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Detailed Site Investigation into Per- and Polyfluoroalkyl Substances (PFAS)

Norfolk Island Airport

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Document Information

Detailed Site Investigation into Per- and Polyfluoroalkyl Substances (PFAS), Norfolk Island Airport

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Executive Summary

Senversa was engaged by the Department of Infrastructure, Transport, Cities and Regional Development (DITCRD) now the Department for Infrastructure, Transport, Regional Development and Communications (DITRDC) to prepare a Detailed Environmental Investigation of per- and poly-fluoroalkyl substances (PFAS) site conditions at Norfolk Island Airport (the site) and surrounding catchments.

The investigation was initiated after a CSIRO led investigation identified elevated levels of PFAS in the Mission Creek surface water catchment in December 2019. A preliminary site investigation (PSI) with targeted sampling was then undertaken in January 2020 and resulted in the identification of PFAS sources areas and provision of alternative water supplies and PFAS management measures on Norfolk Island Airport, properties within the Mission Creek Catchment, the hospital and council works depot. The PSI results included in this assessment refer to conditions before PFAS management measures were implemented.

The key objectives of this detailed site investigation (DSI) were to confirm key PFAS source areas, pathways and receptors of PFAS contamination identified within the PSI.

The scope of the DSI included grid based surficial assessment of PFAS source areas; targeted deeper soils assessment; assessment of the waste water treatment plant; sequential paired sediment and surface water sampling along Mission and Watermill Creeks, further confirmatory sampling of on and off-site drinking water sources and assessment of produce in the Mission Creek Catchment. The DSI comprised laboratory analysis of 235 soil, 40 sediment, 26 surface water, 5 groundwater, 41 water and tap, 22 grass and 7 biota (produce) samples. These results refer to conditions after PFAS management measures were implemented.

Through completion of this scope of work, Senversa was able to achieve the objectives outlined in **Section 1.2** and draw the following conclusions:

PFAS Source Area Identification

- Six PFAS primary source areas (Group 1 Source Areas) were confirmed within the Airport, with Primary Sources 1 (Former Fire Station and Foam Shed) and 2 (Former Flushing Out Area) considered to represent the main sources of PFAS identified within Mission Creek surface water. All six sources were associated with the training, storage and / or maintenance of fire trucks that historically used Legacy AFFF.
- Concentrations of PFOS+PFHxS were highest in soils within Source Area 4 (Current Drill Ground) which is expected as this was where Legacy AFFF was used most recently. However, there was limited evidence of surface water impacted down-gradient of Source Zone 4 within Mission Creek.
- Assessment of sub-surface conditions within PFAS source areas found higher concentrations of PFAS were generally present at depth (between 0.5 and 1.5+ m) when surficial soil concentrations exceed 0.05 mg/kg, indicative of vertical washing into the soil profile and/or surface removal by rainfall flushing.
- PFAS was identified in wastewater at the WWTP, with a PFOS+PFHxS concentration of 0.24 µg/L. The source of the PFAS in WWTP wastewater has not been confirmed, however it is likely to be a combination of different domestic sources and potentially a portion of inflow from identified airport source zones. The presence of PFAS within wastewater should be taken into account as a part of planned upgrades to the WWTP.

Impact to Utilised Water

- All privately owned drinking water sources that were sampled by Senversa reported PFAS (PFOS+PFHxS) concentrations below the adopted health based guidance value (HBGV).
- Concentrations of PFAS in internal water taps at three public facilities (hospital, works depot and fire station) that were previously found to be:
  - Above the adopted HBGV in January 2020 (before PFAS management measures were implemented)
  - Below adopted HBGV in March 2021 (after PFAS management measures were implemented).
- Concentrations of PFAS exceeded the HBGV in one sample collected in 2021 (after PFAS management measures were implemented) from a kitchen tap at airport mechanical/maintenance building in the former fire station (A_TAP4: PFOS+PFHxS: 0.11 µg/L). Reticulated water in this facility was known to have be historically connected to the Airport Bore. The supply of alternate drinking water and signage is considered to mitigate this risk.
- Historically extracted "Airport Bore" water is still present in tanks servicing public toilets within two locations on the island, however the potential for exposure during hand washing is considered relatively low given the frequency and duration of exposure, the limited potential for PFAS adsorption through the skin and the non-volatile nature of PFAS.
- Extracted bore and surface water used for stock watering with the Mission Creek Catchment in March 2021 were lower than January 2021 but still elevated, with concentrations of PFOS+PFHxS ranging up to approximately 2 µg/L.

PFAS in Surface Water Catchments

- Concentrations of PFAS in surface water and groundwater generally decreased by between a half and one third between January 2020 and March 2021. This reduction in concentration is considered likely to have been primarily through 'flushing', driven by the increase in rainfall post January 2020 (i.e. dilution driven) and therefore PFAS concentrations may rebound in future periods of lower rainfall. However, cessation in the use of the Airport Bore, supply of PFAS free alternative water supplies and further time since legacy PFAS containing AFFF was last used and may also have contributed to this reduction.

<u>Mission Creek Surface Water Catchment (</u>after PFAS management measures were implemented)

- Surface water in Mission Creek was found to have the highest concentrations in the World War II Dam (PFOS+PFHxS: 34.6 µg/L) located in the upper southern portion of the catchment close to source zones PS01 and PS02 at the Airport.
- PFAS concentrations consistently decreased with distance at the eight sample locations downstream of the World War II Dam, with the lowest reported concentration of PFOS+PFHxS (1.26 µg/L) reported up-stream of the Mission Pool at MC_SW04.
- Sediment samples from the Mission Creek catchment reported the highest PFAS concentrations adjacent to identified on and off-site PFAS Source Zones. An increase in PFAS concentrations south of the Mission Pool may be associated with higher rates of evaporation in this area.

<u>Watermill / Town Creek Water Catchment (</u>after PFAS management measures were implemented)

- All water samples obtained from within the KAVHA World Heritage Area were found to be below the drinking / stock watering water HBGV.
- PFAS concentrations were below detection limits at the point of discharge into Emily Bay.
- Within the Watermill / Town Creek catchment, the highest PFAS concentration in surface water (PFOS+PFHxS: 1.14 µg/L) was identified downstream of the Airport Maintenance Sheds (PFAS Source Zone 5) at TC_SW06.
- PFAS concentrations consistently decreased at each downstream location away from the airport, however they generally exceeded drinking / stock watering water HBGV until after the "Watermill / Duck Dam".

Other Surface Water Catchments (after PFAS management measures were implemented)

- Concentrations in surface water were below the drinking / stock watering water HBGV in all other catchments with the exception of one marginal exceedance (PFOS+PFHxS: 0.08 µg/L) at ID012_SW03 downstream of the Council works depot in Cascade Creek.

PFAS in Groundwater

- As per the PSI targeted assessment undertaken in January 2020, the highest reported PFAS concentration in groundwater in 2021 (after PFAS management measures were implemented) was in the 'Airport Bore', located near the top of the upper south branch of Mission Creek.
- Similar to the reduction seen in surface water at the World War II Dam, concentrations of PFAS in groundwater collected from the Airport Bore in March 2021 (PFOS+PFHxS: 24.9 µg/L) reduced by between one half to a third from the concentration measured January 2020.
- DITRDC propose to install a point of entry (commonly known as POET) filtration system on the Airport bore to ensure this valuable resource can continue to provide water to the community for non-potable sources.

PFAS in Produce (after PFAS management measures were implemented)

- No PFAS was detected in fruit and vegetables assessed and PFAS reported in egg was below adopted criteria for the human consumption of eggs.
- Marginal (at detection limit) concentrations of PFAS were detected in grass on the airport that is commonly cut and fed to cattle.

Confirmation of Risk

The works undertaken as part of the DSI and PSI have allowed a good understanding of the ways in which people and wildlife on-island might be exposed to PFAS. Based on this information, it has been possible to determine that risks are now low and acceptable for many of the ways in which people might be exposed to PFAS in the environment. This includes drinking water; drinking water is often (on other sites) the most significant PFAS exposure pathway, but on Norfolk Island, concentrations of PFAS in the water people currently drink is below the HBGV, and the risks are therefore assessed to be low.

While it has been possible to rule out potential risks for many of the pathways by which people might be exposed, there are a small number of pathways for which further assessment is required to better assess potential risks. Completion of a human health and ecological risk assessment (HHERA) is recommended to further assess the risks and confirm potentially complete source-pathway-receptor linkages.

Furthermore, to address the identified risks in complete pathways, a PFAS Management Plan (PMP) plan should be prepared and approved, which details all physical and administrative preventative measures required to reduce or eliminate exposure to PFAS. The PFAS Management Plan will detail the ongoing management which is required for each identified source area, and for identified potential exposure pathways (both those pathways which are currently managed, and those for which additional management is identified to be required within the HHERA).

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List of Acronyms

Acronym	Definition
AFFF	Aqueous Film Forming Foam
ALS	Australian Laboratory Services
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASC	Assessment of Site Contamination
ASLP	Australian Standard Leaching Procedure
BoM	Bureau of Meteorology
COC	Chain of Custody
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSM	Conceptual site model
DEH	Department of Health
DITCRC	The Department for Infrastructure, Transport, Regional Development and Communications
DQO	Data Quality Objectives
DSI	Detailed Site Investigation
EPA	Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation
ESLs	Ecological Screening Levels
FSANZ	Food Standards Australia New Zealand
HBGV	Health-based Guidance Value
HEPA	Heads of Environment Protection Authority
HHERA	Human Health and Ecological Risk Assessment
HIL	Health Investigation Level

Acronym	Definition
HSLs	Health-based Screening Level
KAVHA	Kingston and Arthurs Vale Historic Area
LOR	Limit of Reporting
NATA	National Association of Testing Authorities
NEMP	National Environmental Management Plan
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
PCR	Primary Contact Recreation
PFAS	Per- and poly-fluoroalkyl substances
PFBS	Perfluorobutanesulfonic acid
PFCA	Perfluorinated carboxylic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonate
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFPeA	Perfluoropentanoic acid
PFPeS	Perfluoropentane sulfonate
PFSA	Perfluorosulfonic acid
PSI	Preliminary Site Investigation
SPR	Source-Pathway-Receptor
TDS	Total Dissolved Solids
WWTP	Wastewater treatment plant

1.0 Introduction

Senversa was engaged by the Department of Infrastructure, Transport, Cities and Regional Development (DITCRD) now the Department for Infrastructure, Transport, Regional Development and Communications (DITRDC) to prepare a Detailed Environmental Investigation of per- and poly-fluoroalkyl substances (PFAS) site conditions at Norfolk Island Airport (the site) and surrounding catchments. The PFAS detailed environmental investigation process consists of three main steps:

A. Preliminary Site Investigation (Senversa, 2020a).

B. Detailed Site Investigation (this report).

C. Human Health & Ecological Risk Assessment (if deemed necessary).

This Detailed Site Investigation (DSI) has been completed to report on the identification of PFAS sources, contaminant transport pathways and receptors and to present the findings of the initial, targeted investigation into the nature and extent of PFAS at the Norfolk Island Airport and surrounding catchments.

The investigation was initiated after a CSIRO-led assessment of water resources identified elevated levels of PFAS in the Mission Creek water catchment in December 2019.

The location of the airport and the Mission Creek water catchment with reference to the wider Norfolk Island is shown on **Figure 1** below with further detailed on **Figure A1** (in **Appendix A**).

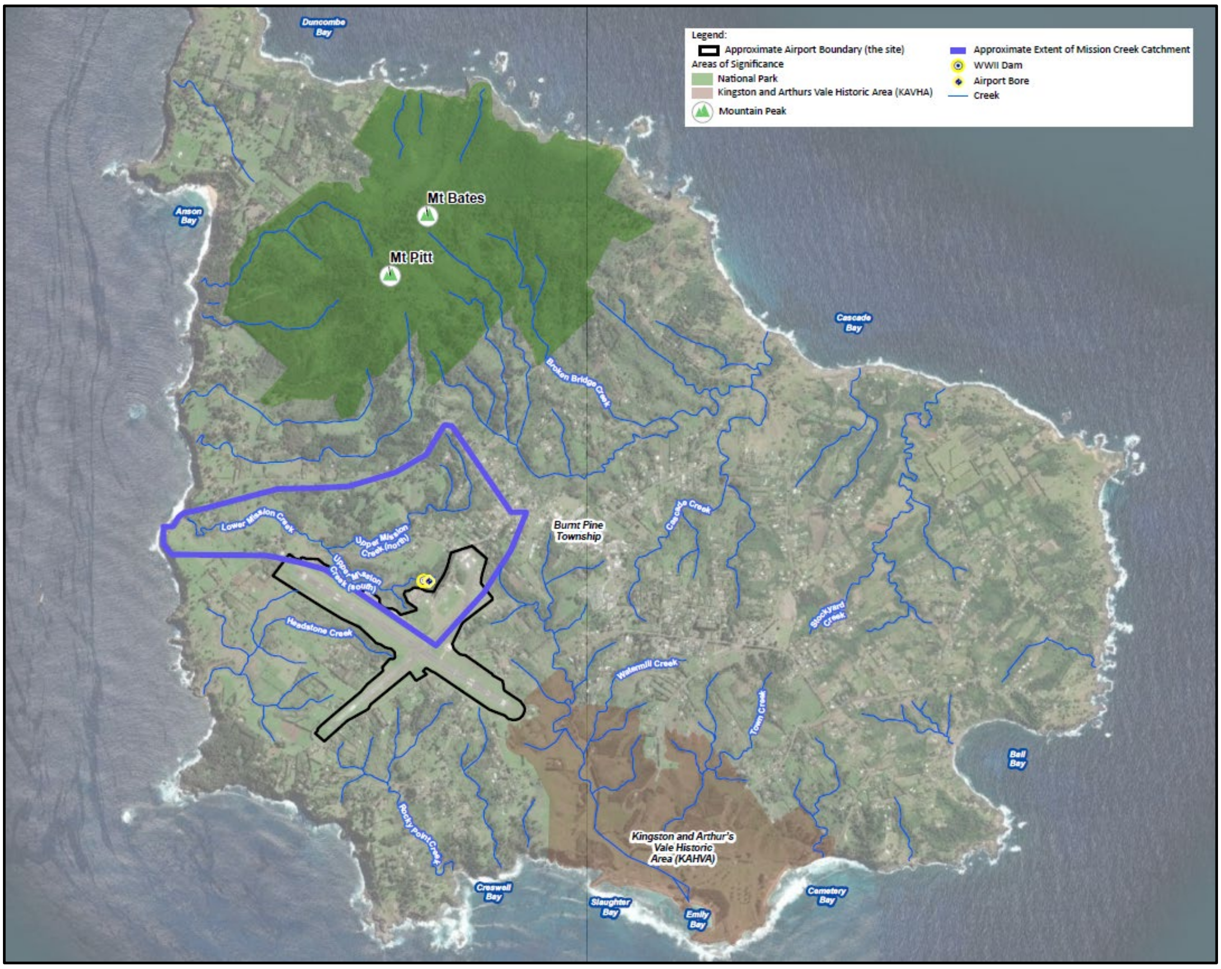

Figure 1: Site Location and Key Norfolk Island Features

1.1 Background

Norfolk Island experienced drought conditions between 2016 and early 2020, with anecdotal reports of groundwater levels dropping across the island as a result of increased reliance on groundwater for drinking and other water uses. Water carting from groundwater bores that remained operational was being undertaken across the island both prior to January 2020. In February 2020 a temporary desalination plant was commissioned by the Australian Government and Army on Norfolk Island.

In December 2019, as a part of a water resource assessment being undertaken CSIRO, three samples from Mission Creek were analysed for PFAS. The results identified PFAS as being present within the headwaters of the Mission Creek catchment directly below the aviation fire services drill ground, adjacent the Airport.

Upon review of the findings of the CSIRO results, DITRDC initiated the PFAS environmental investigation at Norfolk Island with the strategic aim to manage potential risks to human health, or the ecological environment posed by the legacy PFAS contamination from the Norfolk Island Airport and surrounding catchment.

In January 2020 Senversa commenced the Preliminary Site Investigation (PSI) (see **Section 2.4.2** for summary). The PSI found that legacy aqueous film-forming foam (AFFF) containing PFAS as active ingredients was used on Norfolk Island from the early 1980s until 2015 to supress liquid fuel fires and for fire training activities.

Six main “Group 1 Source Areas” (repeated application of legacy AFFF PFAS containing foams and concentrate) were identified within the PSI are shown in **Figure 2** below with further information provided **Figure A2** and with **Table B1**.

The waste water treatment plant (WWTP – PS11) also located on the airport and shown on **Figure 2** below, was considered a Group 2 Source Area (less frequent legacy AFFF application than Group 1).

Figure 2: Group 1 PFAS Source Areas at Norfolk Island Airport

1.2 Objectives

This DSI constitutes the second stage of an assessment of potential risk to human health and the environment associated with the presence of PFAS in the environment at the airport and in surrounding areas.

The objectives of this DSI are to:

- Address data gaps identified within the PSI.
- Collect environmental data require to support completion of a future human health and ecological risk assessment.
- Confirm key sources, pathways and receptors of PFAS contamination identified within the PSI and recommend practical management options to limit further contamination of drinking water sources.
- Ensure all investigation works are undertaken in compliance with the PFAS National Environmental Management Plan (NEMP) 2.0 and The National Environment Protection (Assessment of Site Contamination) Measure 1999 (the ASC NEPM).
- Undertake systematic assessment of the airport property to confirm the extent of on-site source areas identified within the PSI.
- Ensure all known water carter supply sources across the island have been considered.
- Assess potentially impacted off-site land and water uses that may be associated with food production related to the human food chain.
- Ensure that all site-specific information is captured and retained for use by DITRDC, CSIRO and other stakeholders.
- Provide support to DITRDC-led Stakeholder and Community Engagement Activities and ensure stakeholders are proactively and appropriately informed.
- Provide prompt advice / information on the receipt of analytical results to support decision making on Norfolk Island water security projects, public facilities (including fire station / hospital) and the use of the Airport Bore.
- Provide recommendations on the need for the for further site specific human health and / or ecological risk assessment.

1.3 Scope of Works

To achieve the above objectives, Senversa completed the following scope of work:

- Grid based sampling of surface soils across the six on-site source areas to depths up to 0.1 m bgl to further horizontally delineate known impacted areas.
- Targeted assessment of soils (total and leachable concentrations) at hotspots identified during the targeted PSI sampling works to depths up to 1.5 m bgl to assess the vertically extent of known impacts and enable estimation of volumes of soils that may require management / remediation.
- Assessment of soil, water and sediment conditions at the WTTP.
- Sampling of surface water and sediment in drainage channels exiting off-site into Mission Creek.
- Further drinking water sampling of all tanks and taps on-site (airport terminal, council office, fire station, new poly tanks at airport terminal and fire station, bureau meteorology office) and hospital (offsite).
- Further off-site drinking water supply sampling and investigation into current and historic use of Airport Bore water.
- Sampling of soil, grass and biota in Mission Creek Catchment in areas where contaminated groundwater and surface water are currently, or have historically been used to water market gardens, poultry and cattle.
- Grid-based sampling of soil and biota (grass) across the airport where grass is mown (and fed to cows).

- Sampling of surface water (where present) and sediment at 200 m intervals along Mission Creek.
- Sampling surface water and sediment both up and down gradient in Cascade Creek, Watermill Creek and Headstone Creek.
- Sampling of saline sediments at the mouths of creeks known to be impacted by PFAS.
- Preparation of this DSI report on the nature and extent of PFAS, conclusions on risks to sensitive receptors and recommendations for the completion of a human health risk assessment.

2.0 Site Identification and Management

This section defines the parcel of land identified as the Norfolk Island Airport and describes the land use characteristics of on- and off-site areas being assessed in this PSI.

2.1 Site Details

Site identifying details are summarised below.

Table 2-1: Site Planning Information

Item	Relevant Site Information
Site Location and Size	The Norfolk Island Airport site is approximately 120 ha in size and is in the southwestern portion of Norfolk Island. Norfolk Island is situated in the Pacific Ocean, approximately 1,676 km north east of Sydney, NSW. See **Figure A1** for an overview of the site location and **Figure A2** for layout.
Site Use	The site is the Norfolk Island Airport which comprises two runways and associated terminal buildings, maintenance and cargo sheds and carparks. The first runway of the airport was constructed on 25 December 1942 with the assistance of the United States Air Force to assist with war efforts.
Site Zoning	The site is zoned for light industry use with surrounding land zoned for rural and rural residential land use.

2.2 Site Features

Current site features, infrastructure, operations and facilities noted during this assessment and observed during site works are summarised below. Refer to **Appendix C** for site photographs.

Table 2-2: Site Layout and Features

Item	Observations
Current Use	The site is primarily used for aviation purposes with approximately six commercial flights arriving per week and a freight plane arrives/departs weekly. Medivac planes arrive/depart the airport for medical transport services (when required).
Current Site Features	Key site features include: • Operational airport with two runways. • Aircraft and airport operational infrastructure in the northeast portion of the site, including terminals, storage and cargo facilities. • Maintenance facilities in the mid-eastern portion of the site. • Fire station in the mid-eastern portion of the site, south of the maintenance facilities. • Waste Management facility and Bureau of Meteorology (BOM) facility in the northern portion of the site. • WWTP in the central northern portion of the site. • The fire training facility. Boral were temporarily using the space for airport runway upgrade works in early 2020 limiting access during the PSI.

Item	Observations
Surface Water Features and Drainage	No surface water features have been observed onsite, aside from drainage lines and culverts. Refer **Section 3.5** for more information on surface water features and drainage onsite.
Visual Evidence of PFAS Impacts	During the inspection and site works, there was no visual evidence of PFAS-containing impacts such as staining or foaming around areas where PFAS was known to have been used or stored.
Chemical Storage Areas	The site historically used for AFFF concentrate storage was largely unsealed with no bunding or overflow catchment or treatment system evident. The fire station currently has Ansulite AFFF remaining on-site in un-bunded intermediary bulk containers (IBCs) on a mezzanine level. Identified storage areas considered to represent potential PFAS sources zones are discussed in **Table B1**.
Water Supply	On-site water is understood to be a combination of rainwater capture and/or groundwater bore water stored in several large tanks across the site. The groundwater bore that CSIRO identified as being impacted by PFAS, known as the "Airport Bore", has historically been the source of site water (for airport infrastructure and the council office and fire station), which is pumped into a large concrete holding tank.

2.3 Surrounding Land Uses

2.3.1 Adjacent to Norfolk Island Airport

The site is in a rural area west of Burnt Pine township, with land surrounding the site zoned as either 'Rural' or 'Rural Residential' (refer to **Appendix D**). The surrounding land use is predominantly residential and agricultural.

Table 2-3: Surrounding Land Uses

Direction	Land Uses
North	Mission Creek is located to the immediate north-west of the site followed by St Barnabas Chapel, rural properties and Headstone Reserve. The Norfolk Island National Park is located approximately 2 km to the north of the site.
East	Northeast of the site is the township of Burnt Pine, consisting of mixed land use. The land to the immediate east consists of rural and rural residential land.
South	Rural residential properties, Point Ross and Bombara Reserves followed by the South Pacific Ocean approximately 400 m from the most southern point of the site.
West	Rural residential properties, Rocky Point and 100 Acres Reserve followed by the South Pacific Ocean approximately 400 m from the most western point of the site.

2.3.2 Parks and Reserves

The wider island has a number of national parks and reserves providing a refuge for endangered and endemic flora and fauna (see **Section 3.8**) as well as providing recreation for the island community. **Figure 3** below shows the extent of national parks and reserves as documented in the 2018 - 2023 *Norf'k Ailen Riigenl Kaunsl Enwairanment Straeteji* (Norfolk Island Environment Strategy).

