µg/kg/week
	0.0006 µg/kg/day

In June 2022, the USEPA released updated guidance for a number of PFAS (USEPA 2022b). The updated reports proposing toxicity reference values for PFOS and PFOA are only draft at this time, however, the values proposed have been developed for use as drinking water health advisories (i.e. not legal requirements) until finalised. In addition, toxicity reference values (final versions) and drinking water health advisories for PFBS and GenX were also published. GenX is an alternative compound within the PFAS family which is manufactured in the US but not commonly found/reported in Australia. The new values are provided in **Table C4**. Given that the PFOS and PFOA values are draft, it is not appropriate to use these values at this time. These newly derived guidelines are lower (i.e. more stringent) than the Australian TDIs. These values are also well below background levels anywhere in the world including here in Australia. There is much discussion/controversy about the values for PFOS and PFOA in the US including taking the USEPA to court over the values. The USEPA is reconsidering these draft values.

Table C4: TRV for PFAS – USEPA (2022)

Chemical	TRV (µg/kg/day)
PFOA	0.000002
PFOS	0.000008
PFBS	0.3
GenX	0.003

In 2023, the USEPA released updated guidance for PFOS and PFOA in relation to the derivation of drinking water guidelines (USEPA 2023c, 2023a). The updated guidance did not include any change to the draft guidelines discussed above for threshold effects of these chemicals. However, the guidance primarily included an update to the cancer assessment for these chemicals.

On the basis of finding that these chemicals have potential to cause cancer, the legislation around the establishment of drinking water guidelines in the US requires a goal of zero (i.e. MCLG maximum contaminant limit goal) to be set for such chemicals and for the maximum contaminant limit (i.e. MCL – the enforceable value) to be set at the relevant limit of reporting – in this case, 0.004 µg/L. This drinking water MCL converts to a TRV of 0.0001 µg/kg/day based on consumption of 2 L of water per day for a 70 kg person.

At the same time, the USEPA also provided guidance about the presence of PFNA, PFHxS, PFBS and GenX in drinking water (USEPA 2023b). The recommended toxicity reference values used to establish drinking water advisories for these chemicals were as listed in **Table C5**.

Table C5: TRV for PFAS – USEPA (USEPA 2023c, 2023a, 2023b)

Chemical	Drinking water guideline (µg/L)	TRV (µg/kg/day)
PFBS	2	0.6
GenX (HFPO-DA)	0.01	0.003
PFHxS	0.01	0.003[1]
PFNA	0.01	0.003

Notes:

1 value updated due to release of final values in April 2024 as shown at https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

For these 4 chemicals, an additional aspect was included - a hazard index approach as shown in the following equation (USEPA 2023b).

$$Hazard\ index = ((Conc\ GenX)/0.01\ ) + ((Conc\ PFBS)/2\ ) + ((Conc\ PFNA)/0.01\ ) + ((Conc\ PFHxS)/0.01\ )$$

(*where the concentration for each chemical is in units of µg/L)*

Mixtures containing 2 or more of these 4 PFAS should not result in a hazard index greater than 1 calculated using this equation [17].

In 2022, WHO provided draft guidance on PFOS and PFOA in drinking water (WHO 2022). The committee preparing this guidance determined that toxicity information for these chemicals was problematic and they recommended instead that a drinking water guideline be based on the analytical limit of reporting. Given that WHO makes recommendations about drinking water guidelines for developing and developed nations, the limit of reporting recommended was not as stringent as that adopted by the USEPA. A value of 0.1 µg/L was recommended for PFOS and PFOA individually and a value of 0.5 µg/L was recommended for total PFAS (based on the standard suite as used in Australia – i.e. around 30 individual PFAS). An update on the status of this guidance is provided at https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/chemical-hazards-in-drinking-water/per-and-polyfluoroalkyl-substances indicating that these values are still being considered.

FSANZ indicated in December 2021 that, based on an investigation of PFAS levels in the general food supply in Australia (which found low levels in Australian food) and a review of the immune effects of these chemicals, there was no new information that would warrant a change in Australian guidance[18].

Other PFAS

Most international guidelines focus on PFOS and PFOA although this is changing with new guidance being developed to apply to the sum of groups of PFAS in Europe. Guidelines in Australia focus on PFOS, PFHxS and PFOA.

There are, however, many other chemicals that may be included in the PFAS chemicals class. For most of these "other PFAS", limited data are available to evaluate their toxicity. What is available indicates that these other chemicals are likely to be less toxic than PFOS and PFOA. Given these limitations, this assessment has considered the guidelines specifically as indicated in the PFAS NEMP (HEPA 2020) as well as whether there is any change in the conclusions if the sum of all PFAS detected in a sample (i.e. total PFAS) is considered.

[17] https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas
[18] https://www.foodstandards.gov.au/consumer/chemicals/Perfluorinated-compounds

Background Intake

There are a number of ways to determine background intakes of PFOS and PFOA in Australia.

FSANZ undertook a total diet survey for PFAS in food which was published in 2021 (FSANZ 2021). The findings indicated very low levels of these chemicals in food in Australia.

Testing of PFAS in blood has also been undertaken in Australia by researchers in Queensland. (Thompson et al. 2010; Toms et al. 2019; Toms et al. 2014).

It is noted that blood levels of PFAS are reflective of all intakes from consumer products, drinking water and the environment in general, hence no further specific evaluation of other potential sources of PFAS in the environment is required as part of this HHERA. The findings of these studies indicate that people in Australia are exposed to background levels of PFOS, PFOA and PFHxS. These studies indicate that assuming people are already exposed to 10% of the TRV is an appropriate assumption for use in risk assessment in relation to background exposure unrelated to the site of interest in an investigation.

Appendix D Summary of aquatic toxicity for PFAS

Background to the guidelines

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) (the "Guidelines") were first released in 1992 as 1 of a suite of 21 documents forming the National Water Quality Management Strategy (NWQMS). The document was updated in 2000 (based on data and relevant literature to at least 1996), and then again in 2018 with the guidelines released as an online document (ANZG 2018).

This document includes guidelines for the following uses:

- Aquatic ecosystems;
- Primary industries;
- Recreation and aesthetics (now superseded by the NHMRC Recreational Water Quality Guidelines) (NHMRC 2008); and
- Drinking Water (now superseded by the NHMRC Australian Drinking Water Guidelines) (NHMRC 2011 updated 2022).

The Guidelines are based on the concept of ecologically sustainable development and the policies and principles of the NWQMS which include an integrated approach to water quality management, community involvement, government endorsement, the high variability and complexity inherent in natural waterways and the need for ongoing research and dissemination of research findings.

The Guidelines are intended to provide government, industry, consultants and community groups with a sound set of tools that will enable the assessment and management of ambient water quality in a wide range of water resource types, and according to designated environmental values. They are the recommended limits to acceptable change in water quality that will continue to protect the associated environmental values. They are not standards under the *National Environment Protection Council Act* (1994) but rather are adopted for assessing water quality associated with runoff and contamination.

The Guidelines do not signify threshold levels of pollution above which effects will occur. There is no certainty that significant impacts will occur above these recommended limits, as might be required for prosecution in a court of law. Instead, the guidelines provide certainty that there will be no significant impact on water resource values if the guidelines are achieved (i.e. concentrations remain below the guideline value). The documentation associated with the Guidelines states that the Guidelines should not be used as mandatory standards because there is significant uncertainty associated with the derivation and application of water quality guidelines. For example, data on biological effects are not available for all local species; there is uncertainty over the behaviour of contaminants in the field; there is uncertainty in water quality measurements. However, the Guidelines should provide a framework for recognising and protecting water quality for the full range of existing environmental values.

Available guidelines

The Guidelines for the Protection of Aquatic Ecosystems (ANZG 2018) have been developed with the objective of maintaining or enhancing the "ecological integrity" of freshwater and marine ecosystems. Ecological integrity is an umbrella term that describes the health or condition of an ecosystem and its ability to support and maintain key ecological processes and a community of organisms with a species composition, diversity and functional organisation as comparable as possible to that of natural habitats within a region.

ANZG (2018) indicates that the guidelines should be applied in the following steps:

1. Define the primary management aims. The key part of this step is to determine the environmental values to be protected and the level of protection, although it is also important to identify environmental concerns and major natural or anthropogenic factors at this stage.
2. Determine appropriate guideline trigger values for selected indicators. The key part of this step is to determine appropriate guideline trigger values which indicate low risk concentrations of contaminants / stressors.
3. Assess test site data and, where possible, refine trigger values to guidelines.
4. Define water quality objectives.
5. Establish a monitoring and assessment program.

In relation to Step 2, 3 ecosystem conditions, spanning 4 different species protection levels, are recognised by the Guidelines:

1. High conservation/ecological value systems – effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations. The 99% species protection value is designed to cover this ecosystem type.
2. Slightly to moderately disturbed systems - ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. The 95% species protection value is designed to cover this ecosystem type.
3. Highly disturbed systems - measurably degraded ecosystems of lower ecological value. Examples include some shipping ports and sections of harbours serving coastal cities, urban streams receiving road and stormwater runoff, or rural streams receiving runoff from intensive horticulture. The 80% and 90% species protection values are designed to be applied to this ecosystem type. Most regulators consider these lower levels of protection to be values they apply on a temporary basis while plans to improve the ecosystem are prepared and implemented.

A precautionary approach and the concept of “continual improvement” is recommended when selecting a level of protection and it is for this reason that an ecosystem may be designated as “slightly to moderately disturbed” even when significant biological or chemical toxicants / stressors are found to be present. The Guidelines support this approach by recommending that guideline trigger values for slightly to moderately disturbed systems also be applied to highly disturbed ecosystems wherever possible.

The Guidelines also note that the decision to apply a certain protection level to a specific ecosystem is the prerogative of each state jurisdiction or catchment manager, in consultation with the community and stakeholders.