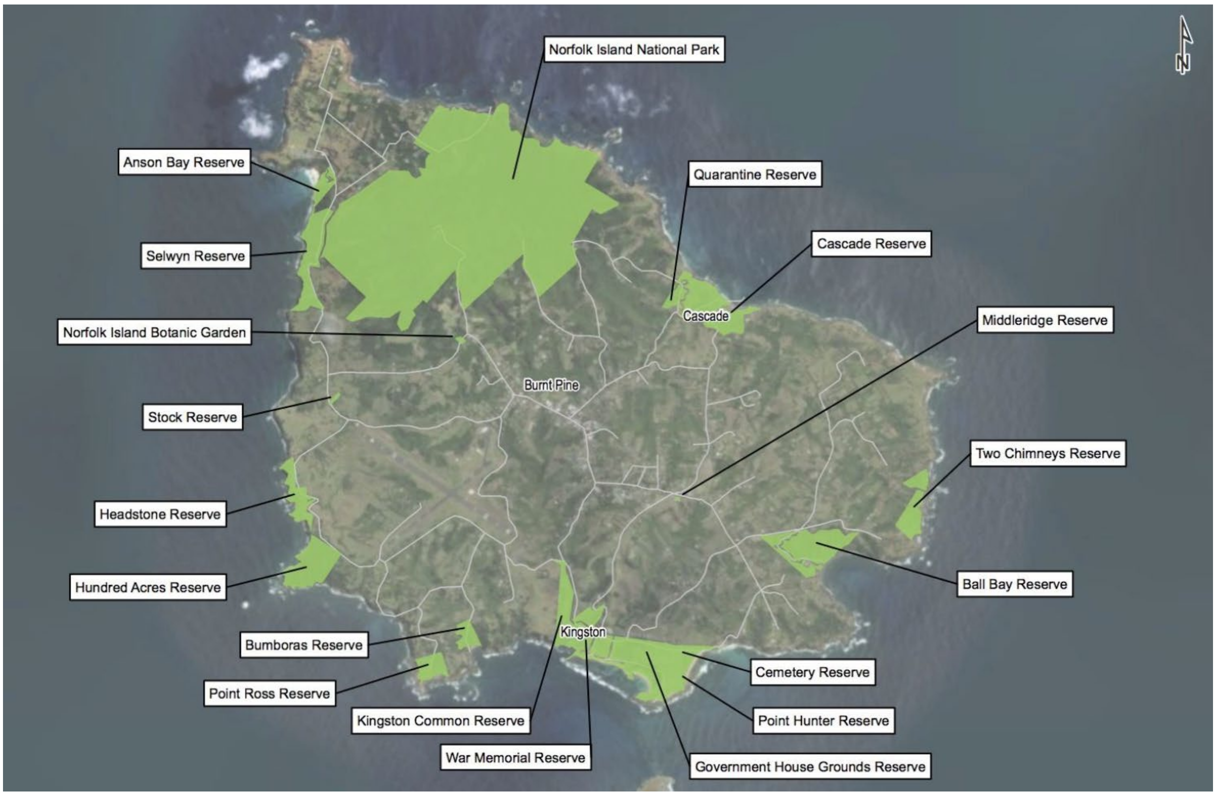

Figure 3: Norfolk Island National Parks and Reserves (from NIRC, 2018)

Wider Norfolk Island also contains the World Heritage Properties listed Australian Convict Sites known as the Kingston and Arthurs Vale Historic Area or KAVHA (see **Figure 1**) and the National Heritage Properties listed HMS Sirius Shipwreck located east of Kingston Pier in Slaughter Bay.

2.4 Previous PFAS Investigations

The only PFAS specific investigation previously undertaken at the island consists of the PFAS Preliminary Site Investigation (PSI) undertaken by Senversa in 2020. However, PFAS was initially identified on the island through an ongoing CSIRO study into water security on Norfolk Island.

There has also been a recent investigation by the NSW Public Works Advisory, into options for the WWTP (see **Figure A6G** in **Appendix A**), which didn't assess PFAS, but provides further context for future water use on the island and is discussed further in **Section 8.1.2**.

2.4.1 CSIRO Investigation

In December 2019, as a part of a wider water resource assessment, CSIRO sampled three sources of water both on and in close proximity to the Norfolk Island Airport. The sampling indicated the presence of PFAS in three samples within the headwaters of the Mission Creek catchment directly below the aviation fire services drill ground, adjacent to the Airport.

In response to the identified PFAS concentrations DITCRD engaged CSIRO to complete sampling of private property water supplies within the Mission Creek Catchment area. The results of this sampling were provided to Senversa as part of their PSI works. CSIRO did not complete any further PFAS investigation.

2.4.2 Senversa PFAS Preliminary Site Investigation

The objectives of this Preliminary Site Investigation (PSI) included investigation of potential PFAS source areas; identification of PFAS migration pathways and sensitive receptors; and the targeted assessment of drinking water sources across the island.

The scope of work included a two week on-island investigation undertaken in January 2020 to meet with the community and identify potential PFAS source areas; assess sensitive human and ecological receptors; and confirm key drinking water sources that should be assessed for PFAS impact. The targeted sampling undertaken included the collection of 172 samples consisting of 25 groundwater samples, 17 surface water samples, 41 sediment samples and 89 soil samples both on the airport and across the wider island.

Through the completion of the PSI and targeted groundwater, surface water, soil and sediment assessment works, Senversa was able to draw the following key conclusions:

- All privately owned drinking water sources that were sampled by Senversa were found to have concentrations below the adopted health-based guidance value (HBGV) for PFAS (PFOS+PFHxS).
- Concentrations of PFAS above the adopted HBGV was identified in three public facilities (hospital, works depot and fire station) at internal water taps and groundwater tanks. Upon confirmation of the analytical results, alternative drinking water supplies were implemented at these locations and other potentially impacted public facilities (including the airport, which is understood to have previously used the same water source as the facilities mentioned above).
- The elevated PFAS concentrations at all three public facilities was linked to supply of water from the same "Airport Bore" within the Mission Creek catchment that was identified by CSIRO in December 2019 as having elevated concentrations of PFAS.
- PFAS was identified in three water sources used for the watering of stock, chicken eggs and vegetables within the Mission Creek catchment.
- Concentrations of PFAS above the HBGV in groundwater was restricted to the Mission Creek surface water catchment.
- Elevated concentrations of PFAS above the HBGV was identified within the surface waters of Mission Creek and Watermill Creek. Concentrations above laboratory detection limits but below the HBGV was identified in Headstone Creek, with the one surface water sample obtained from Broken Bridge Creek below detection limits.

2.5 Interim Advice and Management of Identified PFAS Impacts

Following the identification of PFAS in groundwater in late 2019, DITRDC have provided the following advice and undertaken the following management actions to reduce risks to sensitive receptors as information became available on the nature and extent of PFAS on Norfolk Island:

- Six fact sheets and five media releases have been issued by DITRDC since PFAS was identified within the CSIRO study in 2019.
- Alternative drinking water sources were provided to properties within the Mission Creek catchment while further assessment was undertaken.
- Three public facilities were found to have concentrations of PFAS above adopted health guidelines in their water supply. These facilities now have alternative drinking water supplies.
- The department provided advice not to drink water from the Mission Creek Catchment within the Departmental Factsheet 3 available on the departmental Norfolk Island PFAS webpage.
- Following identification of the hospital filtration system being a source of PFAS in hospital tap water (due to historical use of airport bore water to supply the hospital), parts of the filtration system were replaced.
- Fire station was put on alternative water supply and new water tanks have been (and additional tanks are being) constructed.

All available fact sheets, media releases and available reports relating to PFAS on Norfolk Island are provided (in written and audio versions) for public access at the following DITRDC administered webpage: http://www.infrastructure.gov.au/territories-regions-cities/territories/norfolk-island/pfas.

Further information on the interim management actions already undertaken, together with future management actions proposed to be undertaken in conjunction with a PFAS Management Plan is provided within **Section 9.5**.

2.6 Confirmed and Potential PFAS Source Areas

A total of 17 different types of confirmed and potential PFAS source areas were identified across the wider Norfolk Island within the PSI. The location of these source areas is provided in **Figure 4** below, with further information provided in **Table 2-1** and **Figure A3**.

Figure 4: Confirmed and Potential PFAS Source Areas

The identified sources included six potential PFAS primary source areas (Group 1 Source Areas) within the Airport. These are assessed as the most significant potential sources which may have contributed to the elevated PFAS concentrations identified within the Mission Creek catchment. All six sources were associated with the training, storage and maintenance of fire trucks that historically used PFAS containing aqueous film-forming foam (AFFF). These Group 1 Source Areas were confirmed with the DSI sampling works.

<u>Group 1 Source Areas</u>: Confirmed PFAS source areas where repeated application of legacy AFFF PFAS containing foams and concentrate occurred.

- Confirmed Source Area 01: The former fire station and foam shed.
- Confirmed Source Area 02: Flushing out area in the northeast corner of the site.
- Confirmed Source Area 03: The former drill ground south west of the former fire station in the northeast portion of the site. This area is now utilised as the waste management facility, which includes a composting facility.
- Confirmed Source Area 04: Current fire drill area along the northern site boundary. This area is currently utilised by Boral and was unable to be accessed during the targeted investigation.
- Confirmed Source Area 05: The maintenance depot where general maintenance of fire trucks historically occurred.
- Confirmed Source Area 06: The current fire station.

A further 11 lower significant potential PFAS source areas (Groups 2 – 4 Source Areas) were identified on and outside the airport within the Mission Creek and other catchments. These source areas are summarised below.

Group 2 Source Areas – Confirmed or potential PFAS source areas where legacy AFFF concentrate and / or foam was used or stored more than once, but with less frequent rates of application than Group 1:

- Potential Source Area 07: The Common Oval.
- Potential Source Area 08: St Barnabus Chapel Paddock.
- Confirmed Source Area 09: Council Works Depot / Former fire truck storage.
- Potential Source Area 10: Ball Bay Refuelling Area.
- Confirmed Source Area 11: Wastewater Treatment Plant / Stormwater Drains.

Group 3 Source Areas – Areas where a single application of foams occurred due to an incident or a one-off event:

- Potential Source Area 12: Private residence - Webb Adams Road.
- Potential Source Area 13: Paradise hotel previous Norfolk/colonial other.
- Potential Source Area 14: Perfumery.
- Potential Source Area 15: Headstone Burning area.

Group 4 Source Areas – Areas where no AFFF is known to have been used, however water containing elevated concentrations of PFAS used:

- Potential Source Area 16: Public toilets filled with water from Airport Bore.
- Potential Source Area 17: Hospital tank historically directly filled with water from Airport Bore.

During the week starting 13 September 2021, (after completion of the on-island investigation) a fire on Norfolk Island occurred at two residential properties located on the north side of Selwyn Rd, approximately 200 m south of the intersection with Poverty Rd. The fire was extinguished using with approximately 85,000 litres of water with the legacy PFAS Ansulite 6% also used.

This additional area is also considered a Group 3 Source Area. Future management measures (if any) for this source area and the other source areas identified above will be documented in a future PFAS Management Plan.

2.7 Water Sources and Use

Table 2-4 below documents the known historical and current water sources and uses associated with Airport Bore and where PFAS-impacted water is known to have been utilised.

Table 2-4: Historical and Current Water Sources

Area / Sample Location	Historical Water Source	Current Water Source	Description
AIRPORT (ONSITE)			
Airport Bore Tank	Airport Bore	Airport Bore	AIRPORT BORE sampled from tank adjacent Council offices. Use as holding tank before water is pumped to fire station and treated before use.
A-TANK 1	Airport Bore	Rainwater	Open water pit within building now filled via rainwater.
Airport Terminal Bathrooms (A_TAP1, A_TAP2)	Airport Bore	Airport Bore and A_TANK1	Historically sourced from Airport Bore, now sourced from new airport rainwater tanks.
Maintenance Shed at Airport (A_TAP3)	Airport Bore	Rainwater	Water now sourced from new rainwater tanks.

Area / Sample Location	Historical Water Source	Current Water Source	Description
Former Fire Station - Mech shed adj. airport terminal and Gate 1 (A_TAP4)	Airport Bore	Airport Bore	Airport bore water still connected, however non-use warnings in place. Connection to new airport rainwater tanks planned to be undertaken.
Bureau of Meteorology Office (A_TAP5)	Airport Bore	Airport Bore	Airport bore water still connected, however non-use warnings in place. Connection to new airport rainwater tanks planned to be undertaken.
Airport tanks A_TANK 2 and A_TANK 3 (new tanks since 2020 PSI sampling)	Rainwater	Rainwater	Tanks are in the process of being connected to buildings within the airport precinct.
Current Fire Station taps (kitchen, toilets) (FRE_TAP1, TAP3, TAP5)	Airport Bore	Rainwater	Appears supply from airport bore has been shut off
Fire Hydrants on Airport (FRE_TAP2)	Airport Bore	Airport Bore	Airport bore water still connected, POET proposed to be connected and treating water by Q4 2021.
Council Offices at Airport (COUNCIL_TAP1, TAP2)	Airport Bore	Rainwater	Historically sourced from Airport Bore, now sourced from new airport rainwater tanks.
HOSPITAL (OFFSITE)			
Hospital Tank - concrete underground (PWS_HOSP_TANK1)	Airport Bore	Rainwater	Historically sourced from airport bore via underground line and filling of tanks. All tanks are connected to hospital master tank and filled with rainwater collected from hospital roof.
Hospital Tank - all other tanks (PWS_TANK2-TANK8)	Rainwater	Rainwater	All tanks are connected (feed in) to master tank PWS_HOSP_TANK1
Taps (PWS_HOSP_TAP1-TAP21)	Airport Bore	Rainwater	Through PWS_HOSP_TANK1
WIDER NORFOLK ISLAND INVESTIGATION AREAS			
Council Works Depot (DEPOT_TANK1 and TANK2)	Airport Bore	Airport Bore / Rainwater	Tank1 (rainwater), Tank2 Airport Bore Water. New tank installed at rear of depot for rainwater
Council Works Depot taps (DEPOT_TAP1)	Airport Bore	Rainwater	Historically sourced from Airport Bore, now sourced from new depot rainwater tanks.
Chapel	Rainwater	Rainwater	Local rainwater source.
PWS_HEAD_TOILETS	Airport Bore	Airport Bore	Historically filled via water carter from airport bore. Now filled via water carter from other water sources.
PWS_CAS_TOILETS	Airport Bore	Airport Bore	Historically filled via water carter from airport bore. Now filled via water carter from other water sources.
PWS_EB_TOILETS	Airport Bore	Rainwater	Historically filled via water carter from airport bore. Now filled via water carter from other water sources.
General Use by Residents	Airport Bore	Rainwater, private bore water, Airport Bore, Duck Dam, Headstone Dam, Rainwater	Airport Bore water was publicly accessible until 2020 but is now locked and proposed only to be used at the fire station where it will be treated by POETs in Q4 2021.

3.0 Environmental Setting

Information from several sources, including a site inspection and public reports on regional information were reviewed to establish the environmental setting of the site.

Knowledge of the site's environmental setting is critical to understanding potential PFAS migration pathways and the sensitivity of the receiving environment (i.e. human and ecological receptors).

3.1 Regional Setting

3.1.1 Landscape Setting

The site is located on Norfolk Island, in the South Pacific Ocean north east of Sydney, NSW, and covers an area of approximately 35 square kilometres. Norfolk Island is volcanic in origin with an average elevation of 110 m above sea level rising steeply to 319 m above sea level at the peak of Mount Bates in the north western portion of the island. The island undulates rapidly with several water catchment zones creating steep valleys and low-lying creeks.

Prior to European settlement in 1788, the vegetation on Norfolk Island was a dense subtropical forest of palms, ferns and pines. The island was first settled by East Polynesian seafarers whose artefacts have been dated to ~800 to 1400 AD; however, when Captain Cook first sighted the island in 1774 it was uninhabited. Following two attempts by the British Government to use the island as a penal settlement (1805 to 1814 and 1824 to 1847) the island was settled in 1856, with the permission of the British Government, by Pitcairn Islanders whose islands had become too small for their growing population.

Approximately 80% of the original vegetation has been cleared, and the invasion of remnants by weed species has been extensive. Much of the Norfolk Island landscape has been transformed from a densely vegetated sub-tropical island to a highly modified pastoral landscape characterised by grazed kikuyu pastures bordered by remnant woodland (DEH 2000). The steeply sloped land around Mount Pitt and Mount Bates (now incorporated into the National Park) is the main remaining stand of dense subtropical forest. However, remanent stretches of subtropical forest remain in the steep creek gully's that radiate away from Mount Pit.

3.1.2 Climate

Norfolk Island is classified as a sub-tropical climate which is primarily affected by high-pressure systems which fluctuate over the island annually. The mean maximum temperatures on the island range from 19°C in winter to 25°C in summer with a high average relative humidity of 74% to 79% (BoM, 2021a).

Norfolk Island's median annual rainfall is 1,302 mm with the highest rainfall between May to August, with monthly means of approximately 130 to 147 mm. The driest month is typically November with an average rainfall of 75 mm (BoM, 2021a). Rainfall on the island between 2016 and early 2020 was below average and little to no rain fell on the island between October 2019 and January 2020 (ABC, 2020). However above average rainfall was recorded for the remainder of 2020.

As shown on **Figure 5** below, the mean annual rainfall recorded on Norfolk Island has decreased by 11% over the last 50 years as compared to the period 1915 to 1969 (CSIRO, 2020).

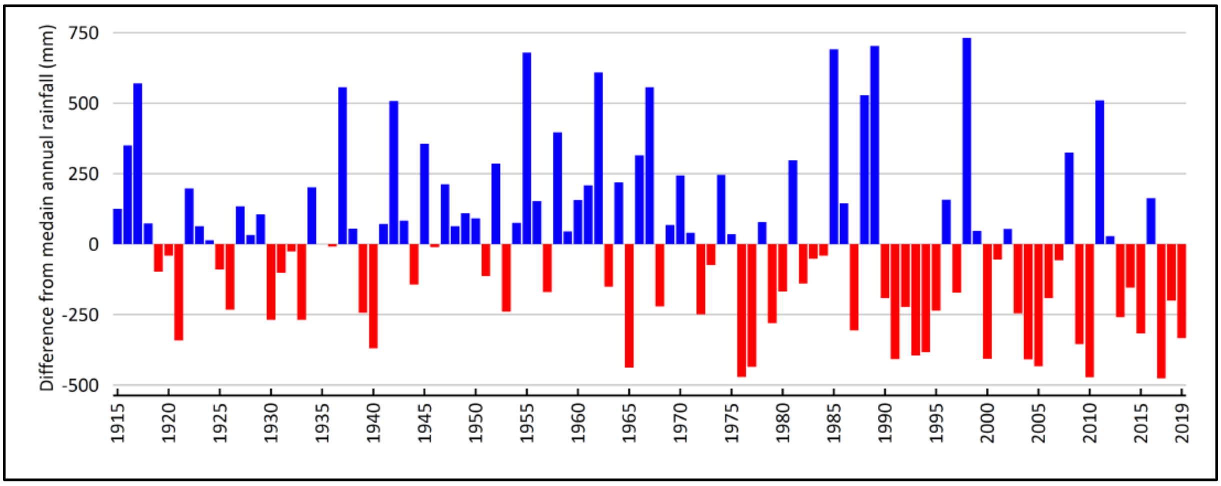

Figure 5: Annual Anomalies in rainfall from the median annual rainfall (CSIRO, 2020)

Winds are predominantly from the east and southeast during summer and autumn, becoming south to south westerly in the winter months. Tropical cyclones occasionally influence the island in the early months of the year (BoM, 2021a).

3.1.3 Topography

The airport site is generally flat however, the surrounding area undulates with steep gullies and surface water bodies in every direction around the site. The airport is between 95 and 115 m above sea level (Geoscience Australia, 2020).

The topography of the site and surrounding land is detailed on **Figure A4** attached with a smaller figure focussed on the airport and Mission Creek Catchment provided on **Figure 6** below. A hydrogeological cross section showing the airport relative to the Mission Creek surface water catchment is also provided as **Figure A14.**

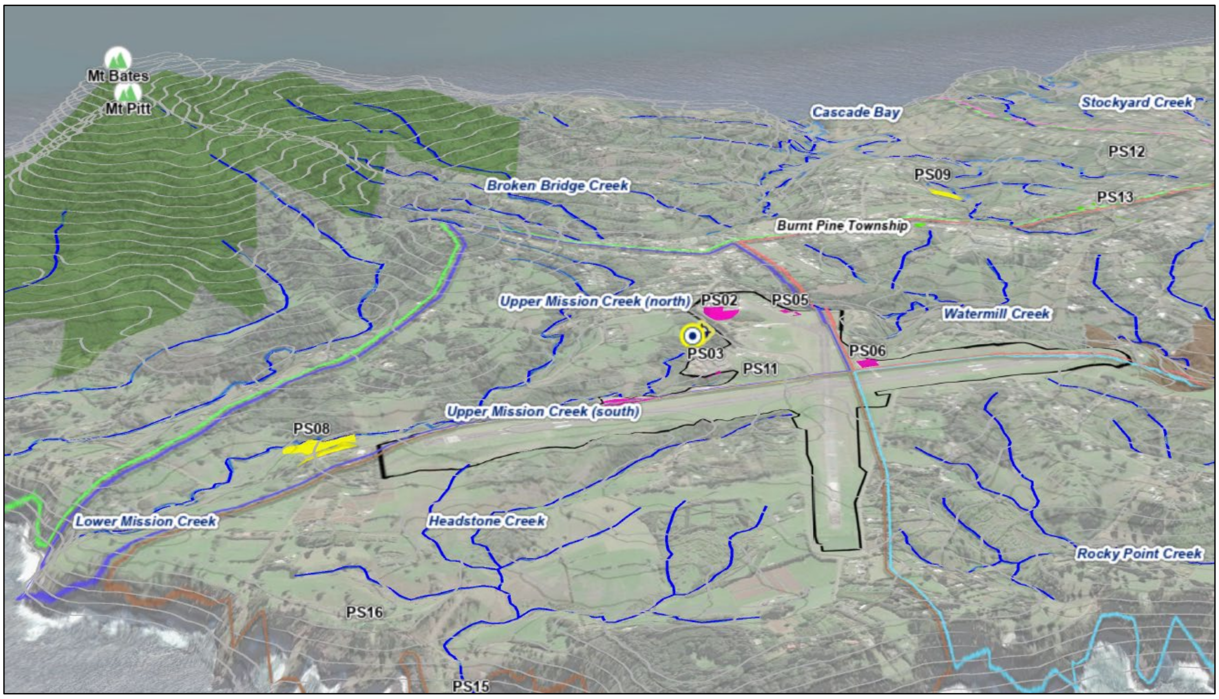

Figure 6: Topographical Model showing Mission Creek Surface Water Catchment

3.2 Geology

3.2.1 Structural Geology

Norfolk Island is the erosional remnant of Pliocene aged volcanic centres located on a north trending continental ridge between New Zealand and North Caledonia (Abell, R S & Falkland A C, 1991). The island consists of the former shield volcano (Mt Pitt) and horizontal basalt flows. The major formations are summarised below:

- Tertiary volcanic sequences are comprised of a series of generally flat lying basalts. Basalt flows are unconformably overlain by and interbedded with pyroclastics (generally tuffs), indicating periods of erosion between cycles of eruption.
- Quaternary aged sedimentary deposits comprising unconsolidated clays and silts are present to the south of the island and along drainage channels and adjacent surface water bodies. Calcarenite limestone is exposed along the coastline near the Kingston Jetty.
- The humid, sub-tropical climate has resulted in deep weathering of the basaltic sheet lavas. The weathered mantle is up to 80 m thick in some sections. The basalt flows generally have fragmental tops which have weathered to clay.
- The prominent soil type found at and surrounding the site is the Rooty Hill Clay.

3.2.2 Soils

Historical geological assessments have identified 11 soil types on Norfolk Island, with six occupying the majority of the island and formed from late-Tertiary basalt flows with interbedded ash and tuff (Figure 2-12). The basalts, pyroclastic ash and tuff deposits originated from a volcanic crater on the south-eastern slopes of Mount Pitt and a smaller crater at Ball Bay that erupted between 3 to 2.3 million years ago (CSIRO, 2020).

Of the remaining five soils, one soil is confined to wind deposited calcareous sands around Emily Bay derived from the adjacent fringing coral reef, one is an unnamed alluvial soil on Watermill Creek, and one is an acid peat in the swamps at Kingston. The remainder are exposed rock on the coastal cliffs and an unnamed skeletal soil on steep slopes around Mount Pitt and other steep areas (CSIRO, 2020).

Refer to **Section 7.1.1** for descriptions of the soils encountered during DSI sampling works, with the borelogs provided in **Appendix L**.

3.3 Hydrogeology

3.3.1 Hydrogeological Units

Based on the foundational research undertaken by Abell (1993), the following hydrostratigraphic sequence was found to be beneath the island:

- Weathered volcanic mantle: Major aquifer on the island, porous but clayey. The upper water table on Norfolk sits within the weathered mantle.
- Basaltic lavas: Heterogeneous water-bearing systems, dominated by water movement through fractures, joints and bedding.
- Vertical movement of groundwater through fractures in the basalt likely form localised, semi-confined aquifers within tuff beds and fragmented layers.

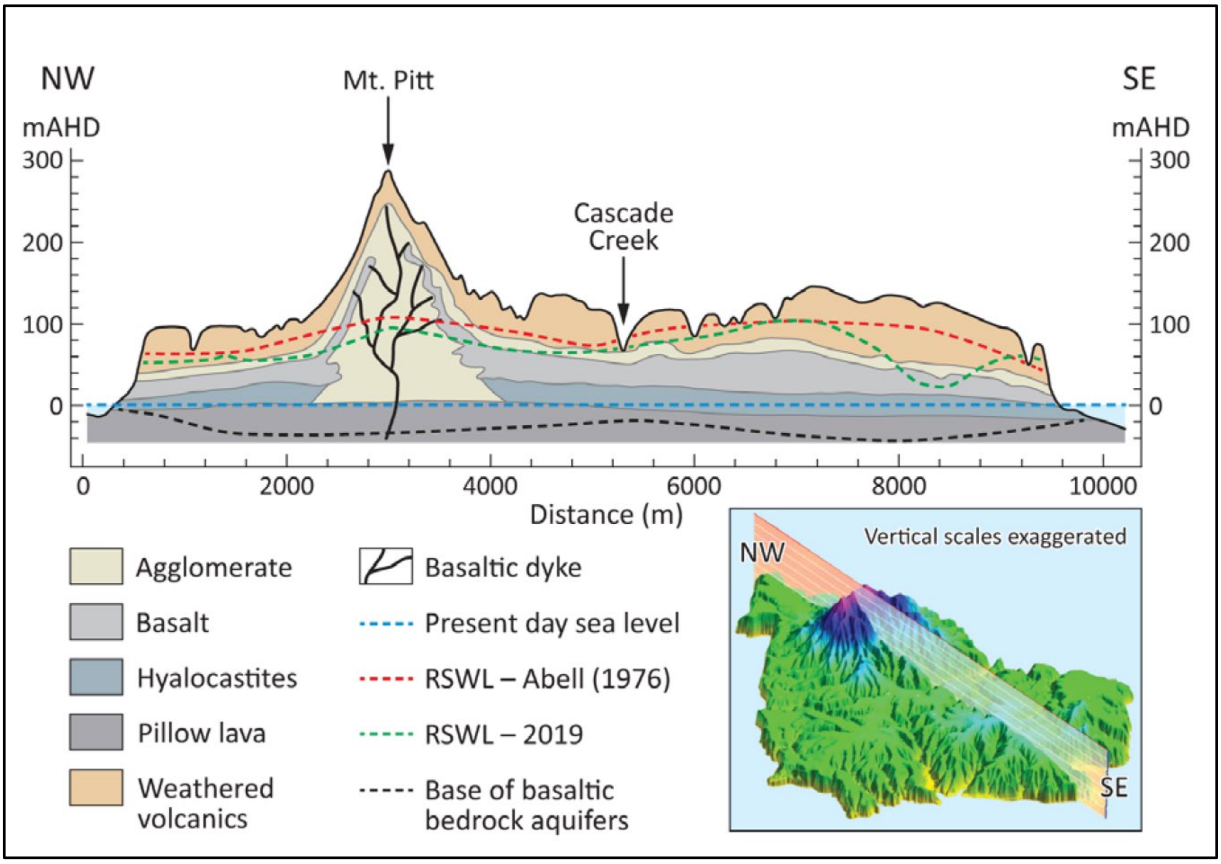

Figure 7: Hydrogeological Cross-Section of Norfolk Island (from CSIRO, 2020)

Groundwater from the weathered mantle gravity feeds and recharges bedrock aquifers through fractures. Permeability increases at or near fractures. There appears to be vertical leakage of groundwater through bedrock fractures forming deeper groundwater reserves. The porous nature of the weathered mantle suggests it has considerable groundwater storage capacity. However, the high percentage of clay, elevated water table and spring seepage type loss suggest that the aquifer has only poor permeability. Refer **Figure 7** for hydrogeological cross-section of Norfolk Island (CSIRO, 2020).

3.3.2 Groundwater Chemistry

Senversa undertook further assessment into groundwater provenance during the PSI, with a piper plot produced from 16 groundwater samples spread across the island. The piper plot (see **Figure 8**) found sodium and potassium to be the dominant cations, with chloride as the dominant anion. This indicates groundwater on Norfolk Island falls within the sodium chloride type, which is expected for the dominant rainfall / freshwater recharge of the island.

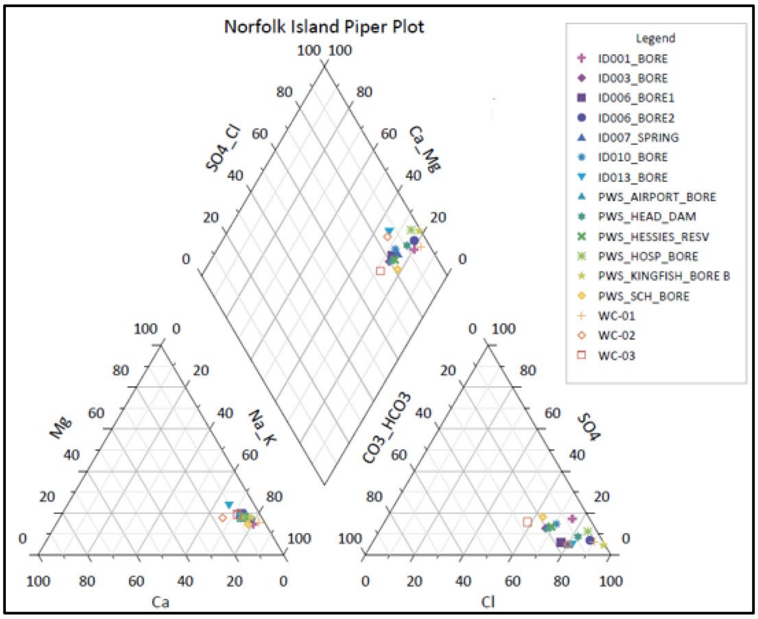

Figure 8: Piper plot detailing ionic balance of groundwater across Norfolk island

3.3.3 Groundwater Depth and Flow Direction

The heterogeneous nature of basaltic aquifers results in a complex groundwater flow regime. In general, groundwater flow follows, to a subdued degree, topographic features, discharging to surface water bodies and further towards the coastline (refer to **Figure 7**). Preferential flow pathways are created by water following the fracture orientation in the basalt.

Expressions of groundwater are present across the island. Seepages are formed where the valley has cut below the water table.

There is uncertainty as to whether there are distinct and potentially separated shallow and deeper aquifer systems on the island. There are a number of existing groundwater bores drilled beneath the sea level that appear to have different characteristics to more shallow bores. CSIRO identified in their studies a number of relevant lithological classes which were deemed to be potentially water-bearing. These included a shallow (<50m) weather volcanics aquifer and a deeper, unweathered but fractured basalt (CSIRO, 2020).

3.3.4 Groundwater Recharge and Discharge

Long-term changes in rainfall have resulted in a profound change to the hydrology of Norfolk Island. Models show percentage reductions in long-term groundwater recharge and streamflow to be about two and five times the percentage reductions in long-term rainfall over the same time period.

Around the airport and Mission Creek Catchment, the most important groundwater recharge area is inferred to be the southern extent of the weather mantle surrounding Mount Pitt and Mount Bates (CSIRO, 2020). The mantle has weathered into red and brown soils containing small areas of fresh basaltic breccias and is dissected on the Broken Bridge and Mission creeks. These creeks have gradually eroded through the weathered mantle draining excess rainfall from other parts of the island.

3.3.5 Groundwater Use

Council provided survey data indicating that there are 228 active groundwater bores, 38 dry bores and 10 “contaminated” bores across the island. Other sources indicate approximately 450 bores exist across the island (Abell, 1993). It is understood that not all bores on the island are registered with the Norfolk Island Regional Council or surveyed for height or location. Groundwater is known to be extracted for stock watering (chickens and cows) on Norfolk Island, however there is no evidence to suggest that groundwater is extracted for recreational purposes (e.g. to fill a swimming pool).

On the airport, there is one known groundwater well (small shed and well body approximately 1 m diameter) that was not in use at the time of the investigation that was sampled by Senversa (Senversa sample A_BORE1, January 2020). This well is located southwest of the banyan tree and should not be confused with the “Airport Bore” that was found to be PFAS impacted by CSIRO that is located just off-site near the head waters of Mission Creek.

This Airport Bore is used to pump water into a large concrete holding tank on site adjacent to the current council office. This water is used across the site and accessed by the public for offsite use via a fill point near the waste management centre access track just off Douglas Drive. There was also anecdotal evidence of this bore being used to supply off-site public buildings in times of low rainfall including the hospital and works depot (through use of a water carter).

New rainwater tanks installed on the airport have reduced the reliance on water from the Airport Bore and provide an alternate, unimpacted water source for the airport terminal buildings and the fire station taps. Based on discussions during the DSI sampling works, it is understood the airport bore is in the process of being disconnected for use across the airport and the water used is from A_Tank1. The Airport Bore may still be connected to areas of the Airport such as the mechanical shed adjacent the airport terminal, fire hydrants and potentially other areas of the site.

3.3.6 Acid Water Management

Peaty acid sulfate soils are present in the lower landscape portion of the island, with the largest known area located in the lower portion of the Mission Creek Catchment as shown on **Figure 9** below.

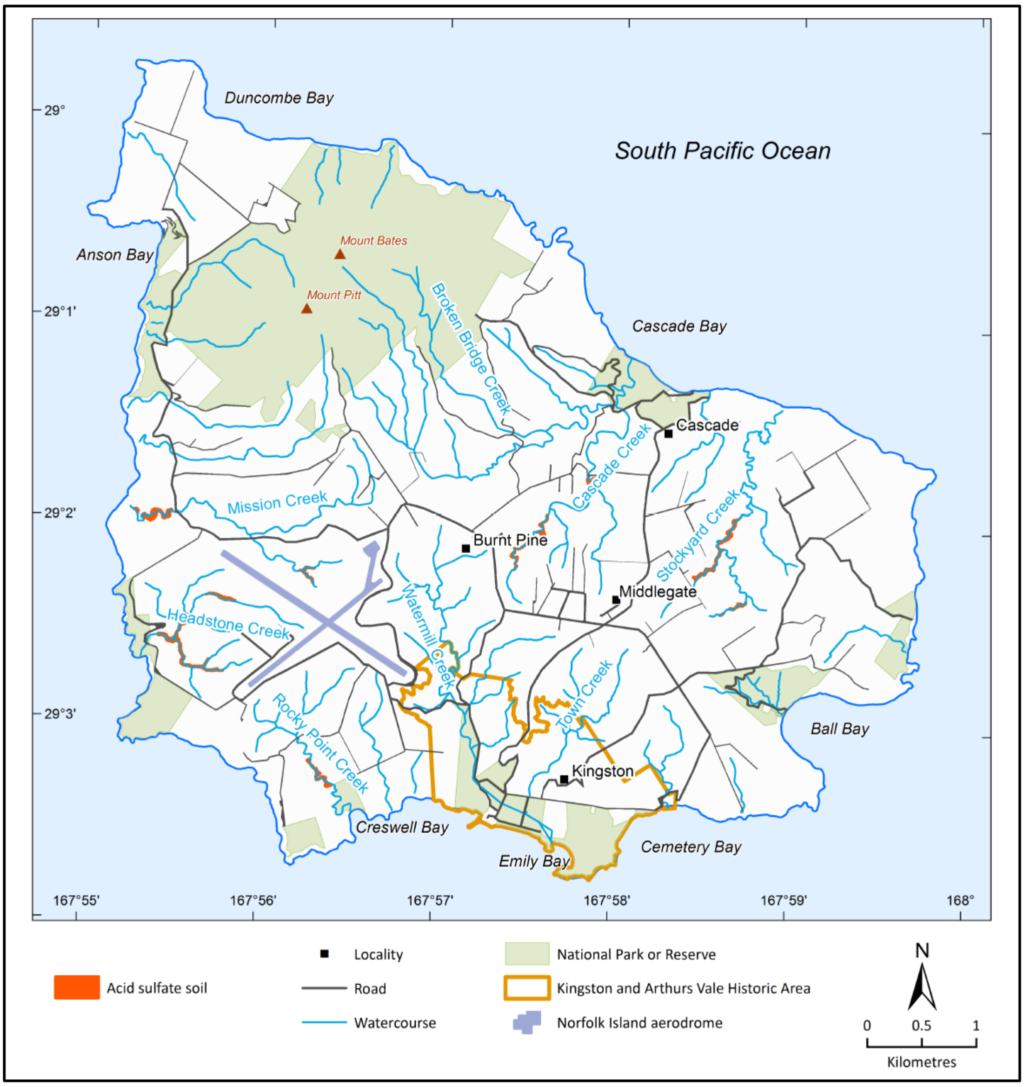

Figure 9: Locations of Acid Peat Soils (CSIRO, 2020)

The drying out of the peat soils during periods low rainfall increases the acidity of surface and groundwaters migrating through these soils. Following the low rainfall experienced in 2019, a small dam at the base of the Mission Creek catchment was anecdotally noted as becoming acidic in 2019.

However, acid water is generated across the island even in areas not noted on above. Long-term degradation of infrastructure in the Kingston and Arthurs Vale Historic Area (KAVHA) is due to contact with acidic drainage water (CSIRO, 2020) producing widespread corrosion/dissolution of calcarenite and cement mortar and rusting metal.

3.3.7 Groundwater Issues and Vulnerability

Overreliance on groundwater resulting in pumping from bores in excess of recharge can result in a thickening of the brackish water zone (see **Figure 7** above). This issue is exacerbated in times of low recharge (e.g. during summer months or in times of drought). In January 2020, this was anecdotally observed to be occurring in a number groundwater bores near the perimeter of the island where groundwater bores had shown increasing salinity.

The shallow, unconfined aquifer is vulnerable to bacteriological and chemical pollution associated with land use practices including domestic and livestock waste (e.g. septic systems and agricultural practices). Based on a digital data set provided by the Norfolk Island Regional Council and reviewed by Senversa, 10 bores predominately around the Burnt Pine area were identified as being “contaminated” by the council was considered likely to be a result of the positioning of the bores close to septic systems / poor maintenance of septic systems, however this could not be confirmed at the time of this investigation. Deeper groundwater is considered potentially less vulnerable to polluting surface activities, however, is anecdotally considered more vulnerable to seawater intrusion based on on-island discussions held in January 2020.

3.4 Terrestrial Environments

3.4.1 On-site Terrestrial Environments

Limited flora and fauna are present due to the highly modified nature of the airport environment. As the site is an airport, birds are excluded where possible, and any unpaved areas of the site is generally covered in grass. The main exception to this is the large Banyan tree present south west of the main terminal and visible on **Figure A2** as the darker green colour immediately south east of the “Former Flushing Area (PS02)”, with the northern edge of the tree shown on **Figure 10** below.

Figure 10: Large Banyan tree present on Airport

Low lying areas near the site boundary have limited thick vegetation. These vegetated areas generally coincide with natural drainage lines towards either Mission Creek, Headstone Creek, Rocky Point Creek and Watermill / Town Creek.

3.4.2 Off-site Terrestrial Environments

Norfolk Island has never been joined to a land mass, resulting in the terrestrial environment having a high number of endemic plants, animals and likely species from other kingdoms where limited research has been undertaken.

Prior to European settlement, Norfolk Island was dominated by subtropical rainforest and native flora of which over 30% is endemic (CSIRO, 2020). A large proportion of the island has been cleared for farmland used for grazing or cropping, with intact native communities being largely restricted to the 6.5 km^2 Norfolk Island National Park centred around Mount Bates and Mount Pitt.

However, even the ‘intact’ forests of Norfolk Island are significantly invaded by a variety of non-native plant species, several of which are serious weeds (CSIRO, 2020). There are also over 200 introduced plant species on the island.

The upper southern portion of the Mission Creek catchment contains remnants of the subtropical ecosystem approximately 100 m either side of the creek. A picture of the remnant subtropical rainforest present around the cleared area near the airport bore shown in **Figure 11** below.

Figure 11: Remnant subtropical rainforest surrounding Airport Bore in Mission Creek Catchment.

3.5 On Site Surface Water Drainage

3.5.1 Site Open Surface Drainage Network

Onsite stormwater in the north east of site near PS01 and PS02 drains into a low lying area on the boundary of site into a stormwater drainage pipe which runs perpendicular to and under the road leading to the waste treatment centre. This stormwater drainage is understood to discharge into Mission Creek.

Across the airport in general, stormwater is expected to run towards the site boundary, away from the runways.

3.5.2 Site Closed Stormwater Network

No underground service diagrams were available, with key information regarding the onsite closed water network is based on anecdotal evidence.

It is understood that an underground pipe historically connected the fire station (PS06) to the Airport Bore. The fire station tanks are no longer filled with Airport Bore water, however the underground infrastructure is understood to remain.

The main terminal building taps are understood to have been historically connected to the Airport Bore and the onsite reservoir (A_TANK1) which collects rainwater. Stormwater drainage lines also run under the taxiway.

3.5.3 Surface Water Features

There are no permanent surface water features present onsite.

3.5.4 Sewer (On-site)

The sewerage line runs above ground onsite from near the airport terminal buildings (in PS02) in a south-westerly direction before moving underground until it reaches the WWTP (PS11).

3.6 Wastewater Treatment

The Norfolk Island WWTP is located in the western portion of the airport, north of the main runway and is the subject of a recent options study prepared by the NSW Public Works Advisory (Norfolk Island Wastewater Options Study, 2019).

The inlet works for the WWTP are shown on **Figure 12** below, with the soils sampled around the WWTP presented in **Figure A6G**.

Figure 12: Wastewater Treatment Plant Inlet

The Norfolk Island WWTP takes effluent from a reticulated sewerage system knowns as the water assurance scheme in place for approximately 50% of the island's population but only collects from about 10% of the land area (approximately 230 connections), servicing the built-up areas of Burnt Pine and Middlegate in the central portion of the island as described below (NSW Public Works Advisory, 2019).

The areas of the island which are connected to the Norfolk Island WWTP starts at the school, then through the Burnt Pine township, along much of New Cascade Rd (includes most of the large tourist accommodations) until it reaches the airport and then the WWTP. **Figure 13** shows the layout of the current sewerage network on Norfolk Island. In addition, when septic systems are pumped out anywhere on the island, the effluent also goes to the sewage plant.

At the airport, the sewer appears to run beneath PFAS Source Areas 1 and 2 and potentially a portion of PFAS Source Area 3. It has not been confirmed whether the sewer is below the water table when it runs beneath these source areas.

Once at the WWTP, sewerage undergoes screening and minor primary treatment through rotating biological contractors (RBC), which does not include any tertiary treatment or disinfection. The screening and grit removed at the inlet pipe to the WWTP are understood to be retained on-site, however, it is unclear how or where (NSW Public Works Advisory, 2019). The WWTP does not have the capability to stabilise the sludge for reuse or land-based disposal, therefore no disposal of sewerage is undertaken on land on Norfolk Island. Both solids and liquids are therefore pumped through a pipeline to an outfall pipe at Headstone Cliff directly into the ocean, as shown in **Figure 13** below. The outfall solids and liquids entering the receiving marine environment are expected to be of poor quality. It is noted, the screening and treatment at the WWTP is not expected to remove any PFAS. The WWTP can treat up to 380 kL/day and currently treats between 70 – 225 kL/day (GCA, 2020).

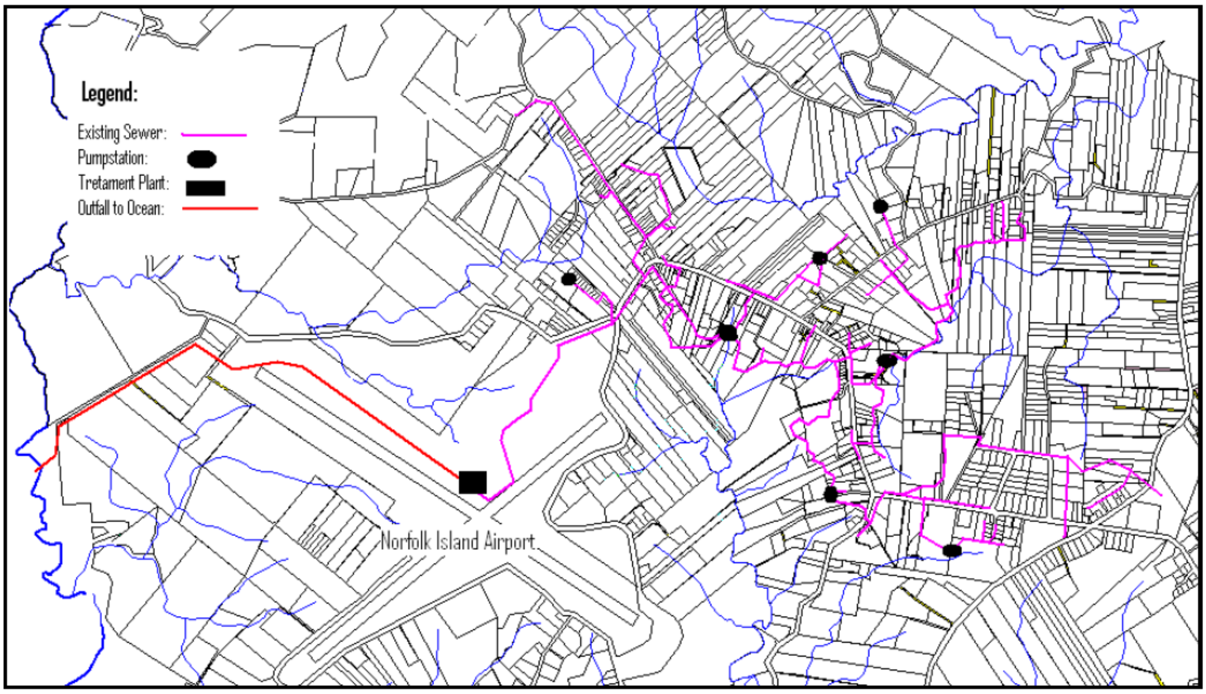

Figure 13: Norfolk Island Wastewater / Sewerage Network and Outfall Pipeline (source: GCA, 2020)

3.7 Off Site Aquatic Environments

Creeks on Norfolk Island are largely ephemeral, flowing only during rainfall events. Ponded water was observed in low lying areas across island. Each catchment zone is shown on **Figure A4**.

Mission Creek, Headstone Creek, Watermill / Town Creek and Rocky Point Creek are considered down-gradient of the airport, with the Mission Creek Catchment considered the most vulnerable to PFAS impacts migrating from the airport due to Fire Training activities undertaken on that side of the airport.

Other catchments listed below are included due to the potential for groundwater extracted from the impacted “Airport Bore” being used in these catchments.