Toxicological basis for the guidelines

For contaminants, (called “toxicants” in the Guidelines), the presented guideline or trigger values represent the best currently-available estimates of what are thought to be concentrations that will pose a low risk level for of a chemical for chronic (sustained) exposures (i.e. concentrations that should cause negligible effects even when present for extended periods).

The preferred data for deriving trigger values comes from multiple-species toxicity tests, i.e. tests that represent the complex interactions of species in the field like mesocosms. However, such data sets are very limited, and these tests are costly to undertake and difficult to interpret. Hence, most of the trigger values have been derived using data from single-species toxicity tests on a range of test species. Where able to be calculated, high reliability trigger values are derived from chronic 'no observed effect concentration' (NOEC) data. However, most trigger values are moderate reliability trigger values, derived from short-term acute toxicity data (from tests ≤96-hour duration). In addition, where a NOEC is not available, a 'lowest observed effect concentration' (LOEC) may be adopted with safety factors (called assessment factors) applied to decrease the value of the guideline as the concentration at which there are no effects is not known. This adds further uncertainty.

Results for individual species are then translated to trigger values for all species using a statistical distribution approach – the species sensitivity distribution (SSD). Once sufficient data is available for use in a species sensitivity distribution, statistical techniques can then be applied to calculate the concentration that would be protective of a pre-determined percentage of species. Where there are insufficient data to allow the determination of a species sensitivity distribution assessment factors are applied.

For most toxicants, the protection level can then be determined and the appropriate trigger level selected and applied. However, this process is less straightforward for toxicants that may bioaccumulate e.g. mercury, polychlorinated biphenyls, organochlorine pesticides and PFOS. For these toxicants, the main issue of concern is not only their direct short-term toxic effect (e.g. the toxic effect that may be due to a fish swimming in water that is impacted with the toxicant) but the indirect risks associated with their longer-term concentration in organisms and the potential for secondary poisoning as the chemical accumulates up the food chain (i.e. the toxic effect that may occur if a bird eats a fish that has been swimming in the water impacted with the toxicant and the toxicant has accumulated in the fish).

Guidelines for PFOS and PFOA

There are no trigger values for PFOS and PFOA (or any other PFAS compounds) in the guidelines available to October 2019 (ANZG 2018).

Between 2016 and 2018, various state regulatory authorities published guidelines for investigating PFAS contaminated sites included trigger values for PFOS and PFOA that were based on draft determinations by ANZECC that were released to regulators for comment (EPA Victoria 2019a; NSW OEH 2017; WA DER 2017b) (noting that the basis for the guidelines were never formally published). These values are listed in **Table D1**.

Table D1: Guidelines for PFOS and PFOA – Protection of freshwater ecosystems

Species Protection Value	PFOS (µg/L)	PFOA (µg/L)
High conservation value systems (99% species protection)	0.00023	19
Slightly to moderately disturbed systems (95% species protection)	0.13	220
Highly disturbed systems (90% species protection)	2.0	623
Highly disturbed systems (80% species protection)	31	1,824

These values have also been listed for screening both fresh and marine waters in the PFAS NEMP (HEPA 2020).

Following the release of the original guidance containing these values in Western Australian guidance, enRiskS went to significant effort to attempt to confirm whether the provided guidelines were representative of those that would be released as part of the updated version of the National (i.e. ANZECC/ARMCANZ) Guidelines, as this document was known to be under review, and remain under review at the time of this assessment. Based on these conversations, it was the understanding of enRiskS, that these trigger values may not be representative of those to be included in the updated version of the Guidelines. More recent conversations confirm that the trigger values for PFOS, in particular, are still a matter of much debate amongst the team working on the guidelines. These discussions are of particular relevance to the 99% protection trigger value as the current value in the NEMP is very low.

Guidance for chemicals that bioaccumulate

The ANZECC Guidelines provide the following guidance on how to deal with bioaccumulative chemicals:

- *Dietary accumulation can be an important route of uptake for some chemicals, and it will need to be addressed in future revisions of the Guidelines;*
- *There is currently no formal and specific international guidance for incorporating bioaccumulation into water quality guidelines;*
- *For those chemicals that have the potential to bioaccumulate, the decision scheme provides for site-specific re-assessment of this issue if suitable data become available. Field investigations of residue levels in appropriate organisms may provide additional evidence for whether or not bioaccumulation is an issue at the site under study; and*
- *In the absence of such local data, a higher level of protection is recommended (e.g. 99% protection for slightly–moderately disturbed systems instead of 95%).*

It is noted that the last point (i.e. use of the 99% protection trigger value) often represents the default position adopted for most contaminated land sites but it is not the only approach that can be used and, based on this guidance, is not the preferred approach recommended by ANZECC. The use of the 99% protection trigger value is a policy decision that does not include specific consideration of scientific information relating to bioaccumulation processes (i.e. does not actually assess the potential for bioaccumulation in aquatic organisms). The “step up” of a protection level is simply a trigger for more careful and detailed assessment as the chemical has been identified to be bioaccumulative. This position may also be confusing to lay people, including members of the community, as the selection of guidelines may appear somewhat arbitrary as the protection levels are not equidistant (i.e. evenly spaced).

Another option for dealing with bioaccumulative substances is the use of actual sampling of aquatic biota to determine whether organisms that may be present in an aquatic system are actually being exposed to chemicals like PFOS in a form that can get into their systems and be accumulated.

The currently preferred approach for sites where PFOS may be present is to use the 95% protection trigger value to determine if there is a potential for direct toxicity to aquatic organisms and to use field sampling of aquatic biota to assess the potential for bioaccumulation and secondary poisoning. Further discussion of the toxicological basis for this approach is provided below.

Guidelines for PFOS and PFOA

Background

There were no trigger values for PFOS and PFOA in the ANZECC/ARMCANZ guidelines published in 2000 or the online system launched in 2018[19].

Between 2016 and 2018, various state regulatory authorities published guidelines for investigating PFAS contaminated sites including draft WQG for PFOS and PFOA that were based on draft determinations by ANZECC. The supporting information about how these values were determined was released to regulators for comment but has never been publicly released (EPA Victoria 2019b; NSW OEH 2017; WA DER 2017a).

The demand for guidance during this time period was significant, so it is understandable that these draft values were adopted for use in Australia. These values were listed in the National Environmental Management Plan for PFAS sites (HEPA 2018, 2020) and they are listed in **Table D2**.

Table D2: Guidelines for PFOS and PFOA – Protection of Freshwater Ecosystems (HEPA 2020)

Species Protection Value	PFOS (µg/L)	PFOA (µg/L)
High conservation value systems (99% species protection)	0.00023	19
Slightly to moderately disturbed systems (95% species protection)	0.13	220
Highly disturbed systems (90% species protection)	2.0	623
Highly disturbed systems (80% species protection)	31	1,824

The PFAS NEMP recommended they be used for screening both fresh and marine waters.

Issues with these values – background

These guidelines have never been finalised and there has been much discussion of the appropriateness of the data used in this evaluation, especially, given that the 99% species protection value is around 1,000 times lower than the 95% species protection value.

The difference in these 2 values is much larger than for most other bioaccumulative chemicals for which water quality guidelines exist. For chemicals like the organochlorine pesticides, a difference of 10 fold has been more common. This large difference points to an issue in the dataset.

CSIRO scientists have undertaken a number of recalculations of the 99% species protection value since the draft values were issued for a number of reasons including:

- Difficult nature of the available ecotoxicity data which included some studies that did not follow standard guidance about treatment concentrations, nor reported appropriate dose-response relationships to indicate the most relevant endpoint for use in a water quality guideline calculation.
- Differences in toxicity to plants versus animals for these chemicals – plants are less susceptible to impacts when exposed to these chemicals and consideration was given as to

[19] www.waterquality.gov.au

whether the calculations should focus on the animal data only (or at least for this potential for a bimodal distribution to be considered).

- Availability of more appropriate software to calculate the species sensitivity distribution for guideline development (Environment Canada developed more robust software that undertook these calculations more effectively than the software recommended in ANZG guidance[20])

These recalculations have resulted in 99% species protection values around 0.05 µg/L (Batley et al. 2018; Page et al. 2019).

In addition, to these recalculations by CSIRO, the literature includes discussion of the differences between WQG values available internationally. A comparison of international water quality guidelines for PFOS and PFOA is provided in **Figure D1** (Zodrow et al. 2021).

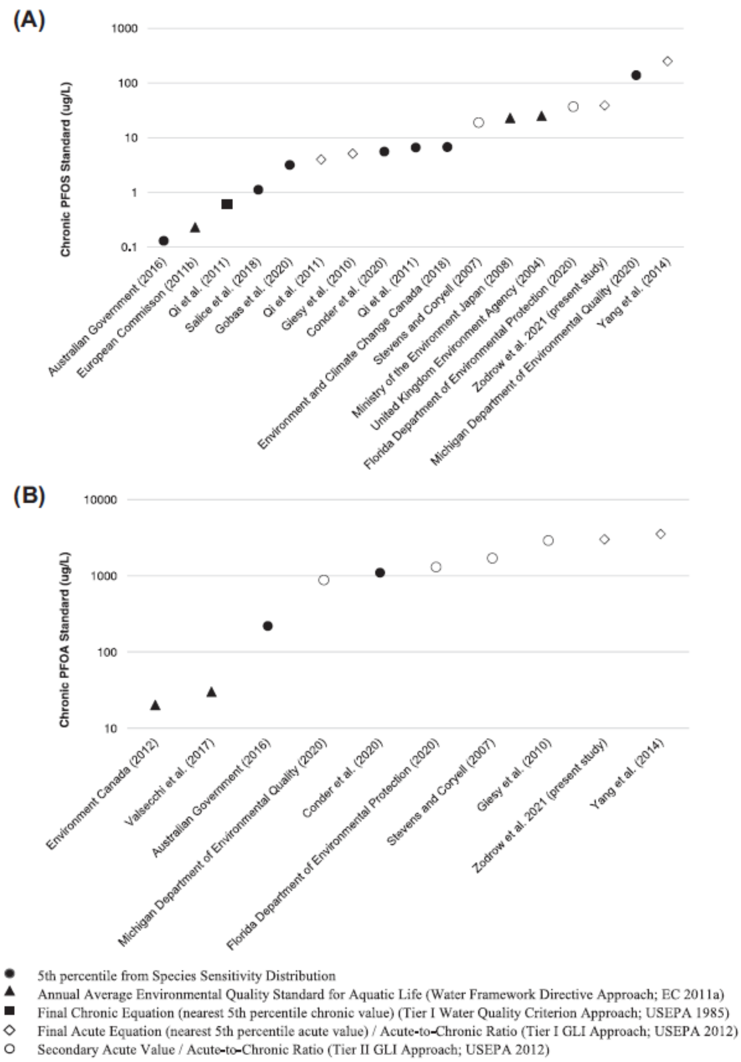

Figure D1: Comparison of aquatic guidelines for PFOS and PFOA (Zodrow et al. 2021)

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[20] https://bcgov-env.shinyapps.io/ssdtools/

The guidelines range over more than 3 orders of magnitude for PFOS and more than 2 orders of magnitude for PFOA (Zodrow et al. 2021). The values for Australia are the lowest or close to the lowest of all the values included. The differences in these guidelines arise due to the use of different datasets for the calculations and/or due to differences in how species sensitivity distributions are calculated.

Zodrow et al. (2021) note that they have not included data for the most sensitive studies in the guidelines they have developed in this paper. These most sensitive studies have, however, been included in guidelines like those for Australia (Ji et al. 2008; Keiter et al. 2012; MacDonald et al. 2004). Zodrow et al. (2021) note that these data were not included based on guidance from the Great Lake Initiative about the types of data that should be used in guideline calculations. The exclusion of these data explains the large difference between the risk based screening levels for PFOS from this study and the water quality guidelines generated in Australia.

In Australia, as discussed above, it is recommended that 99% species protection guideline values are used for bioaccumulative chemicals. For PFOS, there is an unusually large difference between the 95% and 99% species protection values which has led to much discussion about the 99% species protection guideline value. This 99% species protection guideline value is also much lower than the range of other guidelines for the protection of freshwater ecosystems from international sources as shown in **Figure D1** and listed in (Environment Canada 2015; Giesy et al. 2010; Qi et. al. 2011; RIVM 2010; Yang et. al. 2013) (and others).

The Australian guidelines have included consideration of specific studies that showed effects on aquatic organisms at much lower concentrations which do not appear to have been considered by many of the international sources (based on a draft technical brief which is no longer current). The lack of adoption of these studies into the datasets for other aquatic guidelines by international jurisdiction raised concern amongst regulators in Australia that just adopting international guidelines was not sufficiently protective.

The available ecotoxicology data indicate that of the different species studied (which includes zooplankton, algae, plants, insects, invertebrates, fish and frogs), the most sensitive species / studies are the following:

- European damselfly (*Enallagma cyathigerum*) (Environment Canada 2015): NOEC of <0.01 mg PFOS/L (i.e. <10 µg PFOS/L)
- Freshwater midge (invertebrate) (*Chironomus tentans)* (MacDonald et al. 2004): NOEC of <0.0023 mg PFOS/L (i.e. <2.3 µg PFOS/L)
- The multi-generation fish studies including that with the Japanese Rice Fish or Medaka (*Oryzias latipes*) (Ankley et al. 2005; Du et al. 2009; Han & Fang 2010; Ji et al. 2008; Keiter et al. 2012; Wang et al. 2011): NOEC of <0.01 mg PFOS/L (i.e. <10 µg PFOS/L).

The data for the all of these species are discussed below followed by discussion of the new data have been generated between 2020 and 2024.

European damselfly and freshwater midge

Environment Canada (2015) undertook a review of the available aquatic toxicity values for chronic (long-term) exposure to PFOS, reporting that the most sensitive species was the European damselfly, with no effects on survival reported at 10 µg/L during a 320-day exposure study (Environment Canada 2015).

The toxicity of PFOS to the freshwater midge was studied in 2004 (MacDonald et al. 2004) through the use of an acute toxicity test and a chronic life-cycle test. The nominal concentrations used in this study were 1, 5, 10, 20, 40, 80 and 150 µg/L for the acute test and 1, 5, 10, 50 and 100 µg/L for the life cycle test. Measured concentrations were 0.8, 4.6, 11.5, 24.1, 49.1, 96.2, 150.1 µg/L and 2.3, 14.4, 21.7, 94.9 and 149 µg/L respectively.

The endpoints of survival, growth, emergence and reproduction were assessed, with survival, growth and emergence reported to be significantly affected. Reproduction was not affected at the concentrations at which females emerged. The authors concluded that the study results suggested that PFOS was as much as 3 orders of magnitude more toxic to the freshwater midge than previously reported for other aquatic organisms.

A summary of reported ecotoxicology endpoints for the freshwater midge when exposed to PFOS is provided in **Table D3**.

Table D3: Summary of Endpoints for the Freshwater Midge (MacDonald et al. 2004)

Endpoint	NOEC (µg PFOS/L)	EC10 (µg PFOS/L)	EC50 (µg PFOS/L)
36-day exposure			
Total emergence	<2.3	89	95
20-day exposure			
Growth	22	88	94
Survival	95	86	92
10-day exposure			
Growth	49	49	87
Survival	49	108	>105

The most sensitive endpoint in **Table D3** is emergence.

MacDonald et. al. (2004) reported that time to first emergence, rate of emergence and total emergence per treatment were all affected by increasing PFOS concentrations with total emergence most sensitive, as illustrated in **Figure D2** which shows the number of larvae that remained on the surface of the sediment after failing to build tubes. **Figure D3** shows the % cumulative emergence, with increasing PFOS concentrations.

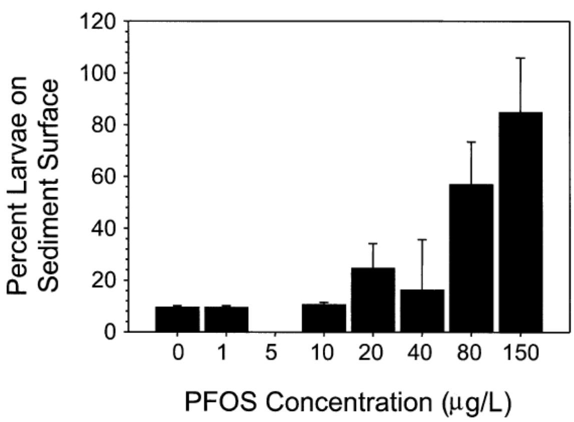

Fig. 2. Percentage of surviving larvae failing to build tubes and found residing at the sediment surface at completion of a 10-d exposure to perfluorooctane sulfonic acid (PFOS). Error bars represent the standard deviation.

Figure D2: Dose response curve from MacDonald et al. (2004)

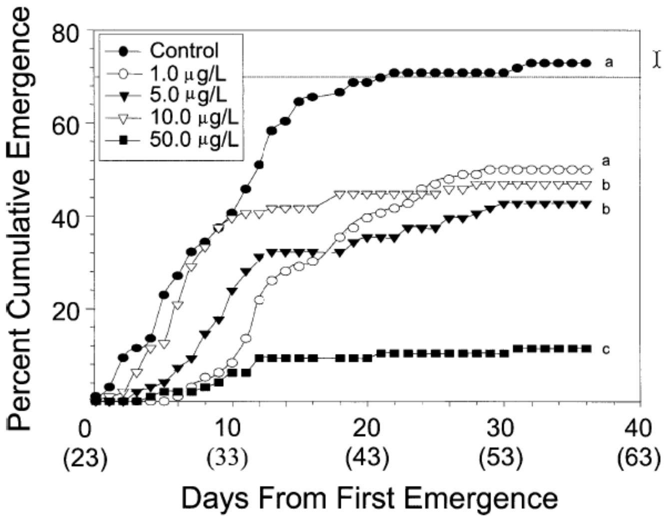

Figure D3: Cumulative dose response curve from MacDonald et al. (2004)

While the evidence for an effect on emergence with increasing PFOS concentrations is apparent from the figures, **Figures D2** and **D3** as well as **Table D2** indicate that the story is complex.

The EC10 values (the concentration at which 10% of test organisms are affected) obtained were similar for the 36 day and 20 day exposure period. The NOEC values (the concentrations at which there is no observable effect), on the other hand, were variable. For example, the NOEC for the emergence endpoint is <2.3 µg/L (i.e. an effect was seen at the lowest concentration tested) but the EC10 for same endpoint was 89 µg/L.

It is generally expected that an EC10 should be roughly equivalent to a NOEC which is why the difference in the results for NOEC and EC10 for emergence looks anomalous. However, and as shown by the **Figure D3**, there is clearly a difference between the 1 µg/L treatment and the control, which confirms the presence of an effect on emergence due to PFOS concentration.

What is also apparent, though, is that there was little difference in the level of effect seen at all concentrations tested between 1 and 10 µg/L (i.e. the dose response curves are all very similar/same for these treatments). This suggests that there is no difference in effects on emergence within this concentration range.

There is, however, a dose response across the experiment as the effect on emergence is much higher than the controls for the 50 µg/L treatment.

In this case, using an EC10 value of 89 µg/L to generate a water quality guideline instead of a LOEC/NOEC of 2.3 µg/L would appear to greatly underestimate potential for effects and not be protective.

Multi-Generation Fish Studies

Multi-generation toxicity studies in fish are important when evaluating potential effects on aquatic organisms from PFOS, given the persistent nature and widespread occurrence of the chemical.

Data from 6 multi-generation fish studies (Keiter et al 2012, Ji et al 2008, Ankley et al 2005, Wang et al 2011, Du et al 2009, Han and Fang 2010) were reviewed. The details of each study are presented in **Table D4**.