3.7.1 Mission Creek Catchment Drainage

For the purposes of this investigation the Mission Creek Catchment is considered to have two distinct areas, upper and lower Mission Creek Catchments, as shown in **Figure 14** below and a hydrogeological cross-section of Mission Creek Catchment is presented in **Figure A14**.

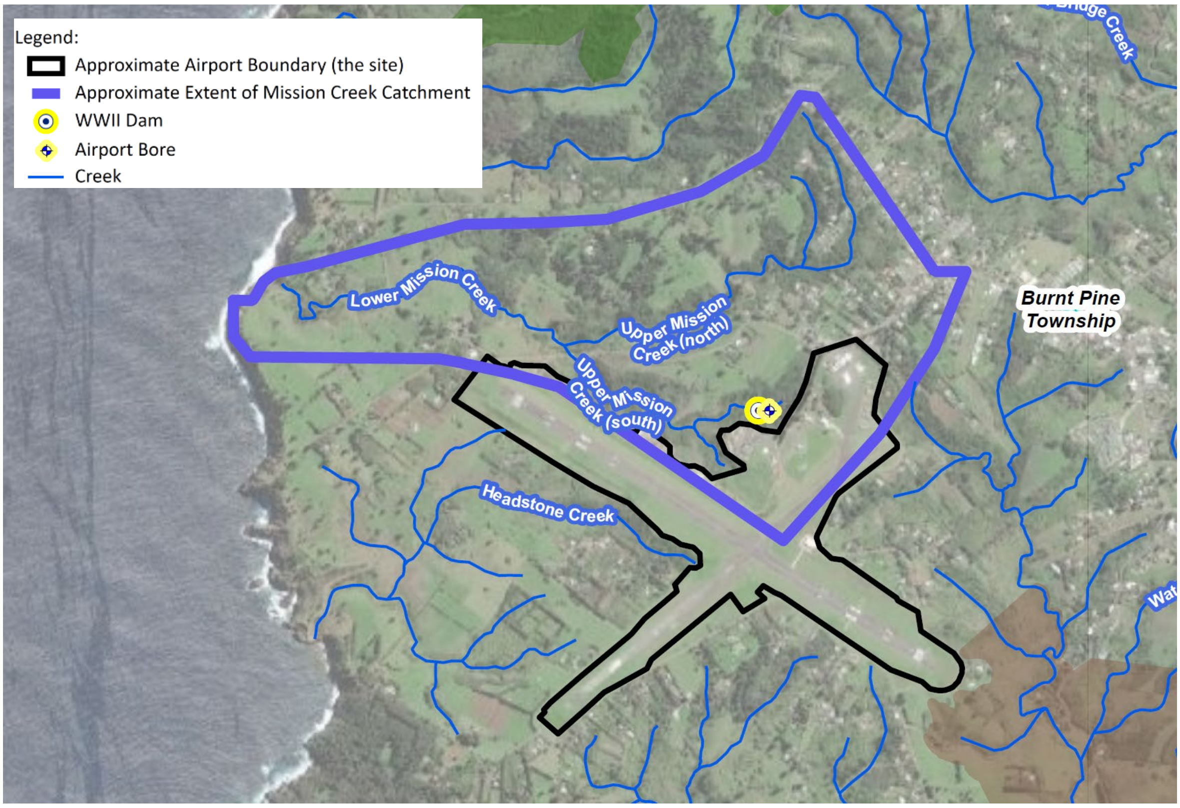

Figure 14: Mission Creek Catchment showing Upper and Lower Mission Creek

The first area includes the upper southern portion of the Mission Creek catchment above the culvert on Douglas Drive. There are no known PFAS Source Areas identified up-gradient of the upper northern portion of the Mission Creek Catchment. The upper southern portion of Mission Creek is defined by steep embankments sloping to a densely vegetated environment containing remnant sections of sub-tropical rainforest approximately 100 m either side of the creek. This area is largely inaccessible to livestock and includes the World War II Dam. The creek in this area was found to be ponded or gently flowing at the time of sampling (March 2021). This is considered to be a slightly modified environment.

The second area of the Mission Creek Catchment extends from the Douglas Drive culvert to the creeks discharge point to the ocean. This area is largely agricultural, passing through paddocks with grazing livestock and includes the St. Barnabus Church paddocks (PS08). At the time of sampling the creek in this area was largely dry with some small sections of ponded, discontinuous water. This area is considered to be highly modified.

3.7.2 Headstone Creek Catchment Drainage

The Headstone Creek Catchment is the area to the southwest of the airport. This catchment includes Headstone Dam, Headstone Point Reserve, and the Headstone Waste Management Centre. The area is largely agricultural and is considered to be a highly modified environment.

3.7.3 Rocky Point Catchment Drainage

The Rocky Point Catchment is the area to the south of the airport. This catchment includes Bumbora Reserve. It is largely agricultural and residential and is considered to be a lightly modified environment.

3.7.4 Watermill / Town Creek Catchment Drainage

The Watermill / Town Creek Catchment includes the Burnt Pine commercial district and the Kingston UNESCO World Heritage Site and discharge at Emily Bay. Watermill Creek drains a small area of the airport (NE corner) and runs behind the main township of Burnt Pine. Town Creek drains a largely rural area south of the school, before meeting Watermill Creek near Slaughter Bay approximately 200 m before exiting into Emily Bay.

Key surface water bodies in this area include the Watermill Dam (also colloquially referred to as 'Duck Dam'). This area is considered to be commercial and residential with some agricultural grazing areas in Kingston towards the site discharge point. This catchment is considered to be highly modified.

3.7.5 Stockyard Catchment Drainage

The Stockyard Catchment encompasses the area surrounding Stockyard Creek . Key features in this catchment include the Cascade Pier and the Ball Bay industrial area. The majority of this catchment is agricultural with limited industrial areas at the piers. This area is considered to be slightly to moderately modified.

3.7.6 Broken Bridge Creek Catchment Drainage (including Cascade Creek)

The Broken Bridge Creek Catchment includes the area south east of the National Park, where the Broken Bridge Creek drains the south eastern portion Mt Pitt and the north western portion of Burnt Pine (including the hospital).

Cascade Creek drains a largely agricultural area south east of Burnt Pine (including the Works Depot (PS 09), before joining with Broken Bridge Creek approximately 200 m before discharge into Cascade Bay. This catchment is considered to be slightly modified.

3.7.7 Other Mt Pitt Water Bodies Catchment

The remainder of the Mt Pitt Water Bodies, including the National Park and northern areas of the island are considered separate from the Broken Bridge Creek Catchment as described above. These water bodies are up-gradient of key source areas and are considered largely unmodified for the purposes of this investigation.

3.7.8 South Pacific Ocean

All creeks on Norfolk Island discharge to the South Pacific Ocean.

3.8 Listed Endangered Species

Review of the EPBC Act Protected Matters Report extracted in May 2021 (**Appendix E**) finds no threatened ecological communities listed, however 88 threatened on-island species and 44 migratory species that are known to occur in the area.

3.8.1 Endangered Terrestrial Species

Of the endemic plant species 2 are considered extinct and 28 are currently listed as endangered or critically endangered under the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act). Endangered or critically endangered plant species listed include the following:

<u>Plants</u>

- Norfolk Island Abutilon *(Abutilon julianae).*
- Chaff Tree, Soft-wood *(Achyranthes arborescens).*
- Phillip Island Chaffy Tree (Achyranthes margaretarum).

- Tree Nettle, Nettletree *(Boehmeria australis subsp. Australis).*
- Clematis *(Clematis dubia).*
- Mountain Procris *(Elatostema montanum).*
- Norfolk Island Euphorbia *(Euphorbia norfolkiana).*
- Phillip Island Hibiscus *(Hibiscus insularis).*
- Norfolk Island Mahoe *(Melicytus latifolius).*
- Shade Tree, Broad-leaved Meryta *(Meryta latifolia).*
- Popwood, Sandalwood, Bastard Ironwood *(Myoporum obscurum).*
- Norfolk Island Phreatia *(Phreatia limenophylax).*
- Kurrajong *(Wikstroemia australis).*

From the Animalia kingdom, birds and land snails are the only listed endangered terrestrial species. The Island has no endemic mammals, and its only noted mammals (bats) are now extinct.

<u>Birds</u>

- Endemic Species: Of the three listed endemic birds, two are considered endangered:
  - Norfolk Island Green Parrot (*Cyanoramphus cookii*).
  - Norfolk Island Boobook (Ninox novaeseelandiae undulata).
- Migratory birds: Eight migratory birds listed as likely to occur within the area (including long lived albatrosses) are listed as either endangered or critically endangered. A photo of a migratory bird species known to be present on the island is included in **Figure 15** below.
- It is noted that many of the migratory birds nest on the nearby Nepean and Phillip Island which are included in the Norfolk Island EPBC listed and therefore are unlikely to be impacted PFAS derived from the site. However, a number of migratory birds, such as the Red-tailed Tropicbird observed during the DSI field works in **Figure 15** below, do utilise Norfolk Island.

Figure 15: Red-tailed tropicbird (juvenile), at Rocky Point (Headstone Creek Catchment), March 2021

Land Snails

- Norfolk Island has 70 described species of land snail, however the true number may be smaller as perhaps 30 – 40 species (Australian Museum Research Institute, 2020).
- The last five remaining large species of endemic land snail (others became extinct due to rat predation) are listed as critically endangered (see **Appendix E**).
- Fossil records show most species were once widespread across the island, however they are now found primarily in the National Park, (area of 6.5 km^2) and steep creek gullies in the remnants of the subtropical rainforest that once covered the island.
- The endemic land snails exhibit a wide range of sizes (1 – 22 mm) and shell shapes. One species (*Cryptochropa exagitans*) sticks dirt to its shell for camouflage as shown in **Figure 16** below (Australian Museum Research Institute, 2020).

Figure 16: The Norfolk Island Endemic Land Snail *Cryptochropa exagitans*

3.8.2 Endangered Aquatic Species

All aquatic species listed are marine species only, with limited information on endemic fish and other aquatic species on Norfolk Island available. Therefore, with the exception of marine benthic fauna, most risks posed by PFAS at island discharge points (i.e. Mission Creek, sewer outfall) are likely to be short lived due to PFAS concentrations being quickly diluted in the South Pacific Ocean.

Marine species listed as endangered are all migratory and include the Blue and Southern Right Whales, together with the Loggerhead and Leatherback Turtles.

3.9 Potable Drinking and Stock Water Use

Bore water is not widely consumed in times of high rainfall. In times of drought, when tank water is not readily available, bore water may be extracted for drinking water purposes.

Water carting from groundwater bores was undertaken across the island both prior to and during January 2020 and in February 2020 a temporary desalination plant was commissioned by the Australian Government and Army on Norfolk Island.

Bore water is known to be extracted for stock watering (chickens and cows) on at least three properties in the Mission Creek catchment. Water extracted from Watermill Creek is also used for livestock watering (cattle and piggeries) between the airport and the duck dam.

Residents have access to water from two public stand-pipes: one by the Watermill Dam (Duck Dam), which is sourced from a hillside spring; and a second adjacent Headstone Creek (Headstone Dam). This water is understood to be used for non-potable uses (potentially including stock watering).

3.10 Irrigated Water Use

Irrigated water is understood to not be used on site, however grass on site may be affected by rainfall runoff over impacted soils and over areas of historical AFFF use (refer to **Table B1** potential PFAS Source Areas on site).

Additionally, water use during fire training and to flush out fire trucks is likely to have contributed to PFAS impacts and to surface runoff over areas of historical AFFF use. It is understood, flush outs of the fire trucks occurred up to three times a week and historically took place in the unsealed area to the south of the former fire station (PS02) where it would runoff towards Mission Creek. Currently, the fire station uses approximately 15,000 L per day (once every fortnight) for live fire training (NIRC, 2020).

Large-scale annual training drills historically took place in the vacant land behind St Barnabas Chapel (PS located approximately 250 m northwest of the western extent of the east-west runway.

Irrigation water derived from bores is used across the island for small commercial and private residential gardens. CSIRO estimated approximately 10.8 hectares of cultivated land is used for commercial food production, up to 75% of which may be irrigated. An additional 5 hectares of land is estimated to be used for medium to large scale vegetable gardens, it is unknown to what extent these gardens are irrigated. The source of irrigation water is unknown however is expected to be predominantly bore water or pumped from surface water bodies, based on anecdotal evidence provided during the investigation and sampling works.

It is understood that water is not widely used for irrigation of grassed paddocks (i.e. for livestock grazing) on the island.

4.0 Properties of PFAS

4.1 Introduction to PFAS

PFAS are a large group of fluorinated compounds which were first manufactured in the 1940's and have been widely used for a number of industrial applications and consumer products since.

PFAS form strong surfactants which are utilised in applications requiring heat resistance, dispersion of liquids, fire suppressant and surface protection (HEPA, 2020). The pervasive use of PFAS in products and industrial processes over decades and its resistance to break down, has resulted in PFAS being detected throughout the environment from legacy AFFF and other non-AFFF sources.

PFOS ($C_8F_{17}SO_3$) is the most common PFAS found in the Australian environment (and on Norfolk Island) due to its widespread historic use and its physico-chemical characteristics. PFOS is also the ultimate degradation or metabolic perfluorinated compound for a number of longer chain PFAS. PFOS is listed as a persistent organic pollutant (POP) under the Stockholm Convention.

The PFAS compounds that are most commonly found in the environment and for which the most scientific information exists are PFOS, PFOA and PFHxS (CONCAWE 2016, CRC CARE 2017) and are analytes for which Australian-derived PFAS screening criteria exist.

4.2 Use of PFAS at Norfolk Island Airport

Nationally, airports have been identified in the PFAS National Environmental Management Plan (HEPA, 2018) as sites with the potential for PFAS impacts. The main source of PFAS at airports is the historical use of aqueous film-forming foams (AFFFs) containing PFAS as active ingredients. AFFFs are 'Class B' firefighting foams that are used to prevent or extinguish flammable liquid fires by forming a barrier that inhibits oxygen from feeding the fire, while limiting volatilisation of flammable vapours from fuels.

Historically (from the 1970s), airports across Australia used AFFF that contained perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) (herein referred to as legacy AFFF), as distinct from currently produced AFFF formulations that do not contain PFAS as active ingredients. The primary AFFF product in use at airport and defence sites prior to the early 2000s was 3M Lightwater™, which is known to contain several PFAS compounds, including PFOS and PFOA. Many airport and defence sites replaced 3M Lightwater™ with Ansulite®, however Ansulite® was found to contain trace amounts of PFOS and PFOA (AirServices, 2007).

It is understood that legacy AFFF containing PFAS as active ingredients was used on Norfolk Island from the early 1980s until 2015 to supress liquid fuel fires and for fire training activities. The PSI identified the following use at Norfolk Island Airport:

- Protein foam was utilised until the introduction of 3M Lightwater® in the early 1980s. Protein foam does not contain PFAS.
- PFAS containing 3M Lightwater® was used by the Norfolk Island Fire Service for approximately 20 years (from the early 1980s) until the change to Tyco Ansulite® (also PFAS-containing but with a lower PFAS concentration) occurred in 2004.
- The use of PFAS containing products ceased in 2015.
- Flush outs of the fire trucks occurred up to three times a week. This historically took place in the unsealed area to the south of the former fire station where it would runoff towards Mission Creek.
- Tyco Ansulite® was still present in the current fire station in March 2021 prior to an acceptable off-island disposal methodology being developed.

4.3 Assessment of PFAS Types

This DSI focusses on PFOS, PFOA and PFHxS, which are the only PFAS to meet the screening criteria for persistence, bioaccumulation, potential for long range environmental transport, and evidence for adverse impacts to be listed on the Stockholm Convention's Persistent Organic Pollutants. Therefore, criteria for the assessment of risk within the PFAS NEMP 2.0 is provided for these three PFAS only. However, additional PFAS may be listed in the future.

This DSI also assesses concentrations of another 25 other PFAS (listed in **Section 5.4**) which are able to be accurately analysed under NATA accredited methods in Australia.

In Australian sites where legacy AFFF has been utilised (including on Norfolk Island Airport), PFOS and PFHxS are predominantly the most widespread PFAS detected. PFOS and PFHxS were both detected in more than 60% of water samples analysed at Norfolk Island (as part of the PSI and this DSI) and almost double the prevalence compared to the remaining PFAS. The next most commonly detected PFAS that were detected in more than 25% of water samples obtained in Norfolk Island samples are listed below:

- Perfluoropentane sulfonic acid (PFPeS).
- Perfluorohexanoic acid (PFHxA).
- Perfluorobutane sulfonic acid (PFBS).
- Perfluoropentanoic acid (PFPeA).
- Perfluorooctanoic acid (PFOA).

A summary of the chain length of these seven PFAS together with their soil organic carbon/water partition coefficient (where known) is provided in **Table 4-1** below.

Abbrievated Name	Carbon Chain Length	log K_{oc} (ml. g^{-1})	OECD Chain Length
PFOS	8 Carbons	4.2 - 4.5	Long-chain PFSA
PFOA	8 Carbons	1.89 - 3.5	Long-chain PFCA
PFHxS	6 Carbons	2.05 - 3.7	Long-chain PFSA
PFHxA	6 Carbons	1.31 - 2.1	Short-chain PFCA
PFPeS	5 Carbons	-	Short-chain PFSA
PFPeA	5 Carbons	1.37	Short-chain PFCA
PFBS	4 Carbons	1.22 - 1.79	Short-chain PFSA

Table 4-1: Properties of the seven most prevalent detectable PFAS in surface water

There is also wide range of other PFAS, known as precursors, that can transform into PFSA's or other potentially hazardous PFAS in products in the environment, and are also considered environmentally significant. However, the focus of the investigation has been on those PFAS for which the toxicity and chemical properties are understood.

4.4 Variable PFAS Retardation

Studies have found very few of the PFAS compounds present in groundwater were significant contributors to the legacy AFFF formation. PFCAs are largely absent from AFFF formulations but are among the most prevalent PFAS in groundwater (Anderson et a., 2016).

The variable retardation of PFAS is considered likely to be largely driven by interfacial adsorption + organic carbon sorption. Other factors likely to contribute are pH, ionic composition of aquifer, formulation of AFFF, co-contaminants present, remedial actions attempted, the degradation environment and transformation of precursors (Brusseau, 2019).

The assessment of variable retardation can be a critical part of the future management of PFAS impacts due to the following reasons:

- Sensitive receptors are often not present within PFAS source zone (i.e. the concentration of PFAS at the source zone is often not the driver for remediation).
    - Sensitive receptors are commonly impacted down-gradient after variable retardation of PFAS has taken place at either:
    - Surface Water Discharge Point.
    - Groundwater Discharge Point.
- The retardation of PFOS, PFOA, PFHxS and other PFAS can be multiple orders of magnitude different, particularly in groundwater (Anderson et a., 2016).

Research has also linked variable retardation to PFAS chain length, with Brusseau (2019) finding that as short-chain PFAS will undergo much less air-water interfacial adsorption than a longer-chain compound of the same structure a smaller retardation factor would be calculated for the short-chain compound (i.e. short chain PFAS will generally be retarded less). Therefore, shorter chain PFAS (e.g. PFHxS) have more potential to travel further than longer chain (PFOS).

Table 4-2 below illustrates the differences in key short-chain and long-chain PFSAs and Perfluorinated carboxylic acids (PFCAs), together with whether they are considered long or short chain (taken from ITRC, 2020).

Number of Carbons	4	5	6	7	8	9	10	11	12
PFCAs	Short-chain PFCAs				Long-chain PFCAs				
	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA
PFSAs	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFUnS	PFDoS
	Short-chain PFSAs		Long-chain PFSAs						

Table 4-2: Chain Length Definition of PFSAs and PFCAs

To assess the relative migration rates of PFOS and PFHxS from identified source to surface water body and receptor (where relevant), the concentrations of the seven most prevalent detectable PFAS in surface water (see **Table 4-1** in **Section 4.3**) are assessed known distances away from the identified source in surface water in **Section 7.2.6**.

5.0 Investigation Approach and Methodology

5.1 Investigation Rationale

A summary of the PFAS impacts identified in the PSI (along the PSI sample IDs) and the investigation rationale (along with DSI sample IDs) is presented in **Table** 5-1 below. Sampling outside of the scope is denoted in *italics*.

Note **Table** 5-1 does not include an exhaustive count of all samples collected as part of the PSI and DSI, rather the samples from the PSI where PFAS impacts or where data gaps were identified. Refer to the analytical tables in **Appendix B** for a comprehensive list of samples from the PSI and DSI works.

Table 5-1: Investigation Rationale

Activity	Investigation Locations	PSI Sample IDs	DSI Sample IDs	Investigation Rationale / Justification
Soil Sampling	**PFAS Source Areas (PS) 01 and 02** 5 of 8 targeted surface soil samples in this area contained elevated concentrations of PFAS exceeding 0.1 mg/kg in the PSI. • Soil bores to vertically and laterally delineate PFAS contamination. • Surface samples to laterally delineate PFAS contamination to the east, south and west.	A_SS17 to A_SS24	A_SB01 to A_SB10 *A_SB11 toA_SB12* A_SS64 to A_SS67, A_SS82 to A_SS96	Although all total soil concentrations of PFAS were below adopted criteria on the airport to protect airport users, they represent a potential ongoing source of surface or groundwater contamination. Based on review of leachability data from the PSI (20 samples), leachable concentrations above health-based guidance values for drinking water were identified in all samples. A clear relationship is observed between soil and leachable concentrations as part of the PSI. On this basis, soils with higher concentrations are associated with a higher potential to act as an ongoing source. Leachable PFOS and PFHxS concentrations were above the recreational HBGV (0.7 µg/L) in 12 of 20 samples, and in 11 of these samples, the corresponding soil concentration was >0.01 mg/kg (A_SD09 (0.0053 mg/kg was the exception to this finding). 0.01 mg/kg PFOS+PFHxS has therefore qualitatively been selected as a
	PS 03 4 of 8 targeted surface soil samples in this area contained elevated concentrations of PFAS exceeding 0.01 mg/kg. • Targeted soil bores to delineate PFAS contamination. • *Additional surface soil samples.*	A_SS01 to A_SS08	*A_SS116 to A_SS122* A_SB23 to A_SB26	

Activity	Investigation Locations	PSI Sample IDs	DSI Sample IDs	Investigation Rationale / Justification
	PS 04 PS 04 was unable to be accessed during the PSI due to runway upgrade works and the area being occupied by Boral. Grid-based surface soil sampling in this area to assess for PFAS contamination. • Targeted soil bores in areas where visible evidence training and burning may have occurred. • Surface samples collected on the southern boundary of this area contained elevated concentrations of PFAS exceeding 0.01 mg/kg. Additional targeted surface samples to the south, east and west to further delineate laterally.	-	A_SS101 to A_SS115, A_SB18 to A_SB22	guide concentration above which soils have a higher potential to act as an ongoing source. Based on this and with consideration of the extent of elevated concentrations across the site and potential future management / remediation actions that may be required to be implemented, further assess / delineate concentrations of PFOS+PFHxS above 0.01 mg/kg on the site as discussed at each of the investigation locations.
	PS 05 • Additional 6 targeted surface soil sampling to the north and south of this area to delineate surface soil impacts.	A_SS52 to A_SS56	A_SS71 to A_SS77	
	PS 06 One targeted surface soil sample in this location contained PFAS exceeding 0.1 mg/kg with several other sample locations exceeding 0.01 mg/kg. • 6 soil bores to vertically delineate contamination.	A_SS41 to A_SS51	A_SB12 to A_SB17	
	PS 11 **Not assessed/sampled in the PSI.** • 10 targeted surface soil samples in and around the WWTP and drainage lines around the plant. • *Sampling of the liquid output at WWTP.*	-	A_STP_SS01 to A_STP_SS10 *A_STP_OUT*	
	PS 07 Three soil samples from the Common Oval (PS7), targeting the area used annually for fire-fighting foam displays.	-	TC_SS01 to TC_SS03	PFAS is known to bioaccumulate in certain food sources where PFAS contamination is present in soil. Sampling to target surface accessible soils (e.g. cropped areas, areas where livestock or poultry habit, etc).