Table D4: Summary of Multi-Generation Fish Studies

Study	Fish Species / Solvent	PFOS Dosing Regime (µg/L)	Life Stage at Commencement of Experiment	Generations Considered by Study	Endpoints Assessed				
					Survival	Growth	Sex Ratio	Histology	Fecundity / Fertility
Keiter et al. 2012 (Keiter et al. 2012)	Zebrafish / None	0, 0.6, 100, 300	Eggs (2-4 hours post fertilisation)	F0 grew from eggs to reproducing adults; F1 eggs to reproducing adults; F2 eggs to 14-day old fry	No mortality / malformations in F0 for any treatment; no survival and definite malformations at 300 µg/L; effects at 100 µg/L at swim up stage; 42% survival at 100 µg/L for F2	Significant reduction for F0 males for all treatments (no dose response; just a difference from controls) at 90 and 180 days post fertilisation; same effect for F1	Not assessed	Vacuolisation in the liver at 100 and 300 µg/L in F0 and F1	Controls reported 190 eggs per female in F0 and 40 eggs per female in F1; no discussion provided; all PFOS related changes are within this range so effects may not be treatment related; no effect seen on fertility
Ji et al. 2008 (Ji et al. 2008)	Japanese medaka / None	0, 10, 100, 1,000	Sexually mature fish	F0 adults exposed for 14 days; F1 eggs to 100 days post hatch	No mortality effects in F0; significant mortality in F1 - any F1 from fish exposed to PFOS in F0 generation showed effects on survival regardless of exposure regime during F1	Increase in ovaries in F0 females but otherwise no effects; control fish for F1 that came from F0 exposed to each of the PFOS treatments showed significant decrease in growth at 100 days.	Not assessed	Only studied the thyroid, not the liver; significant changes noted in thyroid for all F1 from parents exposed in F0 (all doses)	Dose dependent decrease in number of eggs per spawning in F0; significant changes in hatchability and time to hatch when parents were exposed to 1,000 µg/L for all F1 treatments
Ankley et al. 2005 (Ankley et al. 2005)	Fathead minnow / None	0, 30, 100, 300, 1,000	Sexually mature fish	Adults exposed for 21 days; eggs produced in final 7 days grown out for 24 days in same treatments	1,000 µg/L was lethal within 14 days (some died others not healthy so sacrificed); no mortality in adults at any other treatment or on fry	No significant effects at up to 300 µg/L	Not assessed	Vacuolisation in the liver at 300 µg/L	Ceased spawning at 1,000 µg/L; reduced spawning at 100 and 300 µg/L; 21 d EC50 230 µg/L; reduction in fertilisation at 250 µg/L
Wang et al. 2011 (Wang et al. 2011)	Zebrafish / DMSO	0, 5, 50, 250	Eggs (8 hours post fertilisation)	F0 exposed from eggs to 5 months old; eggs produced grown out to 8 days old	No info on survival in F0; all larvae in F1 died for those mothers exposed to 250 µg/L; larvae were in clean water throughout so effects due to parental exposure; 65% survival at 50 µg/L at 8 days; all survived at 5 µg/L	Significant reduction at 250 µg/L in both sexes; significant reduction at 50 µg/L for males; growth not assessed in F1	Less males in F0 at end of 150 days at 250 µg/L	Not assessed	No significant effects on spawning for all females all treatments; reduction in fertilisation at 250 µg/L. No effect on hatching rates
Du et al. 2009 (Du et al. 2009)	Zebrafish / DMSO	0, 10, 50, 250	Fry (14 days post fertilisation)	14-day old fry exposed for 70 days with 30 days depuration/recovery following. Eggs from these adults grown out but didn't state how long for	No impacts on survival of F0 for 70 d exposure; malformations in larvae at 50 µg/L and 250 µg/L; all malformed larvae died 4-5 days post hatching	Reduction in size of female gonads at 50 and 250 µg/L; reduction was even bigger for fish after 30 d recovery time	Ratio not significantly altered but controls were 28% females; 10 µg/L 34%; 50 µg/L 36% and 250 µg/L 40%.	Vacuolisation in the liver of males at 250 µg/L after 70 d exposure, still there after 30 d recovery period	No information on spawning success; hatching success was similar for all treatments (75 to 80%)
Han and Fang 2010 (Han & Fang 2010)	Zebrafish / DMSO	0, 100, 500, 2,500	Sexually mature fish	Adults exposed for 3 weeks with 1 week recovery; pregnant female retained and larvae success checked at 14 days	No mortality in males; 33% survival in females at 2,500 µg/L; 90% survival at 100 and 500 µg/L; 43% survival for F1 larvae at 500 µg/L and 95% at 100 µg/L; malformations in 40% at 50 µg/L and 100% in 250 µg/L	Adult females reduced food intake, emaciation and body bend at 2,500 µg/L after 5 weeks	No change obvious	Vacuolisation in the liver at 2,500 µg/L	No effect on number of offspring per group
				NOEC range	**0.6-5 µg/L**	**0.6-5 µg/L**	**0.6-10 µg/L**	**0.6-10 µg/L**	**0.6-5 µg/L**

A detailed review of **Table D4** indicates that:

- The study quality and consistency varied. For example, 3 studies used dimethyl sulfoxide (DMSO) as a carrier solvent and 3 used water only. However, the 3 studies that used DMSO did not include a solvent control which makes the interpretation of effects that may be due to PFOS problematic (due to potential confounding from effects due to the solvent). It is a standard requirement of ecotoxicity testing to include a control with and without the carrier solvent if 1 is used (i.e. 2 types of controls). The fact that these were not included in these 3 studies severely limits their validity/acceptability.
- Study design varied with 2 studies set up on a flow through basis, and 4 were semi-static studies with renewal intervals varying between 24 hours to every week. These studies incorporated both 50% and 100% renewal. This variation in experimentation conditions makes interpretation problematic (again due to the potential for confounding factors).
- Most studies reported effects in the 1-10 µg/L range with confidence, with 1 study (Keiter et al. 2012) reporting effects on growth at 0.6 µg/L (all the other endpoints for this study reported no effects at 0.6 µg/L with effects only at 100 µg/L). However, the effect on growth reported by Keiter et. al. (2012) did not show increasing effect with increasing concentration (i.e. did not show a dose-response). This means that the cause of this effect cannot be determined with confidence (i.e. it cannot be determined whether this effect was due to exposure to PFOS or due to something else e.g. the study design or an unidentified confounding factor). If the potential for effects at 0.6 µg/L is disregarded, this is consistent with the other multi-generational fish studies, and with the study for the other sensitive aquatic organisms (i.e. the freshwater midge and damselfly (refer above)).
- PFOS treatment concentrations across all the studies ranged from 0.6 to 1,000 µg/L, however, few of the studies focused on treatment concentrations below 50 to 100 µg/L i.e. 1 treatment concentration in this range for the first 5 studies and no treatment concentrations in this range for the last study. This makes it difficult to identify effects at the lower end of the treatment range which appears to be most important.

The overall implication is that, based on the available data, it is not possible to differentiate between any effect at low PFOS concentrations, due to lack of treatment doses in this range.

This is particularly important because, when deriving water quality guidelines, it is the shape of the tail end of the statistical distribution that determines the difference between the 95% and 99% species protection value. If there are insufficient (or inadequate) data to determine the shape of the distribution at these low concentrations, the statistical analysis will likely yield a large difference between the 95% and 99% protection trigger values which has occurred for PFOS.

The following is also worth noting when considering the applicability of the 99% versus the 95% species protection value:

- The Australian approach for determining water quality guidelines (i.e. the SSD approach) is based on an approach developed by RIVM. However, RIVM (2010) concluded the following with respect to the application of this approach for PFOS:
  - *"The dataset does in principle fulfil the requirements for performing a species sensitivity distribution with respect to the number and type of species tested, however, all LOECs are for species that appear to the sensitive to PFOS and for*

which no NOECs are available in the dataset. For this reason, the lower end of the species sensitivity distribution cannot be estimated. It is, therefore, not considered justified to derive a [guideline] by statistical extrapolation."

This suggests that Australia should proceed with caution prior to using a SSD to determine guidelines for PFOS using the data that were available in 2016 when this guideline was first drafted.

- The mode of action for effects in the multi-generation fish studies (or any aquatic toxicology studies with PFAS for that matter) is not well understood. This makes it difficult to determine the relevance of effects on the overall survival of a population (i.e. some effects may be reversible or not adverse, and so do not affect the overall population health).
- Given that PFOS bioaccumulates significantly, 1 proposed mode of action for the multi-generation effects in fish is due to the eggs and larvae being exposed to PFOS both via residues from the mother which get transferred into the eggs as they form and in the water in which they are living. This means overall exposure is higher for the same water concentration compared to the situation where new eggs from parent fish that have never been exposed are tested for a full lifecycle (i.e. 1 generation not multi-generation).
- Multi-generation studies are difficult to undertake as they need to be run for extended periods; follow a range of effects in the organisms rather than a single effect and sufficient animals need to be present in the treatments to allow appropriate sampling throughout the exposure period. Few laboratories have the resources (space, funding and equipment) needed as well as the ability to control the presence of PFAS in the test space to be able to undertake this type of study appropriately.

New ecotoxicity data for PFAS

Additional ecotoxicity studies for PFOS specifically and for a range of PFAS in fish have been undertaken since the draft Australian guideline was developed more than 5 years ago.

SERDP multi-generation test

US researchers undertook a study specifically to replicate the study that provided the data that have proven most difficult to interpret for use in the determination of the Australian guideline (Keiter et al. 2012). This new study is reported in (Gust et al. 2024).

The study included more treatment concentrations (0, 0.1, 0.6, 3.2, 20 and 100 µg/L) than the original version of this experiment (0, 0.6, 10 and 100 µg/L). The results for the repeat of the study indicate that effects at 0.6 µg/L, which were seen in the original study, have not been able to be replicated. The study reported a statistically significant effect on survival only at the highest concentrations tested – i.e. around 100 µg/L (measured values ranged from 75-131 µg/L depending on the generation and age of the fry. The study reported that other effects such as decreased body weight or reproduction were covered by a mean effective concentration of 47 µg/L (i.e. mean of all types of effects across all generations). The study noted issues with the dose response relationships for many of these subtle effects similar to the issues with the original study (Keiter et al. 2012).

These endpoints are at least 50 times higher than the value currently used in the database to determine the Australian water quality guidelines for PFOS. Using 47 µg/L in the ANZG species sensitivity distribution for PFOS instead of the value from Keiter et al. (2012) will make a difference to the water quality guideline values.

Zebrafish review

Also late in 2023, a review article was published discussing the ecotoxicity of PFOS to zebrafish due to the large number of studies available and the confusion/limitations of many of the studies (Pandelides et al. 2023).

This review article has determined a no effect screening level and a low effect screening level for zebrafish. The no effect screening level is 31 µg/L and the low effect screening level is 96 µg/L.

Using the no effect screening level in the ANZG species sensitivity distribution for PFOS instead of the value from Keiter et al. (2012) will make a difference to the water quality guideline values.

Other ecotoxicity studies

Other studies generating ecotoxicity data for PFOS, PFOA and other PFAS in fish (i.e. whole animal) have also been undertaken (Rericha et al. 2021; Truong et al. 2022).

Truong et al. (2022) used USEPA information and the developmental zebrafish platform to assess 139 different PFAS. This study looked at up to 10 different concentrations for each chemical. The different concentrations used ranged from around 1-10 µg/L to >10,000 µg/L. Of the 139 chemicals, 49 caused changes in morphology (i.e. malformations) or effects on the embryo or larvae. The most potent PFAS for these effects was PFDA. For the 8 most commonly studied PFAS, the ranking based on effects was PFDA>FOSA>PFOS>PFHpS>PFTrDA>8:2 FTS>PFUnDA>PFHxS. The study also looked at the difference between volatile and non-volatile PFAS to determine if there was a pattern regarding these development effects and found that non-volatile PFAS (i.e. the ones that have been more commonly studied and are present in the environment more often) are the ones most likely to cause impacts. The majority of the PFAS that did not show any effects in this assay were volatile ones that are precursors to PFOS and PFOA and related compounds (Truong et al. 2022).

Rericha et al. (2021) looked at 58 individual PFAS using a similar approach. One thing identified by this group was that using a methanol solvent control did not cause significant developmental effects but using isopropanol did cause effects. This is an important issue to note when reviewing ecotoxicity studies. Most of the common PFAS groups (perfluoroalkyl carboxylic acids and perfluoroalkyl sulfonic acids) caused some effects in larvae. The concentrations used in these studies were higher than normally reported in the environment (Rericha et al. 2021).

Potential for Secondary Poisoning – i.e. bioaccumulation

For PFOS, there is evidence that the potential for secondary poisoning can be more important than aquatic toxicity from direct exposure to PFOS in the water in which the aquatic organisms (e.g. fish) live. This is very different to most of the toxicants covered by the existing Guidelines (ANZG 2018).

Secondary poisoning describes the process whereby effects are reported on a higher-level organism like a bird or a mammal because their diet consists of lower organisms that are living in the environment of interest and are likely to contain the chemical of interest (e.g. birds consuming fish that lived in water where a bioaccumulative chemical like PFOS was present).

The classic example is the widespread effects reported in the American Bald Eagle due to the indiscriminate use of DDT following the second world war. The eagles were not directly exposed to DDT (during spraying, for example) but ate fish contaminated with DDT (and other animals that had eaten the fish contaminated with DDT) when DDT washed into rivers and creeks following its use as an insecticide.

The guideline calculations for PFOS presented by RIVM (2010) and Giesy et. al. (2010) show that PFOS can accumulate to concentrations that might affect higher organisms at water concentrations much lower than those at which direct effects on aquatic organisms would be expected.

This may be due to aquatic organisms being able to remove PFOS from their systems via the gills (i.e. depurate) limiting their exposure as proposed in (Martin et al. 2003). No similar pathway exists for air breathing organisms (e.g. birds). This means bioaccumulation can occur to much greater levels in these higher organisms as they cannot remove the chemical from their systems.

Zodrow et al. (2021) developed risk based screening levels for different types of higher organisms. The screening level for direct exposure of aquatic organisms in water was 40 µg/L for PFOS but the screening level based on protecting higher organisms such as mink or tree swallows or pelicans ranged from 0.05 to 1.1 µg/L for PFOS. This highlights the difference between guidelines based on direct toxicity and those based on protecting the diet of higher organisms for this type of chemical (Zodrow et al. 2021).

For chemicals that bioaccumulate like DDT, it is possible to model uptake through the food chain sufficiently well to allow soil/sediment/water guidelines to be considered. Due to the difficulties associated with the surfactant nature of PFAS and the impact of that on modelling the uptake of PFOS through the food chain, consideration of bioaccumulation potential should be considered on a site-specific basis and, where relevant, be based on the development of the conceptual site model for a specific site or situation (CSM).

Newer water quality guideline values

USEPA draft water quality guidelines and other proposed guidelines

The USEPA released a draft PFOS aquatic life criterion in 2022. Their draft value is 8.4 µg/L for a scenario equivalent to the Australian 95% species protection values (USEPA 2022c).

Papers summarising relevant data for developing water quality guidelines include 1 by Zodrow et al. (2021) and 1 by Ankley et al. (2021) (Ankley et al. 2021; Zodrow et al. 2021).

In particular, the study by Zodrow et al. (2021) developed risk based screening levels for a range of PFAS including PFOS and PFOA for water and soil. The water quality guideline for PFOS from this work was a value of 39 µg/L – this value is more in line with the Australian 95% species protection values. For uptake into wildlife from consuming aquatic organisms (i.e. bioaccumulation), the value for PFOS is 0.2-1 µg/L (Zodrow et al. 2021).

The USEPA identified 17 PFAS as having the potential to cause effects in a high throughput assay panel in their ToxCast program. Other researchers looked at 113 different PFAS confirming results for well studied PFAS and identifying a range of PFAS that would be useful to study further (Truong et al. 2022).

Newly released draft WQG for PFOS in Australia

In addition to the USEPA draft guideline released in 2022, an update to the WQG for PFOS was released early in 2023 as a draft for public consultation. Comments have closed and are being considered prior to finalisation of the guideline for official release and implementation.

The new draft guidelines published early in 2023 are listed in **Table D5**.

Table D5: Newly released draft Australian water quality guidelines for PFOS (ANZG 2023)

Species protection level	Draft water quality guideline (µg/L)
99%	0.0091
95%	0.48
90%	2.7
80%	17

The dataset used in the calculation of these guidelines does not include results from the SERDP study (discussed above) undertaken to address issues identified in the work by Keiter et al. (2012) as the Gust et al. (2024) paper was not published at the time. It is available at the time of this assessment.

Preferred software

In addition to the new draft guidelines for PFOS released in Australia in 2023, the technical committee also indicated that they have changed the preferred software for calculating species sensitivity distributions. The change is from Burrlioz[21] to SSDTools[22].

Using the same database as used for the 2023 draft PFOS guidelines along with the new preferred software provides guidelines as listed in **Table D6**.

Table D6: Updated Australian water quality guidelines for PFOS using SSDTools

Species protection level	Draft water quality guideline (µg/L)
99%	0.02
95%	0.6
90%	2.5
80%	13

In addition, using the same database as used for the 2023 draft PFOS guidelines with the exception of the Keiter et al. (2012) data point is removed and the addition of the value from Gust et al. (2024) (i.e. 47 µg/L) along with the new preferred software provides guidelines as listed in **Table D7**.

[21] https://research.csiro.au/software/burrlioz/
[22] https://bcgov-env.shinyapps.io/ssdtools/ and https://shinyssd.tools/

Table D7: Updated Australian water quality guidelines for PFOS using SSDTools (using data from Gust et al. (2024) to replace data from Keiter et al. (2012)

Species protection level	Draft water quality guideline (µg/L)
99%	0.08
95%	1.3
90%	3.5
80%	17

In summary:

- The most sensitive aquatic species to PFOS are reported to be the European Damselfly, the freshwater midge, and fish species including the zebra fish, Japanese medaka and fathead minnow in multi-generation studies.
- While some data are available with which to infer a no effect concentration from these studies (which could then be used in guideline development), the data are difficult to interpret due to differences in the way the studies have been undertaken and the presence of potential confounding factors.
- In addition, it is the shape of the tail end of the statistical distribution that determines the difference between the 95% and 99% species protection value. There are limited data available in many of the studies to determine effects (or not) at concentrations less than 50 µg/L. If there are insufficient (or inadequate) data to determine the shape of the distribution at these low concentrations, the statistical analysis will likely yield a large difference between the 95% and 99% protection trigger values which has occurred here.
- The Australian approach for determining water quality guidelines is based on a statistical approach developed by RIVM. However, RIVM (2010) concluded that it was not appropriate to use this statistical approach to derive a guideline value for PFOS, given the available dataset.
- Good quality data to assist guideline development have recently been published and there are additional reviews of the whole dataset for PFOS now available.

Using the updated draft PFOS 95% species protection guideline value is appropriate (and potentially should be a higher value) for considering the potential for direct toxicity to aquatic organisms in this assessment. This draft value for PFOS is still lower (i.e. more conservative) than the water quality guidelines used for protection of ecosystems in Canada (i.e. 6.8 µg/L) or in the US (i.e. 8.4 µg/L). These PFOS guidelines from Canada and the US are equivalent to 95% species protection guideline values in Australia.

Published guidelines for the protection of terrestrial and aquatic environments from government agencies are not available for PFHxS or many of the other PFAS. However, data are becoming available for a range of PFAS[23] and some studies generating such guidelines are being published (Zodrow et al. 2021).