Activity	Investigation Locations	PSI Sample IDs	DSI Sample IDs	Investigation Rationale / Justification
	PS 09 Targeted soil sampling within the Council Works Depot targeted areas around the impacted water tanks and where fire trucks were thought to have been previously washed down. Further sediment obtained in drainage lines.	-	DEPOT_SS01 to DEPOT SS14	
	Targeted sampling of surface soils in private properties where contaminated groundwater or surface water has been used for irrigation or stock watering purposes, leading from the site to Cascade and from within Cascade Creek (6 samples).	ID008_SS01 to ID008_SS03	ID013_SS01 to ID013_SS07	
Surface Water and Sediment Sampling	**PS 05** One sediment sample collected from a dry drain contained elevated levels of PFAS exceeding 0.1 mg/kg. Sediment and surface water sample in this drain both onsite and off-site to further assess PFAS impacts. **Other** • Further sampling of all drainage lines on-site where water is present after rainfall.	AD_SD09 and AD_SD10	Not sampled, no water present during DSI sampling.	Known contamination in sediment in drainage lines across the site and extending off-site. Confirmation of extent will inform management decisions. Surface water was not present in on-site drains during the PSI. Surface water sampling in drains and low lying areas (where water is present) as PFAS has the potential to migrate further down the drainage lines during periods of heavy rainfall.
	• Sampling of surface water and sediment in drainage lines entering Mission, Headstone and Watermill creek from the site. • Sampling of surface water and sediment in Mission Creek every 200 m. • Sampling up and down gradient in both Headstone and Watermill Creek. • Sampling saline sediments at the mouth of Mission, Headstone and Watermill Creek *(not completed for Mission Creek and Headstone).* • Surface water and sediment sampling of drainage lines in the sewage treatment area. • Sampling at likely points of groundwater discharge from the main public toilets (PS16) supplied by the airport bore within the main tourist area (Headstone, Cascade and Emily Bay)	MC_SD01 to MC_SD10 PWS-WWII_DAM PWD_HEAD_DAM ID011_SD01 to ID011_SD02 TC_SW01 to TC_SW02	MC_SD04, MC_SD07, MC_SD11 to MC_SD29, WWII_DAM, MC_SW11, MC_SW13, MC_SW21, MC_SW24 to MC_SW28, HC_SW01, PWD_HEAD_DAM, PWS_HEAD_TOILETS, PWS_HCASC_TOILETS, PWS_EB_TOILETS, TC_SD02 to TC_SD13, TC_SW02 to TC_SW07, TC_SW12, TC_SW13, A_STP_SS01 to A_STP_SS10	Confirmation of the extent of PFAS in surface water bodies off-site required to assess risks to potentially sensitive receptors.

Activity	Investigation Locations	PSI Sample IDs	DSI Sample IDs	Investigation Rationale / Justification
Biota Sampling	• Sampling of grass and biota (i.e. eggs, fruit, vegetables) in Mission Creek Catchment in areas where contaminated groundwater and surface water are currently, or have historically been used to water market gardens, poultry and cattle. • Biota samples are proposed to be collected with the Mission Creek Catchment. • Sampling of grass across the airport.	-	ID013_BIOTA1 to BIOTA5, BIOTA7, BIOTA8 (paired with ID013_SS01 to SS05, SS07 and SS08) MC_BIOTA7, BIOTA12, BIOTA13, BIOTA18 A_BIOTA123 to A_BIOTA139	PFAS is known to bioaccumulate in certain food sources where PFAS contamination is present in soil and water used for irrigation. Senversa proposes to obtain biota samples from fruit and vegetable (where possible) as well as grass and eggs to target key properties within the Mission Creek catchment and to assess PFAS concentrations in food that is being sold across the Island. Sampling of grass at the airport to assess PFAS concentrations in grass cuttings fed to cows.
Drinking / Stock Water Sources	• Sampling of all available taps and tanks on-site including airport terminal taps, BoM, hospital, council and fire station taps and all tanks.	FRE_TAP1 to FRE_TAP2	*A_TANK 1 and A_TANK3 (new tanks)* A_TAP1 to A_TAP5, FRE_TAP1, FRE_TAP3, FRE_TAP5	PFAS was present above detection limits in taps on-site in the fire station. Assessment into other taps and water sources on the island is required to confirm the suitability of the water supply.
	• Further off-site drinking water supply sampling and investigation into current and historic use of Airport Bore water. • Confirmatory and further assessment of utilised existing groundwater bores within the Mission Creek Catchment that were not previously sampled.	A_BORE1, PWS_AIRPORT_BORE PWS_HOSP_TNAK1 to TANK5 PWS_HOSP_TAP1 to TAP4	PWS_HOSP_TAP1, TAP4, TAP4, TAP4a, TAP6, TAP10 ID013_SS01 to SS05, SS07, SS08, ID013_SW01 paired with ID013_BIOTA1 to BIOTA5, BIOTA7, BIOTA8	Further tap testing at the hospital. Samples will also be obtained from water sources used to water stock, chickens and vegetables to support biota testing above.

The investigations did not include an extensive investigation of the extent of PFAS in groundwater. Based on the outcome of the PSI, it was considered there is limited value further documenting the extent of PFAS in groundwater as it was unlikely to influence the assessment of risk / management measures that may be put in place.

5.2 Data Quality Objectives

Senversa adopted quality assurance procedures to provide a consistent approach to evaluation of whether the data quality objectives (DQOs) required by the project have been achieved. The approach, detailed in a seven-step process, was consistent with NEPM DQO process, as outlined in Schedule B2 *Guideline on Site Characterisation.* The approach focusses on assessment of the useability of the data in terms of accuracy and reliability in forming conclusions on the condition of the element of the environment being investigated. The approach taken by Senversa in accordance with the seven-step DQO process is presented in **Appendix F**.

5.3 Environmental Media Investigated

The PSI identified a number of potential AFFF source areas with the potential to enter soil, surface water, sediment and groundwater. The investigation approach and rationale for the DSI (2021) works are based on the identified sources, potential for AFFF to impact the environment and the preliminary CSM assessment in the PSI (Senversa, 2020).

This DSI report also includes the following additional results:

- Results of sampling completed by Senversa as part of the Stage 1 PSI sampling works (Senversa, 2020a).
- Groundwater and surface water samples by other companies (CSIRO, 2020).

Samples obtained on private property are discussed within this report, however the location of the sample is not disclosed or shown on figures unless permission was granted by the private landholder.

5.3.1 Summary of Sampling

Table 5-2 below summarises the types and number of sampling locations during the PSI and DSI works.

Table 5-2: Summary of Sampling Locations Completed

Sampling Locations	On-site		Off-site	
	PSI	DSI	PSI	DSI
Soil – surface	63	67	13	26
Soil – bore	-	26	-	3
Surface water	-	-	11	26
Sediment	20	-	15	40
Groundwater Bores	2*	1**	19	3
Water Tanks / Taps	2	16	28	51
Grass	-	17	-	17
Biota (other)	-	-	-	7

* A_BORE1 and airport bore

** airport bore

5.3.2 Fieldwork Methodology

A detailed account of the field methodology undertaken for the DSI (Stage 2) works is included in **Appendix G** and calibration certificates for equipment are included in **Appendix H**.

5.4 Laboratory Analysis

Australian Laboratory Services Pty Ltd (ALS) was the primary analytical laboratory and Envirolab was the secondary laboratory for all samples.

Primary water and soil samples collected were analysed for the extended PFAS suite of 28 analytes. The following table summarises the laboratory analysis completed.

Table 5-3: Summary of Laboratory Analysis Completed

Sample Type	Number of Samples Analysed			
	On-site (PSI)	On-site (DSI)	Off-site (PSI)	Off-site (DSI)
Soil	63	206	13	29
Sediment	9	0	2	40
Surface Water	6	0	5	26
Groundwater – Bores	2*	1**	19	4
Water Tanks / Taps	-	12	1	29
Grass	-	17	-	4
Biota	-	-	-	7

* A_BORE1 and airport bore

** airport bore

The laboratory certificates of analysis provided by the primary and secondary laboratories and accompanying chain of custody (COC) documentation are provided as **Appendix I**.

5.5 Quality Assurance and Quality Control

The data quality assurance and quality control (QA / QC) procedures adopted by Senversa provide a consistent approach to evaluation of whether the data quality objectives required by the project have been achieved. The process focuses on assessment of the useability of the data in terms of accuracy and reliability in forming conclusions on the condition of the element of the environment being investigated. The approach is generally based on guidance from the following sources:

- Australia Standard (AS 4482.1) - Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil, Part 1: Non-volatile and Semi-volatile compounds (Standards Australia, 2005).
- National Environment Protection Council (NEPC) - National Environment Protection (Assessment of Site Contamination) Measure (NEPM) - Schedule B (3) Guideline on Laboratory Analysis of Potentially Contaminated Soils (2013).
- United States Environmental Protection Agency (USEPA) - Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4 (2000).
- United States Environmental Protection Agency (USEPA) - Guidance on Environmental Data Verification and Data Validation EPA QA/G-8 (2002).

The data validation approach and methodology undertaken is presented in **Appendix G**. The results of the quality assurance and quality control assessment that was completed for the project are discussed in presented in **Appendix J**Matrix spike (MS) and laboratory control sample (LCS) frequencies were not undertaken on a majority of the primary batches, which is considered a non-conformance given these test the accuracy and performance of the analytical methods. However, where MS and LCS were undertaken on primary and secondary batches, the majority of results were within acceptable ranges, noting that the primary batches consistently reported bias high. Furthermore, the RPDs generally showed the inter-laboratory duplicates (secondary lab) reported results at lower concentrations that the primary laboratory, where the secondary laboratory batches had acceptable QAQC. This is not anticipated to impact the conclusions drawn as the duplicate and triplicate results were relatively closely correlated with few exceedances of adopted criteria.

On the basis of this, the primary results may have some high bias, however this was considered acceptable, given the investigation and risk assessment is conservative by being based on the higher of the concentrations.

While some of the quality control results were reported to be outside adopted acceptance objectives, the majority of the quality control results indicated that the precision and accuracy of the data was within acceptable limits. The results were therefore considered to be representative of chemical concentrations in the environmental media sampled at the time of sampling, and to be suitable to be used for their intended purpose in providing an understanding of the contamination status of the environmental media assessed.

6.0 Regulatory Framework for Assessment

The ASC NEPM (NEPC, 2013) sets the national framework for the assessment of site contamination relevant for overseas territories like Norfolk Island. The Tier 1 assessment criteria contained within these guidelines generally form the basis of a screening risk assessment. Given the absence of PFAS criteria in the NEPM, assessment criteria have been adopted from the following recently released publications:

- HEPA (2020) PFAS National Environmental Management Plan Version 2.0 (PFAS NEMP 2.0) January 2020; and,
- Department of Health (DoH) (2017) Final Health Based Guidance Values for PFAS for use in site investigations in Australia, developed by Food Standards Australia New Zealand (FSANZ), 2017.

The PFAS NEMP 2.0 was developed by the heads of EPA (HEPA) to establish a practical basis for nationally consistent environmental guidance and standards for managing PFAS contamination. The plan has been developed by all Australian jurisdictions and recognises the need for implementation of best practice regulation through individual jurisdictional mechanisms.

The following sections describe the assessment criteria adopted for this investigation to be used to assess the soil, sediment, groundwater, and surface water quality data.

6.1 Land Use Scenarios

6.1.1 Norfolk Island Airport

Norfolk Island airport is an international airport with access to the airside portion of the airport strictly managed. Other uses of the site include the following:

- Fire Station.
- BoM.
- Council offices.
- Freight forwarding office.
- Former drill ground.
- Waste depot.
- Wastewater treatment plant.

6.1.2 Wider Norfolk Island

- Within Mission Creek – low population density / Predominately farming.
- Wandering cattle scenario.
- High percentage of home grown produce.
- Historical use of groundwater in times of drought.
- Public open spaces / high tourist traffic in KAVHA area.
- One school.
- Hospital.

In the context of the land use scenarios described in the ASC NEPM (NEPC, 2013),**Table 6-1** describes the land use scenarios that apply for this assessment for site contamination (soil and sediment) – as described by the Health Investigation Levels (HILs) provided in the ASC NEPM.

Table 6-1: Land Use Scenarios

HIL	Land Use Scenario (ASC NEPM)	Relevant Site Areas
D	Commercial/industrial includes premises such as shops, offices, factories and industrial sites.	Airport, Burnt Pine shopping area and council depot.
A	Standard residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake (no poultry), includes children's day care centres, preschools and primary schools.	Remainder of Norfolk Island.
B	Residential with minimal opportunities for soil access includes dwellings with fully and permanently paved yard space such as high-rise buildings and flats.	Land use not relevant for Norfolk Island.
C	Public open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and footpaths.	School, Public areas within KAHVA.

6.2 Adopted Screening Criteria

The key contaminants of interest for the project are PFAS, particularly perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and perfluorohexane sulfonic acid (PFHxS). PFAS are a large group of fluorinated compounds with PFOS ($C_8F_{17}SO_3$) being the most commonly found in the environment due to its widespread historic use in consumer products and industrial uses globally as well as its's physico-chemical characteristics. Both PFOS and PFOA have been identified as persistent organic pollutants (POP) which are of particular concern due their persistence, bioaccumulation and toxicity.

PFHxS is another chemical of the PFAS group present in some fire-fighting foams, and has also been used as raw materials or precursors to produce PFAS based products. PFHxS also has different properties affecting its relative migration in surface water and groundwater when compared with PFOS. There is currently considered to be insufficient data to undertake a robust assessment of the potential risks associated with PFAS other than PFOS, PFOA and PFHxS, although it is noted that the toxicity of shorter chain PFAS is likely to be lower.

The adopted soil assessment criteria for PFAS for this investigation have been sourced from the PFAS NEMP 2.0 (HEPA, 2020). Due to the range of land uses identified within the investigation area, three of the four land use scenarios within Table 2 of the PFAS NEMP 2.0 have been adopted. The soil assessment criteria for human health screening values are only applicable to assess human exposure through direct contact with soil and are available for PFOA and the sum of PFHxS and PFOS. The human health-based guideline values should be applied in conjunction with other lines of evidence to consider potential leaching, migration, bioaccumulation and secondary exposure. The degree of conservatism used to develop the human health screening values also means that exceedences of these criteria do not constitute a risk should other pathways be controlled.

In order to assess potential risks to ecological receptors from PFAS impacts in soil, the interim soil guideline values for ecological direct and indirect exposure from the PFAS NEMP 2.0 (HEPA, 2020) have been adopted.

Given the potential for PFAS to bioaccumulate in the environment, a key terrestrial exposure pathway (where habitat exists, and where food sourced from an area with soil impacts has the potential to form a significant portion of the diet of predators) is a pathway of PFAS uptake into lower-order biota, and subsequent exposure to higher-order biota through their diet. The screening levels derived for this pathway are more stringent that those developed for direct exposure of terrestrial organisms to impacts in soil.

The NEMP presents both “indirect” guideline values (which consider this bioaccumulation pathway) in addition to “direct” guideline values, and both have been considered in this assessment, noting that the adoption of the indirect (bioaccumulation) values is a conservative approach where there is limited habitat present, and limited potential for predators to source a significant portion of their diet from an area with soil impacts. It is noted that the screening levels for direct exposure are recommended for interim use as they are derived for the protection of human health via incidental soil contact (open space land use), and as such do not provide a direct assessment of potential terrestrial ecological risks. Notwithstanding these, the screening levels are assessed to offer an appropriate level of protection via direct exposure pathways, as they are lower than screening levels for these pathways developed in other jurisdictions.

Senversa acknowledges that guidelines relating to PFAS are dynamic and evolving and may be subject to change in the future, including the potential for adoption of lower levels for PFAS. The PFAS NEMP 2.0 has been developed as an adaptive plan which is able to respond to emerging research and knowledge. It is acknowledged that changes to criteria may require lower laboratory reporting limits (where achievable by a commercial laboratory) and it is not intended that the DSI reporting will be updated once completed should assessment criteria be amended. Should a review be undertaken of NEMP 2.0 prior to issue of the HHERA and assessment criteria do change, the implications of such changes will be assessed during the completion of a future HHERA.

6.2.1 Soil and Sediment

As a conservative measure, the Human Health Investigation Levels (HILs) for residential use with accessible soil (HIL-A) have been adopted for initial comparison across the wider island (off-site). It is noted that these screening levels are potentially not conservative where home grown produce (grown in PFAS impacted soil) constitutes more than 10% of fruit and vegetables in the diet.

Land used for the production of food, flora and fibre should consider guidelines in the Australia and New Zealand Food Authority Food Standards Code. However, criteria or guidelines for PFAS in soil/sediment are not specified in the NEPM or the Food Standards Code. Assessment criteria have therefore been adopted from other sources which utilise a similar risk-based approach to that used in the NEPM and/or Food Standards Code.

Additionally, there are no published health or ecological screening criteria for PFAS in sediment. The primary issues of concern associated with PFAS in sediment are:

- Potential human health impacts due to direct contact exposure to sediment (e.g. during recreational use of surface water bodies).
- The potential for sediment to act as a source of PFAS that may remobilise into the water column and/or aquatic food chains.
- The potential for sediment and/or sediment pore water concentrations to pose direct ecotoxicological effects.

There is currently insufficient data regarding direct sediment toxicity to sediment dwelling organisms, thus no screening criteria has been adopted for this pathway to derive screening levels for assessment of this risk.

For other pathways/issues, the following criteria have been adopted:

- Health-based screening criteria for residential soil have been adopted to assess potential health risks due to direct contact with sediment by human receptors. While soil criteria are not derived with specific consideration of sediment exposure, the frequency and duration of exposure to sediments during recreational use of water bodies are much lower than those assumed for soil exposure in a residential setting. Use of residential soil criteria is therefore considered protective of potential risk due to sediment exposure.
- Potential impacts on surface water and/or the aquatic food chain have been assessed by comparison of surface water concentrations to relevant screening levels.

- All on-site soil and sediments were compared to health based commercial guidelines. All off-site soils and sediments collected during the targeted assessment were compared to both residential and recreational guidelines as a conservative approach which is considered appropriate in meeting the project objectives. The approach is particularly conservative for sediments, where the potential for exposure will be much lower than for soils in residential back yards.
- It is noted that the residential value considers uptake into home-grown produce (fruit and vegetables) provided the home-grown produce constitutes up to 10% of fruit and vegetables consumed, but does not consider consumption of home-grown poultry/egg or livestock products.

The adopted assessment screening criteria for the current land uses are detailed in **Table 6-2**.

Table 6-2: Adopted Assessment Criteria (Soil and Sediment)

Land Use	Adopted Screening Criteria		
	PFOS+PFHxS	PFOA	PFOS
Human Health • Sensitive Use • Agricultural Use • Recreation / Open Space Use	0.01 mg/kg (sensitive and agriculture) 1 mg/kg (recreation / open space)	0.1 mg/kg (sensitive and agriculture) 10 mg/kg (recreation)	-
Human Health • Commercial Use • Industrial Use	20 mg/kg	PFOA – 50 mg/kg	-
Maintenance of Ecosystems	-	10 mg/kg (direct toxicity)	0.01 mg/kg (secondary poisoning / bioaccumulation) 1 mg/kg (direct toxicity)
Production of Food, Fibre and Flora	-	10 mg/kg (direct toxicity)	0.01 mg/kg (secondary poisoning / bioaccumulation) 1 mg/kg (direct toxicity)
Aesthetics	PFAS are not considered to be relevant indicators for this land use, and it has not been considered further in the DSI.		
Buildings and Structures	PFAS are not considered to be relevant indicators for this land use, and it has not been considered further in the DSI. However, PFAS is reported to adsorb and desorb from permeable materials such as concrete, potentially representing source of PFAS that should be considered in the conduct of the works.		

6.2.2 Surface Water and Water (other)

As detailed in the PFAS NEMP 2.0, the level of protection that should be used to determine the objective for aquatic ecosystems is:

- 99% for ‘largely unmodified’, ‘natural’ and ‘substantially natural’ ecosystems.
- 95% for ‘slightly to moderately modified’ or ‘modified’ ecosystems.
- 90% for ‘highly modified’ or ‘largely modified’ ecosystems.

The above protection levels are relevant for assessment of direct toxicity to aquatic organisms. In accordance with ANZECC & ARMCANZ recommendations, the next higher protection level should be adopted for assessment of potential bioaccumulative / secondary poisoning effects where site-specific data on bioaccumulation is not available (e.g. the 99% level for slightly to moderately disturbed ecosystems).

Norfolk Island does not have defined areas designating status of aquatic ecosystems in each catchment. However, based on the ANZECC (2011) guidance on the level of protection afforded to a water body based on its ecosystem conditions, the following has been adopted:

- Norfolk Island Airport (the site): Highly Modified.
- Upper Mission Creek Catchment (above culvert on Douglas Drive): Slightly to Moderately modified.
- Lower Mission Creek Catchment (below culvert on Douglas Drive): Slightly to Moderately modified.
- Headstone Creek Catchment: Slightly to Moderately modified.
- Rocky Point Creek: Slightly to Moderately Modified.
- Town Creek / Watermill Creek: Slightly to Moderately modified.
- Stockyard Creek: Slightly to Moderately Modified.
- Broken Bridge Creek / Cascade Creek: Slightly to Moderately Modified.
- Other Mt Pitt Water Bodies: Largely Unmodified.

Screening criteria (also commonly referred to as water quality objectives or investigation levels) for the uses of surface water were adopted in general accordance with the PFAS NEMP 2.0 (2020) and NHMRC (2019) and are detailed in **Table 6-3**.

Table 6-3: Adopted Screening Criteria for Surface Water and Water (other)

Water Use	Adopted Screening Criteria	
	PFOS / PFHxS	PFOA
Aquatic ecosystems	0.00023 µg/L (99% protection); 0.13 µg/L (95% protection); 2 µg/L (90% protection); **(PFOS only)**	19 µg/L (99% protection); - 220 µg/L (95% protection; 632 µg/L (90% protection)
Primary and/or secondary contact recreation	2 µg/L **(PFOS and PFHxS)**	10 µg/L
Aesthetic enjoyment	To be assessed based on observations of odour and/or visual amenity impact (noting that aesthetic impacts have not been noted for PFAS impacted water during site investigations).	
Cultural and spiritual values (indigenous and/or non-indigenous)	No specific guidelines available, considered that criteria for other land uses will also be protective of this use.	
Agriculture (stock watering)	0.07 µg/L **(PFOS+PFHxS)**	0.56 µg/L
Drinking (Potable) Water	0.07 µg/L **(PFOS+PFHxS)**	0.56 µg/L

Water Use	Adopted Screening Criteria	
	PFOS / PFHxS	PFOA
Irrigation	Relevant screening levels for this land use are not available. Site-specific risk assessment and or direct sampling of irrigated produce (as undertaken within this DSI) is recommended for irrigated pastures and/or crops where PFAS are detected and water is used for irrigation.	
Aquaculture **Human Consumption of Fish, Crustacea and Molluscs**	As the Creeks on Norfolk Island are largely ephemeral with water flowing only during rainfall events, this land use is not considered relevant to this investigation. Furthermore, there was no evidence of human consumption of freshwater Fish, Crustacea and Molluscs from water bodies or within the Mission Creek Catchment.	
Industrial and commercial use	No generic screening criteria for these uses are available, however, criteria for other land uses relevant to human and animal health (including potable water supply, primary contact recreation and stock watering) are considered relevant and will be considered in assessing impacts to this land use.	

6.2.3 Marine Water

The South Pacific Ocean surrounding Norfolk Island is enclosed with the *Temperate East Marine Park – Norfolk Island*, as shown on **Figure 17** below.

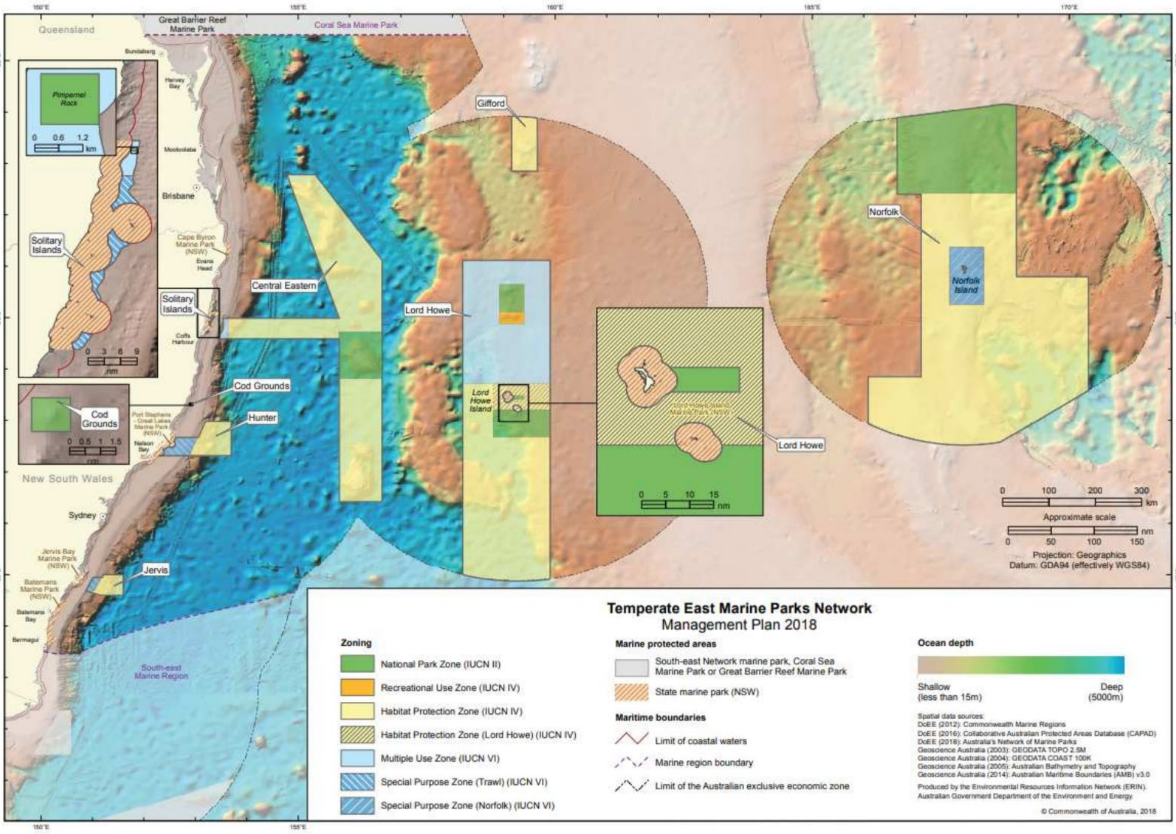

Figure 17: Temperate East Marine Park – Norfolk Island (Source: Director of National Parks, 2018)

Marine water needs to be considered at surface water discharge points, groundwater discharge points and wastewater discharge points.

For the wastewater discharge point there are ANZECC trigger values for commonly assessed wastewater parameters (i.e. total phosphorus, total nitrogen) but not for PFAS.

6.2.4 Biota

Health-based screening and/or investigation levels have been used for preliminary screening of potential health risks where receptors may be exposed to PFAS on or from Norfolk Airport. Screening levels for some relevant exposure pathways / scenarios are published and endorsed by Australian federal guidance documents, and these have been adopted where available.

Trigger points developed by FSANZ for PFAS in the foodstuffs sampled as part of the DSI are summarised in **Table 6-4** (biota / foodstuff) below. Where the values are centred between the PFOS and PFHxS columns, they refer to the sum of the two.

Table 6-4: Health-Based Screening Levels from Australian Guidance – Biota

Food for Human Consumption	Screening Level (ug/kg)			Source of Value and Application Notes
	PFOS	PFHxS	PFOA	
Poultry eggs	11		85	FSANZ (2017) trigger points for investigation
Fruits (all)	0.6		5.1	
Vegetables (all)	1.1		8.8	

7.0 Results

7.1 Soil and Sediment Investigation

As most of the creeks and waterways on Norfolk Island are ephemeral, the distinction between soil and waterway sediments is often not clear. For the purposes of this investigation, the same criteria were also adopted for both soil and sediments and they have been discussed together within this section. This approach is considered valid, as at times when creeks are dry, exposure pathways to sediments may be similar to soil exposure pathways (by both people and ecological receptors).

It is furthermore noted that (as discussed in **Section 6.2.1**, there are no criteria specifically for sediment (which would offer protection to aquatic ecological receptors potentially associated with the sediments at times when creeks contain water), and these risks are therefore assessed primarily through the consideration of water concentrations (rather than sediment concentrations).

Reference is made to relevant sediment samples during discussion of the surface water results (**Section 7.2**).

7.1.1 Soil Conditions

The following table summarises the general sub-surface soil conditions encountered across the site during the DSI. Detailed information is included in the lithological logs in Appendix L and in surface sample descriptions in **Table 7-1**. Photos of soil conditions and cores encountered are included in **Appendix C**.

Table 7-1: Summary of Soil Conditions Encountered (On-site and Off-site)

Approximate Depth Range (m bgl)	Unit / Material	Lithological Description
0.0 to generally 0.3-0.7	Grass/Topsoil/ Crushed Rock	Grass and topsoil were encountered at most sampling locations onsite (airport). Topsoil was encountered at the majority of offsite locations. Topsoil was observed as soil directly below the grass surface cover and generally consisted of: **Fill (topsoil):** Brown, silty sand and sandy silt, with fine grained, poorly graded, sub-rounded sand, non-plastic silt. Some locations included trace gravels. Road base/gravels were observed at surface of the works depot, drill ground and former drill ground.
0.3-0.7 to 1.5 (limit of investigation)	Natural soil	Natural soils were generally consistent across on and off-site sampling locations, which consisted of the following lithology: **Silty CLAY**: Low plasticity, trace fine grained, sand, red-brown, stiff, moist, dry of plastic limit.

The site lithology encountered confirms the presence topsoil across the majority of on and off-site locations. The topsoil generally consists of silt sand and sandy silts, underlain by natural basaltic clay soils.

The typical fill and natural soils encountered are shown in **Plate 1** below.

 

Plate 1: Typical soil profile encountered showing brown silty sand topsoil (left) and natural red brown silty clay (right)

A conceptual Hydrogeological cross section for Mission Creek is included as **Figure A14** in **Appendix A**.

7.1.2 Field Observations

The following observations were recorded during the soil investigation works. Details are included in the relevant bore logs and surface soil sample descriptions are presented in **Appendix K**. Soil investigation locations are presented on **Figure A6** to **Figure A8.**

A summary of the field observations for all locations (on and off-site) is as follows:

- The majority of locations had no remarkable observations.
- Anthropogenic material was noted in one location (A_SB20) in the drill ground area onsite (airport), consisting of burnt rock fragments (indicative of fire training activities).
- Black staining and odours were observed at two locations in the drill ground area (airport) at A_SB20 and A_SB21 (indicative of fire training activities).

7.1.3 Soil Laboratory Results

Soil analytical results (total concentrations) were compared to adopted screening criteria as summarised in **Table B2**. PFAS leachability results are included in **Table B4**. Laboratory certificates of analysis are provided within **Appendix I**.

Soil investigation locations and analytical results screened against adopted ecological and human health screening criteria are presented on **Figure A7** and **Figure A8**. A summary of adopted human health and ecological screening criteria exceedences is included in **Table 7-2** below.

Table 7-2: Summary of Soil Screening Criteria Exceedences

Analyte	Adopted Screening Criteria (mg/kg)				Number of Primary Samples Analysed		Detectable Concentration Range (mg/kg)		Number of Detections		Number of Exceedences	
	Ecological[1]	Ecological[2]	Human Health[3]	Human Health[4]	On-Site	Off-Site	On-site	Off-site	On-site	Off-site	On-site	Off-site
Surface Samples (0.0 – 0.2 m)												
PFOS	**1**	**0.01**	**-**	**-**	97	26	0.0004 – 9.09	0.0007 - 0.155	97	26	4[1], 64[2]	-
PFOS+PFHxS	**-**	**-**	**0.01**	**20**	97	26	0.0002 – 9.13	0.0007 - 0.210	96	26	64[3]	6[3]
PFOA	**10**	**-**	**0.1**	**50**	97	26	0.0001 – 0.0938	<0.0002 - 0.0028	72	6	-	-
Deeper samples (>0.2m and deeper)												
PFOS	**1**	**0.01**	**-**	**-**	46	-	<0.0002 – 3.28	-	43	-	4[1], 34[2]	-
PFOS+PFHxS	**-**	**-**	**0.01**	**20**	46	-	<0.0002 - 3.29	-	43	-	35[3]	-
PFOA	**10**	**-**	**0.1**	**50**	46	-	<0.0002 - 0.117	-	36	-	1[2]	-

1 Ecological – direct toxicity to terrestrial organisms (direct exposure)
2 Ecological – secondary poisoning / bioaccumulation to terrestrial organisms (indirect exposure)
3 Human Health – residential land use
4 Human Health – commercial / industrial land use (no exceedences)
5 Human Health – public open space, applies to three samples only; TC_SS01, TC_SS02 and TC_SS03 (no exceedences)

7.1.4 Summary of Impacts to Land Uses

Table 7-3 summarises the impact that the identified PFAS impacts pose to the relevant land uses of land (as defined in **Section 6.1**) for the current use of the site for ongoing commercial/industrial use onsite (Norfolk Airport) and offsite sensitive uses.

Table 7-3: Land Uses Impact: On and Off-site

Land Use	Land Use Potentially Precluded (Y / N)		Comment
	On-Site	Off-Site	
Maintenance of Ecosystems	Y	Y	**On-site** Several locations in source areas onsite reported PFAS at levels that may have an adverse effect on ecosystems through both direct and indirect exposure.
			Off-site Samples at the depot and private property ID013 recorded PFAS at levels that may have an adverse effect on ecosystems. These samples were below criterion for direct exposure, and hence risks to ecosystems may only be present through indirect exposure.
Human Health (Soil)	N	Y	**On-site** There were no exceedences in Commercial / Industrial land use (HIL-D) for all on-site locations.
			Off-site There were no exceedences in Commercial / Industrial land use (HIL-D) for all off-site locations. One sample from ID013 exceeded residential use criteria indicating contamination at this property may require management if the land is for residential uses (with home grown produce). No exceedences of residential screening criteria were reported at all other off-site locations (with the exception of the Depot, which is commercial/industrial land use), therefore the PFAS identified is not considered to present an unacceptable risk for residential land use. No exceedences of recreation / public open space criteria were reported for the three samples on the common oval at KAVHA.
Human Health (Sediment)	N	Y	**On-site** There were no exceedences in commercial / industrial land use (HIL-D) for sediment samples collected from the airport.
			Off-site Sediment samples in Mission Creek and Watermill / Town Creek exceed residential criteria, however these samples were collected from drainage lines and creek beds where the potential for the growing of home-grown produce is considered to be low. Exposure to impacted sediment creek beds is considered to be lower than that of residential backyards, and as the sediment sampled were below recreational criteria, the PFAS reported is not considered to pose an unacceptable risk under recreational land use (for sediment).
Buildings and Structures	N/A		PFAS are therefore not considered to be relevant indicators for this land use, and it has not been considered further.
Aesthetics	N/A		PFAS are therefore not considered to be relevant indicators for this land use, and it has not been considered further.

Land Use	Land Use Potentially Precluded (Y / N)		Comment
	On-Site	Off-Site	
Production of Food, Flora and Fibre	Y	Y	**On and Off-site** The soils across most the site report PFAS at concentrations below the adopted screening criteria for impact to affect produce quality or yield. However, as on-site and off-site land uses include poultry/livestock keeping and agricultural uses, further site-specific assessment is required (i.e. the HHERA process) to assess whether bioaccumulation of contaminants from soil to food, flora and/or fibre produced as the site may pose a risk to human consumers of relevant food, fibre and flora products (noting that no health-based guidelines are currently specified in the Food Standards Code for PFAS).

7.1.5 Change in PFAS Concentration with Depth

Deeper samples were obtained at 26 Soil Bores (SB01 – SB26), predominately across PFAS source areas on the airport. Soil samples were taken at 0.1, 0.5, 1 and 1.5 m below ground (or where there was a change in lithology), with between two and four of these samples then analysed.

Two charts showing the relation of total PFOS concentrations with depth are provided in **Figure 18** and **Figure 19** below.

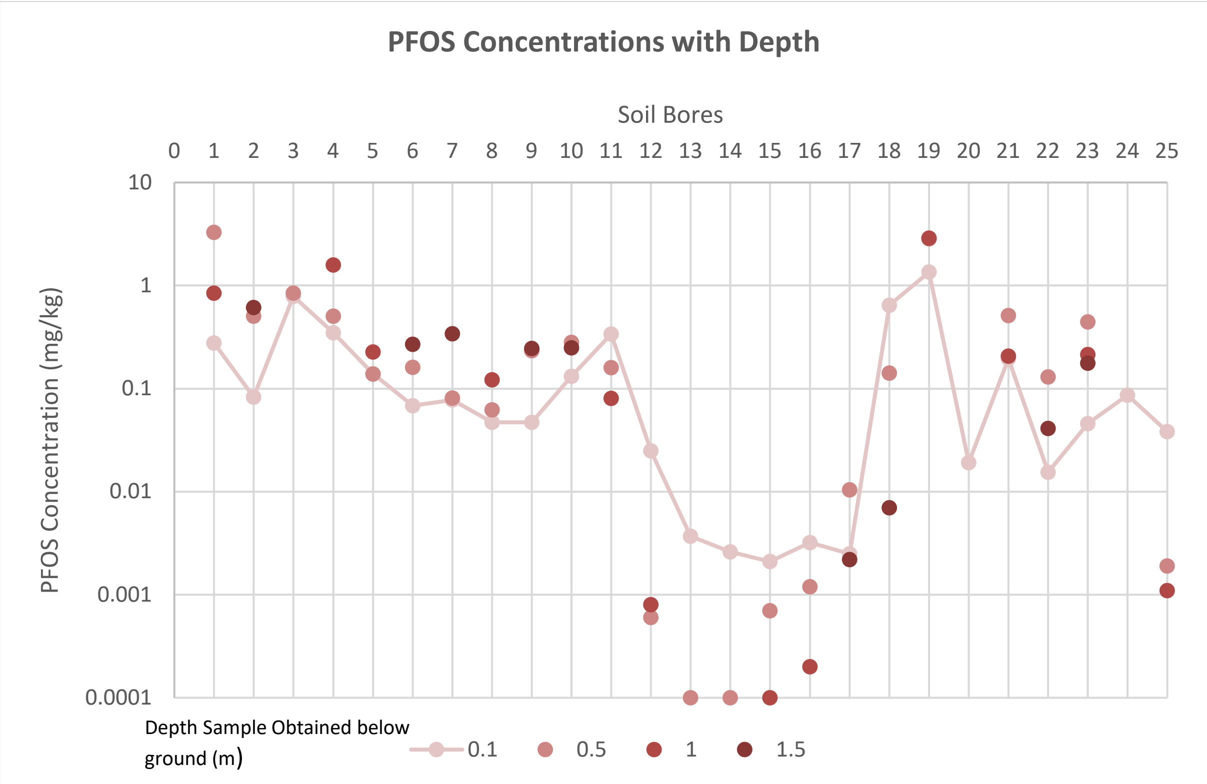

Figure 18: PFOS Concentrations with Depth (Logarithmic Graph of All Soil Bores)

A summary of the soil bores with higher surficial concentration is provided in **Figure 19** below to assist in assessing variation with depth in key source areas.

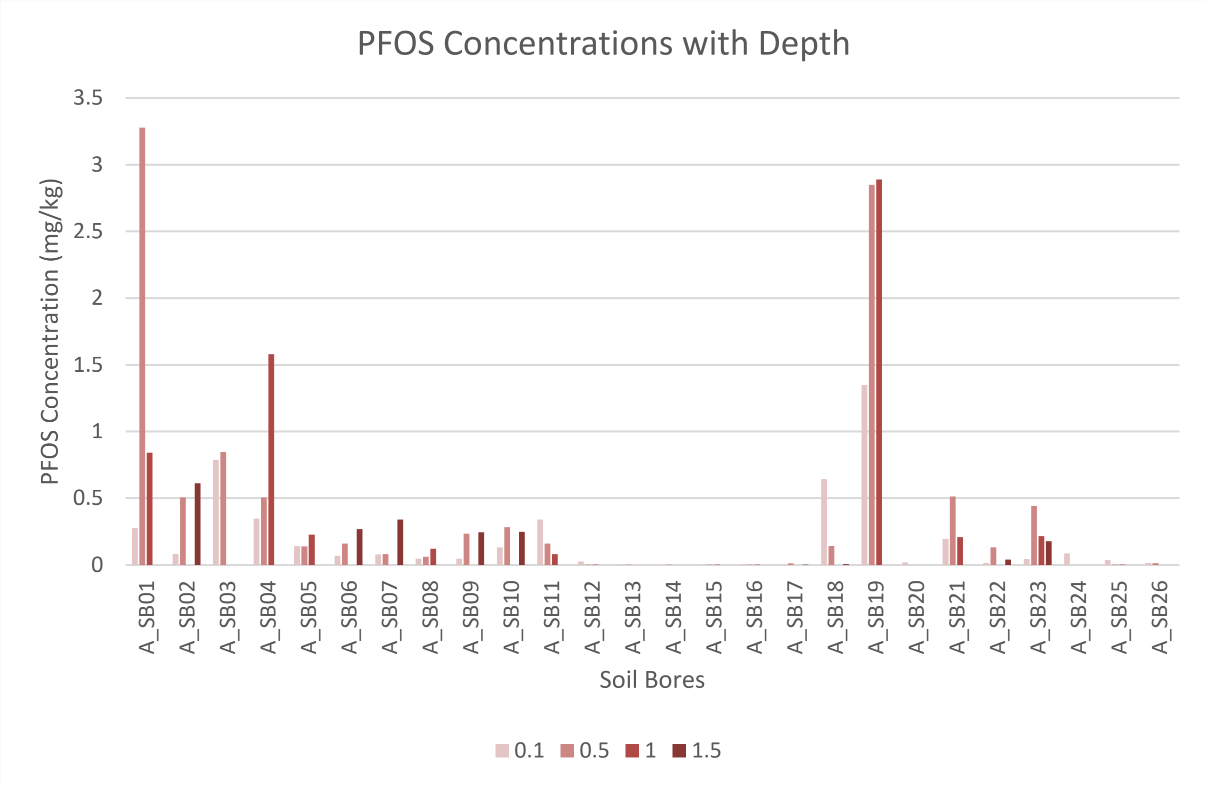

Figure 19: PFOS Concentrations with Depth (Soil concentrations above 0.05 mg/lg)

Key Findings:

- In the middle of source areas where concentrations of PFOS are highest, concentrations generally increased with depth.
- Eight of the 26 soils bores had the highest PFOS concentration at depth indicating that portion of the source area could represent a source of groundwater contamination.
- However, where surficial PFAS concentrations were relatively below low (i.e. below 0.05 mg/kg), the PFAS concentrations decrease with depth.

In most cases, the investigation of deeper concentrations was not considered feasible due to presence of basalt rock.

Based on the assessment undertaken, where concentrations of PFOS+PFHxS are greater than 0.05 mg/kg, concentrations of PFAS increased with depth meaning that soil in this location is considered likely to represent an ongoing potential source of PFAS groundwater contamination.

7.1.6 PFAS in Soil Leachability and Mobility

Soil leachability results discussed in **Section 7.2.6**, a summary of which for key source areas is provided below.

PFOS leachability (Australian Standard Leaching Protocol (ASLP)) results for selected samples (**Table B4**) ranged between <LOR of 0.01 µg/L and 226 µg/L (ASS109 – PS04: Current Drill Ground). A graph showing the relationship between the leachable concentration and total concentration for the highest PFAS soil sample from PFAS Sources Areas 1 – 8, 11 is shown below.

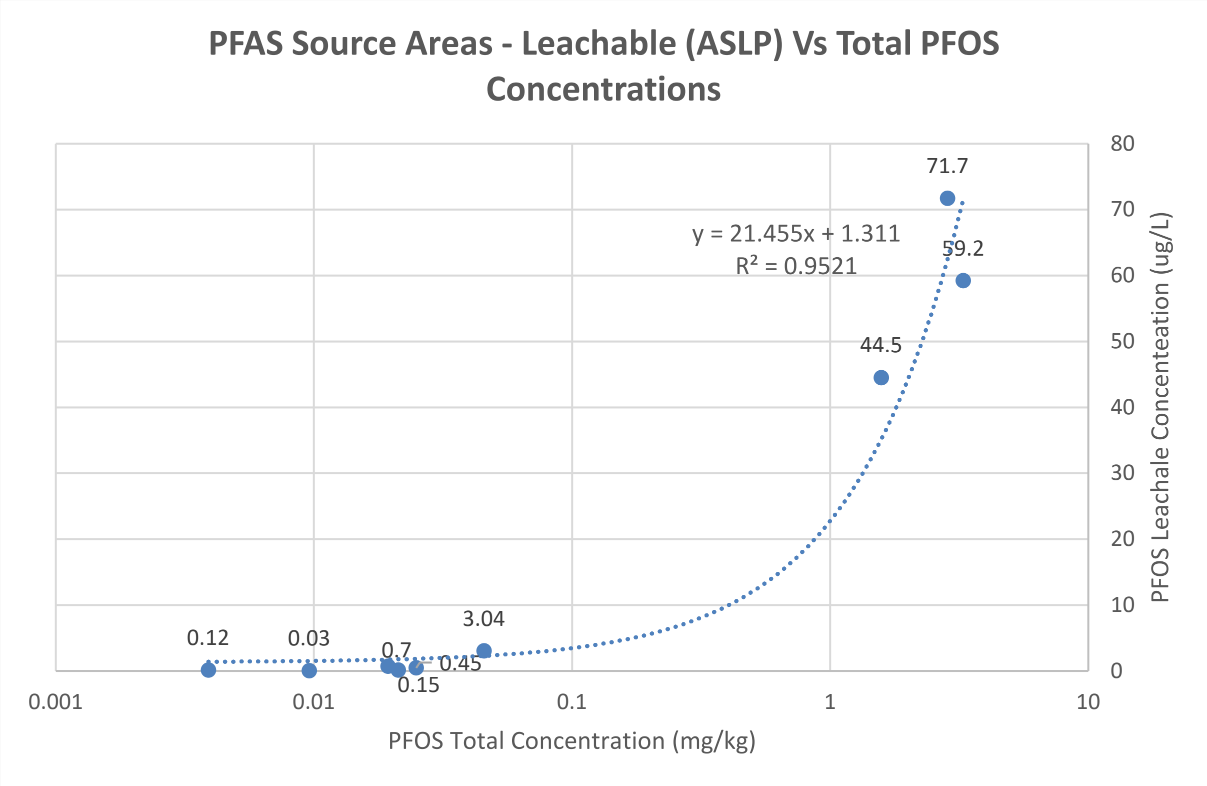

Figure 20: Plot of PFOS Leachability and Total Concentrations (PFAS Sources Areas 1 – 8, 11)

Review of **Figure 20** shows a strong positive correlation of increasing leachability with increasing total concentration in soil. This generally supports the argument assessment of total concentrations will provide a reasonable assessment of likely leachable run-off.