In the meantime, meeting the guidelines for PFOS is expected to be protective for organisms in relation to exposure to other PFAS as these chemicals are likely to be present from similar sources and most evidence indicates that many of the other individual PFAS have similar ecotoxicity or

[23] https://cfpub.epa.gov/ecotox/

lower ecotoxicity to PFOS. Complying with the guideline for PFOS is likely to be protective/conservative for all the other PFAS. It is also important to remember that many of the other PFAS do not bioaccumulate to the extent of PFOS or even bioaccumulate at all.

Appendix E Risk calculations

Ingestion of groundwater for drinking water - adults

$$Daily\ Chemical\ Intake_{IW} = C_W \bullet \frac{IR_W \bullet FI \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(L/kg/day)}$$

Parameters Relevant to Quantification of Exposure		
Ingestion Rate (Irw, L/day)	2	as per ADWG
Fraction Ingested from Source	1	Assumed to be 100%
Bioavailability (B)	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Exposure Frequency (EF, days/year)	365	Adults (ASC NEPM)
Exposure Duration (ED, years)	29	Adults (ASC NEPM)
Exposure Frequency (EF, days/year)	365	Child (ASC NEPM)
Exposure Duration (ED, years)	6	Child (ASC NEPM)
Body Weight (BW, kg)	70	Assumed for adults (ASC NEPM)
Body Weight (BW, kg)	15	Assumed for child (ASC NEPM)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM child (AT = ED*365)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM adult (AT = ED*365)

Key Chemical	Toxicity Data				Concentration in Water (Cw)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Zone 1 - maximum								--			
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000444		1.3E-05	--		0.705	
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0001		2.9E-06	--		0.159	
Zone 2											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000184		5.3E-06	--		0.292	
Zone 3											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0000676		1.9E-06	--		0.107	
Zone 5											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000125		3.6E-06	--		0.198	
Zone 6											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000075		2.1E-06	--		0.119	

Ingestion of groundwater for drinking water - child

$$Daily\ Chemical\ Intake_{IW} = C_W \bullet \frac{IR_W \bullet FI \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(L/kg/day)}$$

Parameters Relevant to Quantification of Exposure		
Ingestion Rate (Irw, L/day)	0.7	as per enHealth Exposure Factors Handbook P90
Fraction Ingested from Source	1	Assumed to be 100%
Bioavailability (B)	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Exposure Frequency (EF, days/year)	365	Adults (ASC NEPM)
Exposure Duration (ED, years)	29	Adults (ASC NEPM)
Exposure Frequency (EF, days/year)	365	Child (ASC NEPM)
Exposure Duration (ED, years)	6	Child (ASC NEPM)
Body Weight (BW, kg)	70	Assumed for adults (ASC NEPM)
Body Weight (BW, kg)	15	Assumed for child (ASC NEPM)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM child (AT = ED*365)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM adult (AT = ED*365)

Key Chemical	Toxicity Data				Concentration in Water (Cw)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Zone 1 - maximum											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000444		2.1E-05	--		1.151	
Zone 1 - refined										--	
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0001		4.7E-06	--		0.259	
Zone 2											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000184		8.6E-06	--		0.4770	
Zone 3											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0000676		3.2E-06	--		0.1753	
Zone 5											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000125		5.8E-06	--		0.3241	
Zone 6											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000075		3.5E-06	--		0.1944	

Incidental ingestion of groundwater during farm activities

$$Daily\ Chemical\ Intake_{IW} = C_W \bullet \frac{IR_W \bullet FI \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(L/kg/day)}$$

Parameters Relevant to Quantification of Exposure		
Ingestion Rate (Irw, L/day)	0.02	as per NRMMC (2006)
Fraction Ingested from Source	1	Assumed to be 100%
Bioavailability (B)	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Exposure Frequency (EF, days/year)	365	Adults (ASC NEPM)
Exposure Duration (ED, years)	29	Adults (ASC NEPM)
Exposure Frequency (EF, days/year)	365	Child (ASC NEPM)
Exposure Duration (ED, years)	6	Child (ASC NEPM)
Body Weight (BW, kg)	70	Assumed for adults (ASC NEPM)
Body Weight (BW, kg)	15	Assumed for child (ASC NEPM)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM child (AT = ED*365)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM adult (AT = ED*365)

Key Chemical	Toxicity Data				Concentration in Water (Cw)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Zone 1 - maximum								--			
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000444		1.3E-07	--		0.00705	
Zone 1 - refined										--	
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0001		2.9E-08			0.00159	
Zone 2											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000184		5.3E-08	--		0.00292	
Zone 3											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0000676		1.9E-08	--		0.00107	
Zone 5											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000125		3.6E-08	--		0.00198	
Zone 6											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000075		2.1E-08	--		0.00119	

Incidental ingestion of groundwater during farm activities - child

$$\textit{Daily Chemical Intake}_{IW} = C_W \bullet \frac{IR_W \bullet FI \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(L/kg/day)}$$

Parameters Relevant to Quantification of Exposure		
Ingestion Rate (Irw, L/day)	0.02	as per NRMMC (2006)
Fraction Ingested from Source	1	Assumed to be 100%
Bioavailability (B)	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Exposure Frequency (EF, days/year)	365	Adults (ASC NEPM)
Exposure Duration (ED, years)	29	Adults (ASC NEPM)
Exposure Frequency (EF, days/year)	365	Child (ASC NEPM)
Exposure Duration (ED, years)	6	Child (ASC NEPM)
Body Weight (BW, kg)	70	Assumed for adults (ASC NEPM)
Body Weight (BW, kg)	15	Assumed for child (ASC NEPM)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM child (AT = ED*365)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM adult (AT = ED*365)

Key Chemical	Toxicity Data				Concentration in Water (Cw)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Zone 1 - maximum								--			
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000444		5.9E-07	--		0.0329	
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0001		1.3E-07	--		0.0074	
Zone 2											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000184		2.5E-07	--		0.01363	
Zone 3											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0000676		9.0E-08	--		0.00501	
Zone 5											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000125		1.7E-07	--		0.00926	
Zone 6											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000075		1.0E-07	--		0.00556	

Incidental ingestion of groundwater during activities around the home - adult

$$Daily\ Chemical\ Intake_{IW} = C_W \bullet \frac{IR_W \bullet FI \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(L/kg/day)}$$

Parameters Relevant to Quantification of Exposure		
Ingestion Rate (Irw, L/day)	0.02	as per NRMMC (2006)
Fraction Ingested from Source	1	Assumed to be 100%
Bioavailability (B)	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Exposure Frequency (EF, days/year)	365	Adults (ASC NEPM)
Exposure Duration (ED, years)	29	Adults (ASC NEPM)
Exposure Frequency (EF, days/year)	365	Child (ASC NEPM)
Exposure Duration (ED, years)	6	Child (ASC NEPM)
Body Weight (BW, kg)	70	Assumed for adults (ASC NEPM)
Body Weight (BW, kg)	15	Assumed for child (ASC NEPM)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM child (AT = ED*365)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM adult (AT = ED*365)

Key Chemical	Toxicity Data				Concentration in Water (Cw)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Zone 1 - maximum								--			
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000444		1.3E-07	--		0.00705	
Zone 1 - refined										--	
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0001		2.9E-08			0.00159	
Zone 2											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000184		5.3E-08	--		0.00292	
Zone 3											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0000676		1.9E-08	--		0.00107	
Zone 5											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000125		3.6E-08	--		0.00198	
Zone 6											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000075		2.1E-08	--		0.00119	

Incidental ingestion of groundwater during activities around the home - child

$$Daily\ Chemical\ Intake_{IW} = C_W \bullet \frac{IR_W \bullet FI \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(L/kg/day)}$$

Parameters Relevant to Quantification of Exposure		
Ingestion Rate (Irw, L/day)	0.02	as per NRMMC (2006)
Fraction Ingested from Source	1	Assumed to be 100%
Bioavailability (B)	100%	Assume 100% bioavailability via ingestion of chemicals in water.
Exposure Frequency (EF, days/year)	365	Adults (ASC NEPM)
Exposure Duration (ED, years)	29	Adults (ASC NEPM)
Exposure Frequency (EF, days/year)	365	Child (ASC NEPM)
Exposure Duration (ED, years)	6	Child (ASC NEPM)
Body Weight (BW, kg)	70	Assumed for adults (ASC NEPM)
Body Weight (BW, kg)	15	Assumed for child (ASC NEPM)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM child (AT = ED*365)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM adult (AT = ED*365)

Key Chemical	Toxicity Data				Concentration in Water (Cw)	Daily Intake		Calculated Risk			
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	% Total Risk	Chronic Hazard Quotient (unitless)	% Total HI
Zone 1 - maximum								--			
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000444		5.9E-07	--		0.0329	
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0001		1.3E-07	--		0.0074	
Zone 2											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000184		2.5E-07	--		0.01363	
Zone 3											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.0000676		9.0E-08	--		0.00501	
Zone 5											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000125		1.7E-07	--		0.00926	
Zone 6											
PFOS+PFHxS		0.00002	10%	1.8E-05	0.000075		1.0E-07	--		0.00556	

Exposure to PFAS via Ingestion of Fruits - Adult

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg bw/day)**

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.14	ASC NEPM
Fraction Home-Grown (FHG)	35%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM
Body Weight (BW, kg)	70	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/ (mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.02	0.000444	0.00000888		6.2E-09	--	0.000345
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.02	0.0001	0.000002		1.4E-09	--	0.000078
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.000184	0.00000368		2.6E-09	--	0.000143
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.0000676	0.000001352		9.5E-10	--	0.000053
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.000125	0.0000025		1.8E-09	--	0.000097
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.000075	0.0000015		1.1E-09	--	0.000058

EnRiskS

Exposure to PFAS via Ingestion of Fruits - Children

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg bw/day)**

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.18	ASC NEPM
Fraction Home-Grown (FHG)	10%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM
Body Weight (BW, kg)	15	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/ (mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.02	0.000444	0.00000888		1.1E-08	--	0.000592
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.02	0.0001	0.000002		2.4E-09	--	0.000133
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.000184	0.00000368		4.4E-09	--	0.000245
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.0000676	0.000001352		1.6E-09	--	0.000090
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.000125	0.0000025		3.0E-09	--	0.000167
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.02	0.000075	0.0000015		1.8E-09	--	0.000100