Review of the old drill ground (Legacy AFFF used up until mid-1990s) and the current drill ground (mid 1990s – until circa 2016), finds the following:

- PS03 (Former Drill Ground) – Leaching Ratio (ug/L : mg/kg): 43.85.
  - Average Leachable Concentrations of PFOS in Soil Bores: 2.28 ug/L.
  - Average Total Concentration of PFOS in Soil Bores: 0.052 mg/kg.
- PS04 (Current Drill Ground) – Leaching Ratio (ug/L : mg/kg): 0.75.
  - Average Leachable Concentrations of PFOS in Soil Bores: 0.713 ug/L.
  - Average Total Concentration of PFOS in Soil Bores: 0.955 mg/kg.

Based on this comparison, PFOS in the soils of the former drill ground are on average more leachable than PFOS in the soils of the current drill ground. The higher leaching ratio within soils of the Former Drill Ground may be associated with a number of different factors including:

- Differing soil type / compaction / preparation.
- Different formulations of legacy AFFF historically.
- The time since legacy AFFF was last applied to the soil.

7.1.7 PFAS Type in Soil Source Zones

Comparative analysis of the seven most prevalent PFAS in surface water samples (see **Section 4.4**) was undertaken on the soil samples with the highest PFAS concentration from each PFAS Source Areas 1 – 11. Soil concentrations on PFAS Source Areas 12 – 17 (all potential source areas) were either on private property, or a relevant sample was not able to be to be obtained (See **Table B1** for more detail).

This analysis is presented as a 100% stacked bar chart and total concentration stacked bar chart shown in **Figure 21** and **Figure 22** below.

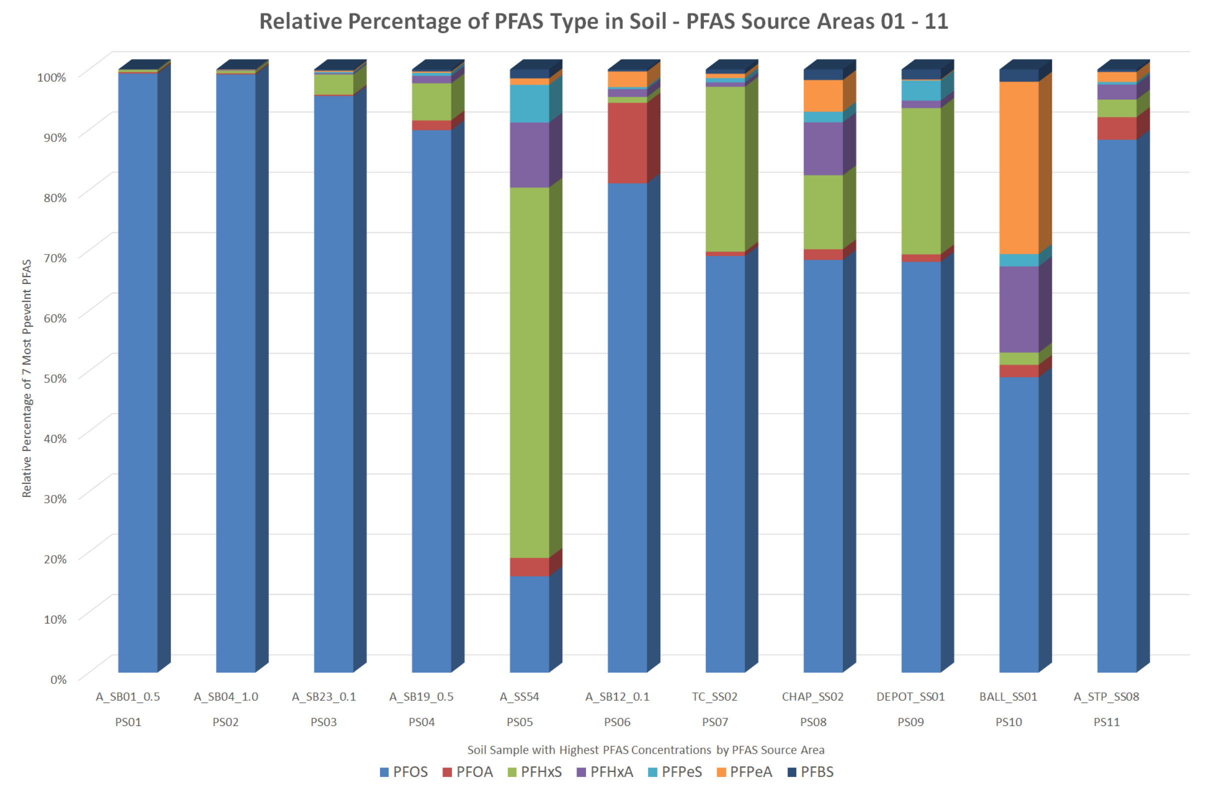

Figure 21: Relative Percentage of PFAS Type in Soil in PFAS Source Areas 01 - 11

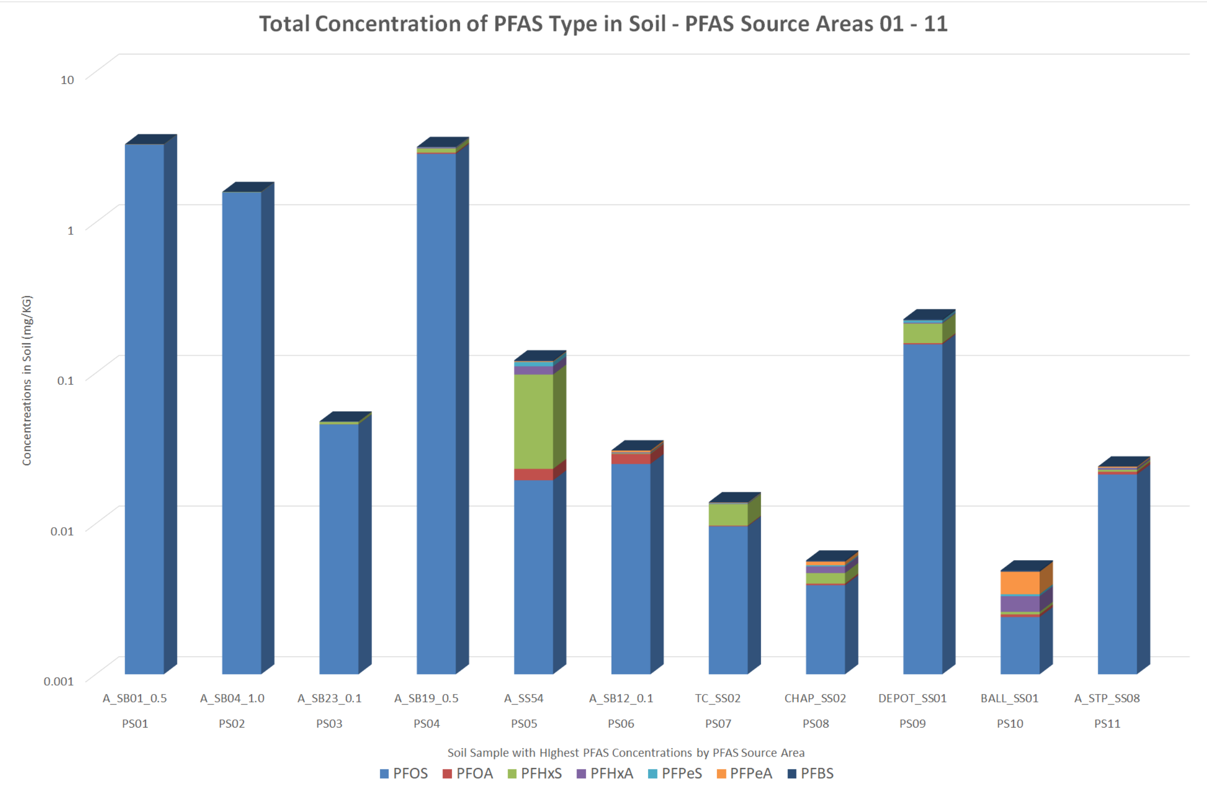

Figure 22: Total concentration of PFAS Type in Soil in PFAS Source Areas 01 - 11

Key findings:

- The maximum concentration of PFOS from PFAS Sources Areas 1 (Former Fire Station and Foam Shed), 2 (Former Flushing Out Area) and 4 (Current Drill Ground) was orders of magnitude larger than the other source areas.
- Review of the PFAS type signatures suggest that the proximity to another source area (potentially more so than the type of source area) results in a similar PFAS signature. This can be seen with the PS01 and PS02; PS03, PS04, PS06 and PS11.
- PFOS dominated the percentage contribution (over 85%) for PFAS Source Areas 1 – 4 and 11.
- PFAS Source Area 5 (Maintenance Depot) had the most variable signature, with a significantly higher relative concentration of PFHxS present. Higher relative concentrations of PFHxS were also present at the off-site PFAS Source Areas 7, 8 and 9.
- PFAS Source Area 6 (Current Fire Station) had the highest relative concentration of PFOA present.
- Potential PFAS Source Area 10 (Ball Bay Refuelling Area) had the highest relative concentration of PFPeA present.

7.1.8 Sediment Laboratory Results

Sediment analytical results were compared to adopted screening criteria as summarised in **Table B3**. PFAS leachability results are included in **Table B4**. Laboratory certificates of analysis are provided within **Appendix I**. Sediment investigation locations and analytical results screened against human health and ecological screening criteria are presented on **Figure A9** and **Figure A10**. A summary of adopted human screening criteria exceedences are included in **Table 7-4** below.

Table 7-4: Summary of Sediment Screening Criteria Exceedences

Analyte	Adopted Screening Criteria (mg/kg)				Number of Primary Samples Analysed		Detectable Concentration Range (mg/kg)		Number of Detections		Number of Exceedences	
	Ecological[1]	Ecological[2]	Human Health[3]	Human Health[4]	On-Site	Off-Site	On-site	Off-site	On-site	Off-site	On-site	Off-site
Sediment Samples (0.0 m)												
PFOS	**1**	**0.01**	**-**	**-**	20	55	<0.0002 - 0.134	<0.0002 - 0.471	19	47	5[2]	29[2]
PFOS+ PFHxS	**-**	**-**	**0.01**	**20**	20	55	0.0003 - 0.141	<0.0002 - 0.524	20	47	6[3]	33[3]
PFOA	**10**	**-**	**0.1**	**50**	20	55	<0.0002 - 0.0058	<0.0002 - 0.0098	6	31	-	-

[1] Ecological – direct toxicity to terrestrial organisms (direct exposure)
[2] Ecological – secondary poisoning / bioaccumulation to terrestrial organisms (indirect exposure)
[3] Human Health – residential land use
[4] Human Health – commercial / industrial land use

7.2 Surface Water Investigation

7.2.1 Rainfall Conditions

Rainfall conditions and the presence of surface water at the site varied significantly between the PSI sampling in January 2020 and the DSI sampling conducted in March 2021, as illustrated by PFAS Source Area 1 looking west in both January 2020 (left) and March 2021 (right) in **Figure 23** below. The condition and colour of grass in area clearly demonstrates the difference in rainfall at the airport during this time.

Figure 23: PS01 looking west in January 2020 (left) and March 2021 (right)

During the PSI, Norfolk Island was observed to be extremely dry and suffering from an extreme water shortage. As a result, limited surface water was present in the ephemeral creeks and streams. **Figure 24** provides a summary of the previous 12 months of rainfall (2019) prior to the PSI sampling being undertaken.

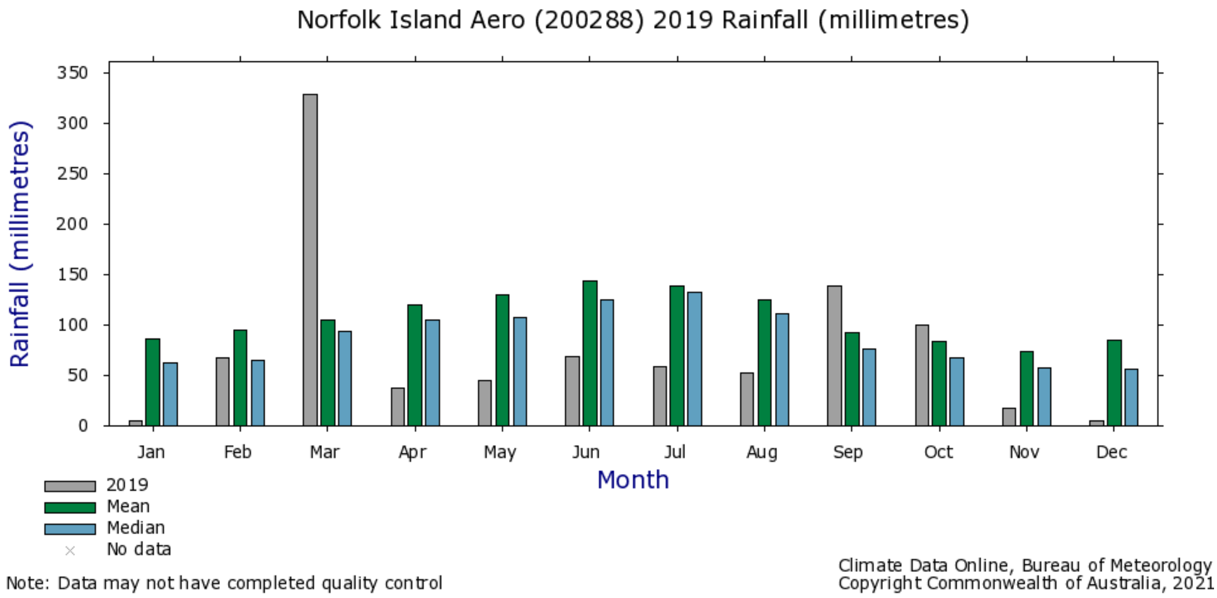

Figure 24: Graph of Mean and Median Monthly Rainfall Data vs 2019 Data for Norfolk Island Aerodrome (BoM, 2021a).

During the DSI, Norfolk Island was observed to be green and lush and is understood to have had reasonable recent rainfall leading up to the sampling works; this is shown in the 2020 month of November, which shows much higher than average rainfall, and this was also confirmed by anecdotal evidence from residents. Despite the recent rainfall, there remained limited surface water presence in the ephemeral creeks and streams. **Figure 25** provides a summary of the previous 12 months of rainfall (2020) prior to the DSI sampling being undertaken.

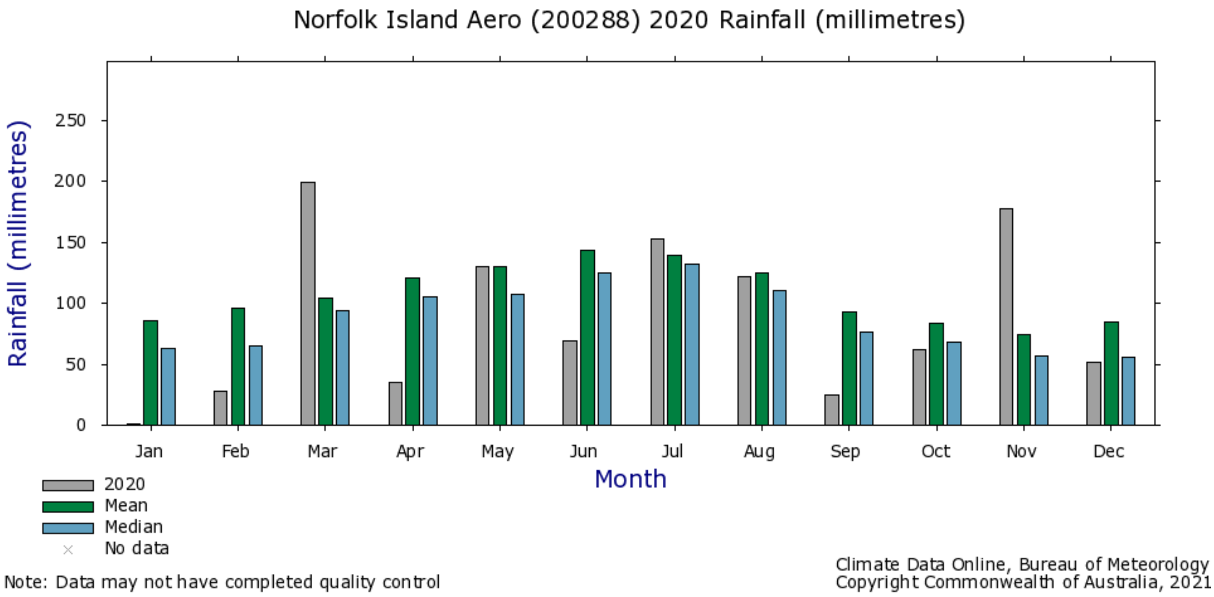

Figure 25: Graph of Mean and Median Monthly Rainfall Data vs 2020 Data for Norfolk Island Aerodrome (BoM, 2021a)

Overall, the rainfall data show there was a significant water shortage in 2019 with only three months recording higher than average rainfall and nine months of rainfall that was well below the averages. Rainfall data from 2020 shows significantly higher rainfall than 2019, with extremely higher than average rainfall in November 2020, which correlates with the La Niña event experienced in Australia and the tropical Pacific, from circa September 2020 to March 2021 (BoM, 2021b).

7.2.2 Surface Water/Sediment Conditions and Field Observations

Descriptions of surface water and sediment samples and observations during DSI sampling are presented in **Appendix L** and summarised in **Table 7-5** below. Sediment and surface water sample locations are presented on **Figure A9** and **Figure A10** (sediment) and **Figure A12** (surface water) for off-site locations.

Table 7-5: Summary of Sediment and Surface Water Conditions and Field Observations (2021)

Surface Water / Sediment Sample Location	Field Observations
On-site Open Drains	• No surface water was present in the open drainage lines and or culverts at or leading off the airport in 2021. A minor rainfall event occurred while sampling was being undertaken. The airport drains were surveyed immediately following rainfall and a day after rainfall and none of the drains contained standing/surface water. • Sediment samples collected from the onsite drains generally comprised brown clayey silt.
Off-site Drains	• No surface water was present in the drain locations adjacent the airport boundary. • Sediment samples collected from the offsite drains generally comprised brown clayey silt.

Surface Water / Sediment Sample Location	Field Observations
Creeks	• Broken Bridge Creek (Cascade Creek, Cockpit): ▪ Four sampling locations had surface water; private property ID012 (2 locations), cockpit weir and at the bridge under prince Phillip drive off Harper's road. ▪ Broken Bridge Creek at the rear of the Hospital was dry and appeared to have been dry for some time. ▪ Sediment was observed at all locations, except cockpit weir. Sediment generally comprised clayey silt and silt clay (brown, dark brown and red brown). • Headstone Creek: ▪ One sample from headstone dam and one sample from the outfall pipe collected. No other sampling locations. ▪ Sediment from headstone dam was a red brown silty clay. No sediment was observed in the outfall pipe area (large cobbles and concrete walls/banks). • Mission Creek and WWII Dam. ▪ 10 of 21 sample locations had surface water during DSI sampling. ▪ Sediment was sampled at all sampling locations (21) and comprised brown silty clay and sandy silts/clays (brown, dark brown and red brown). • Watermill Creek (Town Creek) ▪ 8 of 11 sample locations had surface water during DSI sampling. ▪ Sediment was sampled at all sampling locations (11) and generally comprised brown sand, silty clay and sandy silts/clays (pale brown, orange and orange brown). • Rocky Point Creek: ▪ Not sampled in DSI
Emily Bay	• One marine surface water and sediment sample was down hydraulic gradient of the outlet to Emily Bay (TC_SW07/SD07). • Two sediment samples (TC_SD08 and TC_SD09) were collected from a drainage channel with stone-lines walls/banks (sand base) before Emily Bay, and comprised fine grained pale brown/yellow sand (beach sand).

7.2.3 Surface Water Field Measured Parameters

Descriptions of surface water chemistry and field measurements collected during surface water sampling are presented in **Appendix L** and summarised in **Table 7-6** below.

Table 7-6: Summary of Surface Water Field Parameters

Sample Location	Field Parameters
On-site Open Drains	• No surface water was present during the DSI fieldworks.
Off-Site Drains, Creeks, Dams	• Field TDS concentration for all fresh surface water samples (calculated from EC using 0.65 conversion factor) ranged from 197 mg/L (DEPOT_SW01; a stormwater output pipe at the depot) to 3,793 mg/L (MC_SW04, an intermittently connected stagnant pond with no flowing water). Generally surface water was within the expected TDS range for freshwater streams. • pH ranged from 4.1 (Headstone Dam) to 8.1 (TC_SW12; town creek culvert under Pier St near) with average pH of 6.3 across the island, indicating neutral surface water pH. • Dissolved oxygen (DO) concentrations ranged from 0.16 mg/L (HC_SW01) to 9.42 mg/L (BBC_SW05) indicating a range of anaerobic to aerobic surface water conditions. • Temperature ranged from 19.5º C (MC_SW11) to 29.1º C (TC_SW05). • Redox potential ranged from -82.3 mV (MC_SW24) to 317.7 mV (PWS_HEAD_DAM), indicating a range of oxidising to slightly reducing surface water environments.
Offsite Marine	• Field TDS concentration for the marine sample TC_SW07 (calculated from EC using 0.65 conversion factor) was 40,490 mg/L, which is consistent with the expected TDS range of seawater. • pH, DO, temperature and redox for the marine sample were within the ranges in Off-Site Drains, Creeks, Dams presented above.

7.2.4 Surface Water Laboratory Results

Surface water results were compared to screening guidelines for potable and stock watering (applies for dams, irrigation channels/holding dams), human health – primary contact recreation (applies to drains, rivers, wetlands and lakes) and maintenance of ecosystems (applies to rivers, wetlands and lakes). Surface water analytical results have been compared to adopted screening guidelines and are summarised in **Table B5** and on **Figure A12.** Laboratory certificates of analysis are provided within **Appendix I**.

A summary of screening criteria exceedences from the most recent surface water sampling is included in **Table 7-7** below and discussed further in Nature and Extent of PFAS in Surface Water in **Section 8.3**.

Table 7-7: Summary of Surface Water Screening Criteria Exceedences

Analyte	Adopted Screening Criteria (μg/L)					Number of Locations Sampled		Detectable Concentration Range (μg/L)		Number of Location Detections		Number of Location Exceedences	
	MoE (90%)[1]	MoE (95%)[2]	MoE (99%)[3]	Pot/ SW[4]	PCR[5]	On-Site	Off-Site	On-Site	Off-site	On-Site	Off-site	On-site	Off-site
Creeks and Dams													
PFOS+ PFHxS	**-**	**-**	**-**	**0.07**	**2**	0	27	-	<0.01 - 39.9	-	21	-	21[4], 9[5]
PFOS	**2**	**0.13**	**0.00023**	**-**	**-**	0	27	-	<0.01 - 24.0	-	21	-	9[1], 12[2], 27[3]
PFOA	**632**	**220**	**19**	**0.56**	**10**	0	27	-	<0.01 - 1.25	-	10	-	2[4]

1 MoE - Maintenance of Ecosystems (90% Ecosystems Protection – Freshwater) – applicable to on-site
2 MoE - Maintenance of Ecosystems (95% Ecosystems Protection – Fresh water) -applicable to off-site water in moderately disturbed areas
3 MoE – Maintenance of Ecosystems (99% Ecosystems Protection - Fresh water) – applicable to off-site water in slightly disturbed areas
4 Pot/SW – Stock Watering and Potable Water (stock watering defaults to human drinking water guidelines) (applies to the PFOS+PFHxS)
5 PCR – Primary Contact Recreation (applies to the PFOS+PFHxS)

7.2.5 Summary of Impacts to Water Uses

Table 7-8 below summarises the impact that the identified contamination poses to the uses of surface water at and surrounding the site.