Exposure to PFAS via Ingestion of Green Vegetables - Adult

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg bw/day)**

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.1534	ASC NEPM
Fraction Home-Grown (FHG)	35%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM
Body Weight (BW, kg)	70	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/(mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.79	0.000444	0.00035076		2.7E-07	--	0.014946
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.79	0.0001	0.000079		6.1E-08	--	0.003366
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.000184	0.00014536		1.1E-07	--	0.006194
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.0000676	0.000053404		4.1E-08	--	0.002276
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.000125	0.00009875		7.6E-08	--	0.004208
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.000075	0.00005925		4.5E-08	--	0.002525

Exposure to PFAS via Ingestion of Green Vegetables - Children

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg bw/day)**

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.055	ASC NEPM
Fraction Home-Grown (FHG)	10%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM
Body Weight (BW, kg)	15	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/(mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.79	0.000444	0.00035076		1.3E-07	--	0.007145
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.79	0.0001	0.000079		2.9E-08	--	0.001609
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.000184	0.00014536		5.3E-08	--	0.002961
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.0000676	0.000053404		2.0E-08	--	0.001088
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.000125	0.00009875		3.6E-08	--	0.002012
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.79	0.000075	0.00005925		2.2E-08	--	0.001207

Exposure to PFAS via ingestion of root vegetables - Adult

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg bw/day)**

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.0468	ASC NEPM
Fraction Home-Grown (FHG)	35%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM
Body Weight (BW, kg)	70	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/(mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.51	0.000444	0.00022644		5.3E-08	--	0.002944
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.51	0.0001	0.000051		1.2E-08	--	0.000663
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.000184	0.00009384		2.2E-08	--	0.001220
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.0000676	0.000034476		8.1E-09	--	0.000448
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.000125	0.00006375		1.5E-08	--	0.000829
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.000075	0.00003825		9.0E-09	--	0.000497

Exposure to PFAS via ingestion of root vegetables - Children

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg bw/day)**

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.017	ASC NEPM
Fraction Home-Grown (FHG)	10%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM
Body Weight (BW, kg)	15	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/ (mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.51	0.000444	0.00022644		2.6E-08	--	0.001426
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.51	0.0001	0.000051		5.8E-09	--	0.000321
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.000184	0.00009384		1.1E-08	--	0.000591
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.0000676	0.000034476		3.9E-09	--	0.000217
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.000125	0.00006375		7.2E-09	--	0.000401
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.51	0.000075	0.00003825		4.3E-09	--	0.000241

Exposure to PFAS via Ingestion of tuber veg - Adult

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$

(mg/kg bw/day)

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed maximum
Ingestion Rate (IR, kg/day)	0.0598	ASC NEPM
Fraction Home-Grown (FHG)	35%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM
Body Weight (BW, kg)	70	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/ (mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000444	0.0000888		2.7E-08	--	0.001475
Zone 1 - refined										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.0001	0.00002		6.0E-09	--	0.000332
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000184	0.0000368		1.1E-08	--	0.000611
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.0000676	0.00001352		4.0E-09	--	0.000225
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000125	0.000025		7.5E-09	--	0.000415
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000075	0.000015		4.5E-09	--	0.000249

Exposure to PFAS via Ingestion of tuber veg - Children

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$

(mg/kg bw/day)

C_{fruit} = Cs x Transfer Factor **(mg/kg fresh produce)**

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate (IR, kg/day)	0.028	ASC NEPM
Fraction Home-Grown (FHG)	10%	Assumed relevant for this situation
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM
Body Weight (BW, kg)	15	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM

Key Chemical	Toxicity Data				Transfer Factor = (mg/kg in fruit ww)/ (mg/kg soil)	Concentration in Media (Cs)	Concentration in Fruit	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum										--	--
PFOS+PFHxS		0.00002	10%	0.000018	0.2	0.000444	0.0000888		1.7E-08	--	0.000921
Zone 1 - refined											
PFOS+PFHxS		0.00002	10%	0.000018	0.2	0.0001	0.00002		3.7E-09	--	0.000207
Zone 2										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000184	0.0000368		6.9E-09	--	0.000382
Zone 3										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.0000676	0.00001352		2.5E-09	--	0.000140
Zone 5										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000125	0.000025		4.7E-09	--	0.000259
Zone 6										--	--
PFOS + PFHxS		0.00002	10%	0.000018	0.2	0.000075	0.000015		2.8E-09	--	0.000156

Intake of PFAS by chickens

$$Intake_m = \frac{C_m \times IR_m \times FI \times B_o \times EF \times ED}{BW \times AT}$$ **(mg/kg/day)**

C_{eggs} = (Daily Intake)$_{chickens}$ x Transfer Factor **(mg/kg fresh produce)**

	PFOS	PFHxS	PFOA	units
Adjusted Egg to intake ratio =	37.5	25.8	17.2	mg/kg edib/d / mg/kg bw-d
Egg to intake ratio as per study =	1	0.69	0.46	mg/edible egg-d / mg/d

Average weight of bird = 2 kg ; and average weight of egg without shell = 56g -d

Chicken

Exposure Parameters	Average	Reference
Chicken water ingestion rate (L/day)	0.32	ANZECC
Chicken soil ingestion rate (kg/day)	0.01	OEHHA (2012)
Fraction of produce from site in diet (FI)	1	
Exposure Frequency (EF, days/year)	365	
Exposure Duration (ED, years)	8	Professional advice
Body Weight (BW, kg)	2	AECOM (2017)
Bioaccessibility (B)	100%	
Averaging Time - Threshold (Atn, days)	2920	ED*365

Calculations for PFOS+PFHxS	Concentration in water (mg/L)	Daily intake (chickens) (mg/kg/day)	Ceggs (mg/kg)
Zone 1 - maximum			
PFOS+PFHxS	0.000444	7.1E-05	2.8E-03
Zone 1 - refined			
PFOS+PFHxS	0.0001	1.6E-05	6.3E-04
Zone 2			
PFOS+PFHxS	0.000184	2.9E-05	1.2E-03
Zone 3			
PFOS+PFHxS	0.0000676	1.1E-05	4.2E-04
Zone 5			
PFOS+PFHxS	0.000125	2.0E-05	7.8E-04
Zone 6			
PFOS+PFHxS	0.000075	1.2E-05	4.7E-04

Exposure to Chemicals via Ingestion of Eggs - Adult

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \textbf{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adult		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate of Eggs (IR_{eggs}, kg/day)	0.059	P90 consumer value for >2 yr old from FSANZ (2017)
Fraction Home-Grown Eggs Consumed (FHG)	100%	Assumed relevant for eggs from backyard
Exposure Frequency (EF, days/year)	365	Assume home grown eggs are consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur for 0-5 years ASC NEPM
Body Weight (BW, kg)	70	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM

Agricultural Application

Key Chemical	Toxicity Data				Concentration in egg (mg/kg)	Concentration in Media (Cw or Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/L)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Zone 1 - maximum									--	--
PFOS + PFHxS		0.00002	10%	0.000018	2.78E-03	0.000444		2.3E-06	--	0.130
Zone 1 - refined									--	--
PFOS + PFHxS		0.00002	10%	0.000018	6.25E-04	0.0001		5.3E-07	--	0.0293
Zone 2										
PFOS + PFHxS		0.00002	10%	0.000018	1.15E-03	0.000184		9.7E-07	--	0.0538
Zone 3										
PFOS + PFHxS		0.00002	10%	0.000018	4.23E-04	0.0000676		3.6E-07	--	0.0198
Zone 5										
PFOS + PFHxS		0.00002	10%	0.000018	7.81E-04	0.000125		6.6E-07	--	0.0366
Zone 6										
PFOS + PFHxS		0.00002	10%	0.000018	4.69E-04	0.000075		4.0E-07	--	0.0219

These calculations have assumed the PFOS+PFHxS concentration was present as 100% PFOS as the transfer factor for PFOS results in a higher concentration - i.e. a conservative approach.

Exposure to Chemicals via Ingestion of Eggs - Children

$$\text{Daily Chemical Intake}_{eggs} = C_{eggs} \bullet \frac{IR_{eggs} \bullet FHG \bullet EF \bullet ED}{AT \bullet BW} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Based on site data
Ingestion Rate of Eggs (IR_{eggs}, kg/day)	0.036	P90 consumer value for 2-6 yr old from FSANZ (2017)
Fraction Home-Grown Eggs Consumed (FHG)	100%	Assumed relevant for eggs from backyard
Exposure Frequency (EF, days/year)	365	Assume home grown eggs are consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur for 0-5 years ASC NEPM
Body Weight (BW, kg)	15	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM

Agricultural Application

Key Chemical	Toxicity Data				Concentration in egg (mg/kg)	Concentration in Media (Cw or Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)		(mg/L)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Zone 1 - maximum									--	--
PFOS + PFHxS		0.00002	10%	0.000018	2.78E-03	0.000444		6.7E-06	--	0.370
Zone 1 - refined										
PFOS + PFHxS		0.00002	10%	0.000018	6.25E-04	0.0001		1.5E-06	--	0.0833
Zone 2										
PFOS + PFHxS		0.00002	10%	0.000018	1.15E-03	0.000184		2.8E-06	--	0.153
Zone 3										
PFOS + PFHxS		0.00002	10%	0.000018	4.23E-04	0.0000676		1.0E-06	--	0.0563
Zone 5										
PFOS + PFHxS		0.00002	10%	0.000018	7.81E-04	0.000125		1.9E-06	--	0.104
Zone 6										
PFOS + PFHxS		0.00002	10%	0.000018	4.69E-04	0.000075		1.1E-06	--	0.0625

These calculations have assumed the PFOS+PFHxS concentration was present as 100% PFOS as the transfer factor for PFOS results in a higher concentration - i.e. a conservative approach.

Intake of Chemicals by Cattle - transfer to meat

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ (mg/kg/day)

$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$

	PFOS	PFHxS	PFOA	units
Water to fodder ratio =	3.5	3.5	3.5	mg/kg (plant) (w/w) / mg/L
Meat to intake ratio =	41	4	0.3	mg/kg (meat) / mg/kg bw-d

Cattle

Exposure Parameters	Average	Reference
Cattle water ingestion rate (L/day)	45	ANZECC
Cattle fodder ingestion rate (kg/day) dw	13	as per PFAS NEMP v3 draft
Cattle fodder ingestion rate (kg/day) ww	20	ANZECC/ARMCANZ 2000
Fraction of produce from site in diet (FI)	1	
Exposure Frequency (EF, days/year)	365	
Exposure Duration (ED, years)	2	Professional Advice
Body Weight (BW, kg)	500	Professional Advice
Bioaccessibility (B)	1	
Averaging Time - Threshold (Atn, days)	730	ED*365

Calculations for PFOS+PFHxS, PFOA	Concentration in water (mg/L)	Livestock intake (mg/kg/day)	PFAS in meat (mg/kg ww)
Stock watering			
Zone 1 - maximum			
PFOS+PFHxS	0.000444	4.0E-05	1.6E-03
Zone 1 - refined			
PFOS+PFHxS	0.000100	9.0E-06	3.7E-04
Zone 2			
PFOS+PFHxS	0.000184	1.7E-05	6.8E-04
Zone 3			
PFOS+PFHxS	0.0000676	6.1E-06	2.5E-04
Zone 5			
PFOS+PFHxS	0.000125	1.1E-05	4.6E-04
Zone 6			
PFOS+PFHxS	0.000075	6.8E-06	2.8E-04
Fodder watering			
Zone 1 - maximum			
PFOS+PFHxS	0.000444	6.2E-05	2.5E-03
Zone 1 - refined			
PFOS+PFHxS	0.000100	1.4E-05	5.7E-04
Zone 2			
PFOS+PFHxS	0.000184	2.6E-05	1.1E-03
Zone 3			
PFOS+PFHxS	0.0000676	9.5E-06	3.9E-04
Zone 5			
PFOS+PFHxS	0.000125	1.8E-05	7.2E-04
Zone 6			
PFOS+PFHxS	0.000075	1.1E-05	4.3E-04
Combination			
Zone 1 - maximum			
PFOS+PFHxS	0.000444		4.2E-03
Zone 1 - refined			
PFOS+PFHxS	0.000100		9.4E-04
Zone 2			
PFOS+PFHxS	0.000184		1.7E-03
Zone 3			
PFOS+PFHxS	0.0000676		6.4E-04
Zone 5			
PFOS+PFHxS	0.000125		1.2E-03
Zone 6			
PFOS+PFHxS	0.000075		7.1E-04

Exposure to Chemicals via Ingestion of Meat - Adults

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ (mg/kg/day)

$$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

Parameters Relevant to Quantification of Exposure to Adults		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.16	P90 consumer value for 2-6 yr old from FSANZ (2017)
Fraction Home-Grown Meat Consumed (FHG or FI)	35%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assumed home grown meat consumed every day of the year (at 35% of total intake from home slaughtered)
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM

Agricultural Application

Key Chemical	Toxicity Data				Concentration in Media (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor (mg/kg-day)$^{-1}$	Threshold TDI (mg/kg/day)	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background) (mg/kg/day)	(mg/L)	(mg/kg)	NonThreshold (mg/kg/day)	Threshold (mg/kg/day)	Non-Threshold Risk (unitless)	Chronic Hazard Quotient (unitless)
Stock irrigation only									--	--
Zone 1 - maximum										
PFOS+PFHxS		0.00002	10%	0.000018	0.000444	0.00164		1.3E-06		0.0728
Zone 1 - refined										--
PFOS+PFHxS		0.00002	10%	0.000018	0.000100	0.000369		3.0E-07		0.0164
Zone 2										
PFOS+PFHxS		0.00002	10%	0.000018	0.000184	0.000679		5.4E-07		0.0302
Zone 3										
PFOS+PFHxS		0.00002	10%	0.000018	0.000068	0.000249		2.0E-07		0.0111
Zone 5										
PFOS+PFHxS		0.00002	10%	0.000018	0.000125	0.000461		3.7E-07		0.0205
Zone 6										
PFOS+PFHxS		0.00002	10%	0.000018	0.000075	0.000277		2.2E-07		0.0123
Fodder irrigation only										--
Zone 1 - maximum										
PFOS+PFHxS		0.00002	10%	0.000018	0.000444	0.002549		2.0E-06		0.113
Zone 1 - refined										--
PFOS+PFHxS		0.00002	10%	0.000018	0.000100	0.000574		4.6E-07		0.0255
Zone 2										
PFOS+PFHxS		0.00002	10%	0.000018	0.000184	0.001056		8.4E-07		0.0469
Zone 3										
PFOS+PFHxS		0.00002	10%	0.000018	0.000068	0.000388		3.1E-07		0.0172
Zone 5										
PFOS+PFHxS		0.00002	10%	0.000018	0.000125	0.000718		5.7E-07		0.0319
Zone 6										
PFOS+PFHxS		0.00002	10%	0.000018	0.000075	0.000431		3.4E-07		0.0191
Combined fodder and stock watering										
Zone 1 - maximum										
PFOS+PFHxS		0.00002	10%	0.000018	0.000444	0.00419		3.3E-06		0.186
Zone 1 - refined										--
PFOS+PFHxS		0.00002	10%	0.000018	0.000100	0.000943		7.5E-07		0.0419
Zone 2										
PFOS+PFHxS		0.00002	10%	0.000018	0.000184	0.00174		1.4E-06		0.077
Zone 3										
PFOS+PFHxS		0.00002	10%	0.000018	0.000068	0.000637		5.1E-07		0.0283
Zone 5										
PFOS+PFHxS		0.00002	10%	0.000018	0.000125	0.00118		9.4E-07		0.052
Zone 6										
PFOS+PFHxS		0.00002	10%	0.000018	0.000075	0.000707		5.7E-07		0.0314

These calculations have assumed the PFOS+PFHxS concentration was present as 100% PFOS as the transfer factor for PFOS results in a higher concentration - i.e. a conservative approach.

Exposure to Chemicals via Ingestion of Meat - Children

$$Intake = \frac{C * IR * FI * B * EF * ED}{BW * AT}$$ **(mg/kg/day)**

$$C_{meat} = (DailyIntake)_{cow} \bullet (TransferFactor)$$

Parameters Relevant to Quantification of Exposure to Young Children		
Bioaccessibility (B)	100%	Assumed relevant
Ingestion Rate of Meat (IR_{meat}, kg/day)	0.085	P90 consumer value for 2-6 yr old from FSANZ (2017)
Fraction Home-Grown Meat Consumed (FHG or FI)	35%	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assumed home grown meat consumed every day of the year (at 35% of total intake from home slaughtered)
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM

Agricultural Application

Key Chemical	Toxicity Data				Concentration in Media (Cs)	Concentration in Meat	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)			NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/L)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Stock irrigation only									--	--
Zone 1 - maximum										
PFOS+PFHxS		0.00002	10%	0.000018	0.000444	0.00164		3.2E-06		0.181
Zone 1 - refined										--
PFOS+PFHxS		0.00002	10%	0.000018	0.000100	0.000369		7.3E-07		0.0407
Zone 2										
PFOS+PFHxS		0.00002	10%	0.000018	0.000184	0.000679		1.3E-06		0.0748
Zone 3										
PFOS+PFHxS		0.00002	10%	0.000018	0.000068	0.000249		4.9E-07		0.0275
Zone 5										
PFOS+PFHxS		0.00002	10%	0.000018	0.000125	0.000461		9.1E-07		0.0508
Zone 6										
PFOS+PFHxS		0.00002	10%	0.000018	0.000075	0.000277		5.5E-07		0.0305
Fodder irrigation only										--
Zone 1 - maximum										
PFOS+PFHxS		0.00002	10%	0.000018	0.000444	0.002549		5.1E-06		0.281
Zone 1 - refined										--
PFOS+PFHxS		0.00002	10%	0.000018	0.000100	0.000574		1.1E-06		0.0632
Zone 2										
PFOS+PFHxS		0.00002	10%	0.000018	0.000184	0.001056		2.1E-06		0.1164
Zone 3										
PFOS+PFHxS		0.00002	10%	0.000018	0.000068	0.000388		7.7E-07		0.0428
Zone 5										
PFOS+PFHxS		0.00002	10%	0.000018	0.000125	0.000718		1.4E-06		0.0791
Zone 6										
PFOS+PFHxS		0.00002	10%	0.000018	0.000075	0.000431		8.5E-07		0.0474
Combined fodder and stock watering										
Zone 1 - maximum										
PFOS+PFHxS		0.00002	10%	0.000018	0.000444	0.00419		8.3E-06		0.461
Zone 1 - refined										--
PFOS+PFHxS		0.00002	10%	0.000018	0.000100	0.000943		1.9E-06		0.1039
Zone 2										
PFOS+PFHxS		0.00002	10%	0.000018	0.000184	0.00174		3.4E-06		0.191
Zone 3										
PFOS+PFHxS		0.00002	10%	0.000018	0.000068	0.000637		1.3E-06		0.0702
Zone 5										
PFOS+PFHxS		0.00002	10%	0.000018	0.000125	0.00118		2.3E-06		0.130
Zone 6										
PFOS+PFHxS		0.00002	10%	0.000018	0.000075	0.000707		1.4E-06		0.0779

These calculations have assumed the PFOS+PFHxS concentration was present as 100% PFOS as the transfer factor for PFOS results in a higher concentration - i.e. a conservative approach.