Table 7-8: Impacts to Uses of Surface Water

Water Use	Adopted Criteria Exceeded (Y / N)					Comments
	Mission Creek (upper)	Mission Creek (lower)	Broken Bridge Creek	Headstone Creek	Watermill / Town Creek	
Aquatic ecosystems	Y	Y	Y	N	Y	**Mission Creek (upper):** Exceedences of PFOS ecosystems criteria (95% and 99%) were recorded in Mission Creek. **Mission Creek (lower):** Exceedences of PFOS ecosystems criteria (95% and 99%) were recorded in Mission Creek. **Broken Bridge Creek / Cascade Creek:** Exceedences of PFOS ecosystems criteria (99% only) were recorded in Mission Creek. **Headstone Creek:** No PFAS detected, therefore no exceedences of ecosystems criteria (90%, 95% and 99%) were reported in Headstone Creek. **Watermill / Town Creek:** Exceedences of PFOS ecosystems criteria (95% and 99%) were reported in the upper portion of Watermill Creek (closest to the airport). Further down the creek, concentrations were below the 95%, but some exceedances of the 99%)
Primary and/or secondary contact recreation	Y	Y	N	N	N	**Mission Creek (upper):** Exceedences of PFHxS+PFOS were reported in upper Mission Creek samples. **Mission Creek (lower):** Exceedences of PFHxS+PFOS were reported in lower Mission Creek samples. **Broken Bridge Creek / Cascade Creek:** No exceedences were reported. **Headstone Creek:** No detections and hence no exceedences were reported in Headstone Creek. **Watermill / Town Creek:** No exceedences were reported in Watermill / Town Creek.
Aesthetic enjoyment	N	N	N	N	N	No observations of odour and/or visual amenity impact from PFAS were recorded during the site investigation.
Cultural and Spiritual Values	Y	Y	N	N	Y	As stated in **Section 6.2.2**, no specific guidelines are available. It is considered that criteria for other uses will also be protective of this use.
Stock Water	Y	Y	Y	N	Y	**Mission Creek (upper):** Exceedences of PFHxS+PFOS were reported in upper Mission Creek samples. **Mission Creek (lower):** Exceedences of PFHxS+PFOS were reported in lower Mission Creek samples. **Broken Bridge Creek / Cascade Creek:** One exceedence in stockwater was reported. **Headstone Creek:** No detections and hence no exceedences were reported in Headstone Creek. **Watermill / Town Creek:** Exceedences of PFHxS+PFOS were reported in of Watermill Creek samples.

Water Use	Adopted Criteria Exceeded (Y / N)					Comments
	Mission Creek (upper)	Mission Creek (lower)	Broken Bridge Creek	Headstone Creek	Watermill / Town Creek	
Drinking (Potable) Water	Y	Y	Y	N	Y	**Mission Creek (upper):** Exceedences of PFHxS+PFOS were reported in upperMission Creek samples. **Mission Creek (lower):** Exceedences of PFHxS+PFOS were reported in lower Mission Creek samples. **Broken Bridge Creek / Cascade Creek:** One exceedence in potable water was reported. **Headstone Creek:** No detections and hence no exceedences were reported in Headstone Creek. **Watermill / Town Creek:** Exceedences of PFHxS+PFOS were reported in of Watermill Creek samples.
Irrigation	NA	NA	NA	NA	NA	As stated in **Section 6.2.2**, relevant screening levels for this pathway are not available. Site-specific risk assessment will be recommended and undertaken for irrigated pastures and/or crops where PFAS are detected and water is used for irrigation (i.e. the HHERA process).
Aquaculture **Human consumption of fish, crustacea and molluscs**	Y	Y	N	N	Y	As stated in **Section 6.2.2**, no specific guidelines are available.
Industrial and commercial use	Y	Y	Y	N	Y	As stated in **Section 6.2.2**, no specific guidelines are available. It is considered that criteria for other uses (including potable water supply, primary contact recreation and stock watering) will also be protective of this use.

7.2.6 Comparative PFAS Species Retardation Analysis

As discussed in **Section 4.3,** the seven PFAS types present in at least 25% of surface water samples were assessed to provide a measure of the relative retardation of different PFAS.

The relative concentration of the seven PFAS types in six water samples obtained from down Mission Creek were compared to their 'initial' concentrations at the most up-gradient sample point, which was the WWII dam (near the Airport Bore). This assessment is provided **Figure 26** below, with the sample locations shown on **Figure A6K**.

Sample points from and near a branch of the Mission Creek (MC_SW34, MC_SW24 and MC_SW25) were excluded as they were not considered to represent an accurate measurement of relative retardation in surface water down-gradient of the WWII dam.

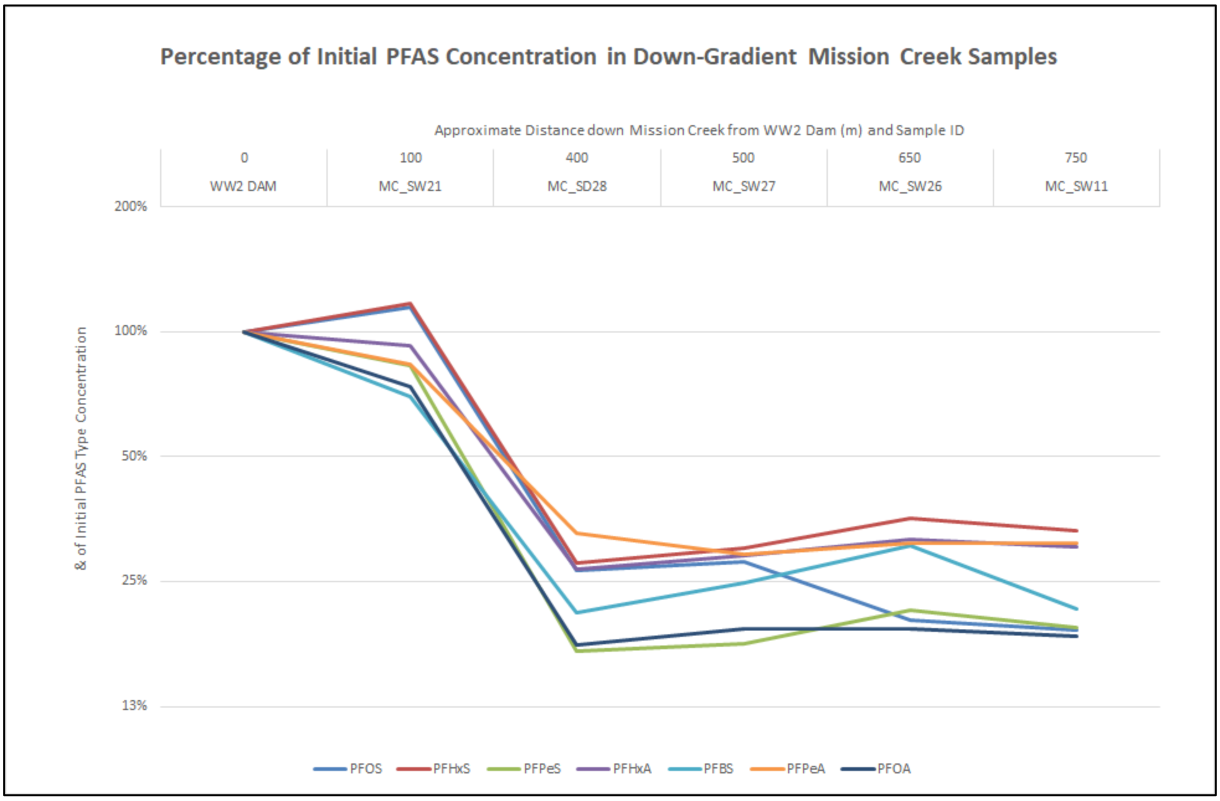

Figure 26: Percentage of Initial PFAS Concentrations in Down-Gradient Missions Creek Samples

Key findings from the assessment found that:

- PFPeA and PFHxA appeared to be retarded at a similar rate to PFHxS.
- PFPeS and PFOA appeared to be retarded at a similar rate to PFOS.
- The retardation of PFBS was variable between PFHxS and PFOS.
- PFHxS appeared to be the least retarded of the seven PFAS Types assessed.
- PFOA appeared to be the most retarded of the seven PFAS types.
- At sample point MC_SW11 (near the Chapel) PFOS was 19% and PFHxS was 33% of their initial WWII Dam concentrations.
- At WWII dam PFOS concentrations were almost twice PFHxS, while from 650 m down-gradient PFHxS had slightly higher concentrations than PFOS.

In conjunction with these surface water findings, at the centre of the key source zone up-gradient of the Mission Creek Catchment, (PS02 – Flushing Out Area) concentrations of PFOS were approximately 20 times higher than PFHxS (at sample ID A_SB04_0.1). The Flushing Out Area is located approximately 300 m up-gradient of the WWII dam.

Transport of PFAS between the Flushing Out Area and the WWII dam is considered likely to consist of a portion of groundwater and surface water flow (particularly in high rainfall events).

Based on this, PFOS appears to be retarded by at least 20 times more than PFHxS, through a combination of surface water and groundwater transport between surficial of primary source zone soils and 1km down-river. In surface water transport only within Mission Creek over a distance of approximately 6,450 m, PFOS appears to be retarded approximately twice as much than PFHxS.

7.3 Groundwater, Tank and Wastewater Investigation

7.3.1 Sampling Conditions

On-site (Airport) Groundwater Bore and Public Toilets (filled with airport bore water)

The on-site water supply extraction bore (Airport Bore), was sampled from the bore holding tank at the airport. Public toilets were sampled directly from the tap in or outside the toilets (same water source).

Tank Water (rainwater) – On-site and Depot

Tank water samples were collected from directly from three water tanks; two at the airport and one at the depot that use rainwater harvested from roofs and collected within tanks.

Offsite Groundwater

Four private properties with bore water used to fill tanks were sampled; one water sample was collected directly from the groundwater bore/well, and three samples were collected from tanks filled with directly with bore water.

Water (including taps and rainwater tanks off-site)

Water samples were collected from taps (point of use) at onsite and offsite locations including private properties. The following samples were analysed as part of this investigation:

- Seven tap water samples within airport.
- Three tap samples from the current fire station (in addition to airport tap samples above).
- Six samples from taps at the hospital.
- Seventeen samples from taps at private properties.

Furthermore, additional samples were collected (but not analysed) and water field measured parameters were collected (as discussed in **Section 7.3.2**)

Wastewater Treatment Plant

One sample of liquid was collected at the output pipe from the WWTP and analysed. The location was post treatment in a pit where the effluent feeds into the outfall pipe that leads to the ocean outfall. Additionally, samples were collected from the input pipe (before screening), from the output of the humus tank, from beneath the rotating biological contractors (RBC) and the effluent pond. These samples were not analysed, as the sample from the outfall pipe was considered most representative for the WWTP.

7.3.2 Water Field Measured Parameters

Descriptions of water chemistry and field measurements collected during water sampling are presented in **Appendix L** and summarised in **Table 7-9** below.

Table 7-9: Summary of Water Field Parameters

Sample Location	Field Parameters
Airport Bore and Public Toilets (airport bore water)	• Field TDS concentrations (calculated from field EC measurements) was 359 mg/L to 407 mg /L, which is considered fresh for groundwater. • pH was 5.61 to 7.5 indicating generally neutral pH. • DO ranged from 4.51 to 6.53 indicating aerobic water conditions. • Temperature was 24.5°C to 25.4°C. • Redox potential was 122 mV to 178.9 mV indicating a range of moderately oxidising water environments.
Tank Water (rainwater) Airport, Depot and Hospital	• Field TDS concentrations (calculated from field EC measurements) ranged from 21 mg/L (hospital tank) to 507 mg/L (depot tank). All tank samples (with the exception of the depot tank) were below 100 mg/L TDS. • pH ranged from 5.64 (airport tank) to 8.99 (hospital tank), indicating neutral to moderately alkaline conditions. • Dissolved oxygen (DO) concentrations ranged from 3.94 mg/L (hospital tank) to 6.44 mg/L (airport tank) indicating aerobic surface water conditions. • Temperature ranged from 22.8º C (airport tank) to 24.9º C (hospital tank). • Redox potential ranged from 82.6 mV (hospital tank) to 219 mV (airport tank), indicating oxidising conditions.
Offsite Groundwater	• Field TDS concentrations (calculated from field EC measurements) ranged from 335 mg/L to 530 mg/L, indicating relatively fresh groundwater. • pH ranged from 4.69 to 6.37 indicating neutral to moderately acidic conditions. • Dissolved oxygen (DO) concentrations ranged from 1.64 mg/L to 6.09 mg/L indicating aerobic surface water conditions. • Temperature ranged from 22.2º C to 24.1º C. • Redox potential ranged from 41.5 mV to 259 mV, indicating oxidising conditions. • Black organic matter and foam/bubbles was noted in water bailed from ID009_Well.
Water On and Offsite (including taps, rainwater tanks off-site)	• Field TDS concentrations (calculated from field EC measurements) ranged from 21 mg/L to 507 mg/L. • pH ranged from 4.64 (hospital tap), indicating slightly acidic water, to 10.07 (airport tap) indicating slightly alkaline water. • Dissolved oxygen (DO) concentrations ranged from 0.65 mg/L (private) to 8.13 mg/L (airport tap) indicating a range of anaerobic to aerobic water conditions. • Temperature ranged from 22.4º C (council tap – airport) to 30.7º C (private). • Redox potential ranged from 82.6 mV (hospital tank) to 271 mV (private), indicating oxidising water environments.
Wastewater Treatment Plant	• No water quality parameters were collected for the treatment plant samples (to due to potential biological hazards and contamination of equipment). • The sample collected was brown, slightly turbid, with a mild sewerage odour.

7.3.3 Laboratory Results

Airport Bore and Public Toilets (Airport Bore Water)

The on-site groundwater bore (airport bore) and on and off-site water analytical results compared to adopted screening criteria are summarised in Table B6.

The airport bore analytical results reported the highest concentrations of PFOA, PFOS, and PFOS and PFHxS from the March 2021 sampling, which exceed all adopted criteria.

Tap water from public toilets at three locations were sampled. The toilets are understood to be filled with airport bore water. Headstone (PWS_HEAD_TOILETS) and Cascade (PWS_HCAS_TOILETS) Public Toilets reported PFAS at concentrations above drinking and stock water, recreational water and ecological criteria.

Emily Bay Public toilets were below laboratory LOR for all PFAS.

Tank Water (Rainwater) Airport, Depot and Hospital

All tank water samples analysed at the airport, depot and hospital were below laboratory LOR for all PFAS.

Offsite Groundwater

Offsite groundwater bores were above the criteria for beneficial uses at three private properties within the Mission Creek Catchment. One property is to the west of the western airport boundary, one further west towards the western end of the island, and one to the north on the cusp of Mission Creek / Broken Bridge Creek Catchments.

Water On and Off site (including on and offsite taps and offsite rainwater tanks)

Drinking water exceedences were reported in water from a tap at airport (A_TAP4) in the former fire station (PS01), which is currently a mechanical/maintenance building. The sample was collected from the kitchen tap. Low level concentrations PFAS were reported in water from the airport terminal female and male toilet basins (A_TAP1 and A_TAP2, respectively), and the Bureau of Meteorology tap (A_TAP5), but were below drinking water criteria. Historically, airport bore water was used as water supply to these areas and the concentrations may be indicative of residual PFAS in infrastructure (i.e. pipework).

All other airport taps sampled and analysed (current fire station, council (at airport), maintenance depot) were below laboratory LOR for all PFAS.

A majority of offsite water (tank and tap water) samples were below laboratory LOR. One private property tap (ID024_TAP1) within the Mission Creek catchment reported PFAS at concentrations that exceeded drinking and stock water, recreational water and ecological criteria. Alternative water supply is in place at this location.

Reported concentrations of PFAS in tank water (rainwater) at the airport, depot and hospital were all below the criteria for adopted beneficial uses.

Wastewater Treatment Plant

The WWTP was sampled from the output pipe at the treatment plant that is understood to discharge to the ocean to the south of Headstone Creek mouth. No further treatment is understood to occur once the wastewaters leave the treatment plant before discharge to ocean. The one sample obtained from the outlet of the WWTP found concentrations of PFOS and PFHxS of 0.24 µg/L.

Laboratory certificates of analysis are provided within **Appendix I**.

7.3.4 Impacts to Water Uses

Table 7-10 below summarises the impact that the identified contamination poses to the uses of surface water at and surrounding the site.

Table 7-10: Impacts to Uses of Water

Water Use	Use Potentially Precluded (Y / N)					Comments
	Airport Bore and Public Toilets (PT)	Tank Water	Offsite Groundwater	Water On- and Offsite (taps/tank)	WWTP	
Aquatic ecosystems	Y	N	Y	Y	Y	**Airport Bore and PT:** PFOS exceeds ecosystems criteria (90%) in airport bore, cascade and headstone public toilets. Emily bay toilets were below detection limit for all PFAS. **Tank Water:** No exceedences of ecosystems criteria (90% and 95%) reported. **Offsite Groundwater:** Exceedences of PFOS ecosystems criteria (95% and 99%) in three of the four bores; no exceedences in Ecosystems 90% criteria. **Water (taps and tanks):** No exceedences of ecosystems criteria 95%, with the exception of one private property tap sample. **WWTP:** The treatment plant exceeded 95% and 99% ecosystems criteria, but not 90%.
Primary and/or secondary contact recreation	Y	N	Y	N	N	**Airport Bore and PT:** PFHxS+PFOS exceeds recreational criteria in airport bore, cascade and headstone public toilets. Emily bay toilets were below detection limit for all PFAS. **Tank Water:** No exceedences of recreational criteria were reported. **Offsite Groundwater:** Exceedence of PFHxS+PFOS at one private property (triplicate exceeds, primary and duplicate are below the criteria). **Water (taps and tanks):** No exceedences of recreational criteria. **WWTP:** No exceedences of recreational criteria.
Aesthetic enjoyment	N	N	N	N	N	No observations of odour and/or visual amenity impact from PFAS were recorded during the site investigation.
Cultural and spiritual values (indigenous and/or non-indigenous)	Y	N	Y	Y	Y	As stated in **Section 6.2.2**, no specific guidelines are available. It is considered that criteria for other uses will also be protective.
Stock water	Y	N	Y	Y	Y	**Airport Bore and PT:** PFHxS+PFOS exceeds stockwater criterion in airport bore, cascade and headstone public toilets. PFOA exceeds criterion in airport bore and headstone toilets. Emily bay toilets were below detection limit for all PFAS. **Tank Water:** No exceedences of stock water criteria were reported. **Offsite Groundwater:** Exceedences of PFHxS+PFOS in groundwater at all four private properties. **Water (taps and tanks):** Exceedences of PFHxS+PFOS in tap water at airport and one private property. **WWTP:** Exceedences of PFHxS+PFOS in the WWTP (A_STP_OUT) output sample.

Water Use	Use Potentially Precluded (Y / N)					Comments
	Airport Bore and Public Toilets (PT)	Tank Water	Offsite Groundwater	Water On- and Offsite (taps/tank)	WWTP	
Drinking (Potable) Water	Y	N	Y	Y	Y	**Airport Bore and PT:** PFHxS+PFOS exceeds drinking water criterion in airport bore, cascade and headstone public toilets. PFOA exceeds criterion in airport bore and headstone toilets. Emily bay toilets were below detection limit for all PFAS. **Tank Water:** No exceedences of drinking water criteria were reported. **Offsite Groundwater:** Exceedences of PFHxS+PFOS in groundwater at all four private properties. **Water (taps and tanks):** Exceedences of PFHxS+PFOS in reticulated water at airport, one private property tap and the WWTP. **WWTP:** Exceedence of PFHxS+PFOS in treatment plant.
Irrigation	N/A	N/A	N/A	N/A	NA	As stated in **Section 6.2.2**, relevant screening levels for this pathway are not available. Site-specific risk assessment will be recommended and undertaken for irrigated pastures and/or crops where PFAS are detected and water is used for irrigation.
Aquaculture **Human consumption of fish, crustacea and molluscs**	Y	N	Y	Y	Y	As stated in **Section 6.2.2**, no specific guidelines are available. It is considered that criteria for other uses will also be protective.
Industrial and commercial use	Y	N	Y	Y	Y	As stated in **Section 6.2.2**, no specific guidelines are available. It is considered that criteria for other uses will also be protective.

7.4 Biota Investigation

7.4.1 Sampling Conditions

Grass

Grass sampling was completed in conjunction with (co-located) soil sampling at 17 locations at the airport (on-site). Airport biota samples were collected from areas across the site where grass is mown and the clippings fed to cattle (anecdotal evidence from airport staff). The condition of grass during sampling was good (green and lush).

Four biota sample (grass) from Mission Creek were collected from the creek bed and co-located with sediment and surface water samples (where surface water was present).

A minimum of 200g of green grass (no soil or roots attached) was collected for analysis.

Chicken Eggs

One chicken egg was collected from a private property (ID013_Biota2). The egg, which was laid on the same day of sampling, was collected from a chicken coop. The water used to water the chickens at this end of the hen house was understood to have been pumped from Mission Creek, which was sampled at the point of use (ID013_SW01). Approximately 80% of chickens in the hen house were watered with rainwater collected from the property.

Fruit, Vegetables and Herbs

Six biota samples were collected from a single private property, which included pawpaw (ID013_Biota1), mango (ID013_Biota3), capsicum (ID013_Biota4), basil (ID013_Biota5), chives (ID013_Biota7), and parsley (ID013_Biota8). Biota samples were paired with surface soil samples.

7.4.2 Biota Laboratory Results

Grass Analytical Results

There is currently no regulatory framework or quality objectives for the assessment of grass or consumption of grass by animals and then subsequent human consumption. Of the 21 sample locations, six locations reported detectable PFAS. Three locations were within the airport and three locations within Mission Creek.

Egg Analytical Results

The egg sampled as part of this investigation from private property ID013 reported 0.004 mg/kg for PFOS and 0.009 mg/kg for PFHxS + PFOS. These PFOS concentrations do not exceed the poultry egg for human consumption standard of 0.011 mg/kg for investigation derived by FSANZ (2017).

Fruit, Vegetables and Herbs Analytical Results

All six fruit, vegetable and herb samples collected and analysed were below detection limits for all PFAS.

7.4.3 Impacts to Biota Use

Table 7-11 below summarises the impact that the identified contamination poses to the use at and surrounding the site. The assessment of impacts to the consumption of the biota does not extend to the grass samples as there are currently no criteria for assessing this use.

Table 7-11: Impacts to Uses of Biota

Biota Use	Biota Use Potentially Precluded (Y / N)			Comments
	Grass (on and offsite)	Eggs (offsite)	Fruit, Vegetables and Herbs	
Food for Human Consumption - Poultry eggs	NA	N	NA	No exceedences for the egg sample. There is a limited data set (one sample), however the risks cannot be excluded based on one sample. Further discussion is provided in Section 7.4.4.
Food for Human Consumption - Fruits (all)	NA	NA	N	No detections and no exceedences in criteria for all biota samples. Four biota samples reported detectable PFAS. Three locations were within the airport and one location within Mission Creek (MC_Biota13).

Biota Use	Biota Use Potentially Precluded (Y / N)			Comments
	Grass (on and offsite)	Eggs (offsite)	Fruit, Vegetables and Herbs	
				Food for human consumption is not considered to be precluded offsite (where tested),
Food for Human Consumption - Vegetables (all)	NA	NA	N	No detections and no exceedences in criteria for all biota samples. Four biota samples reported detectable PFAS. Three locations were within the airport and one location within Mission Creek (MC_Biota13).

7.4.4 Uptake of PFAS into Biota from Impacted Media

Grass

PFAS was below detection limits for grass samples at a majority of locations at the Airport. Detections of PFAS were reported in three areas of the airport: one adjacent the former fire drill ground (PS04); one on the southwest corner of where the two runways intersect; and one in the Former Flushing Area (PS02). PFAS were detected is grass at three of the four Mission Creek sampling locations. PFAS reported in grass samples from the Airport and Mission Creek samples were generally low concentrations.

The surface soil samples (where paired) at these locations also detected PFAS. The Mission Creek biota grass samples were paired with surface water and sediment samples, with all samples detecting PFAS.

Analysis of the reported results showed limited correlation between PFOS concentrations in soil/sediment compared with biota PFOS concentrations with r^2 values of 0.3874 for the Airport and 0.0012 for Mission Creek samples, as shown in **Figure 27** and **Figure 28**, respectively.

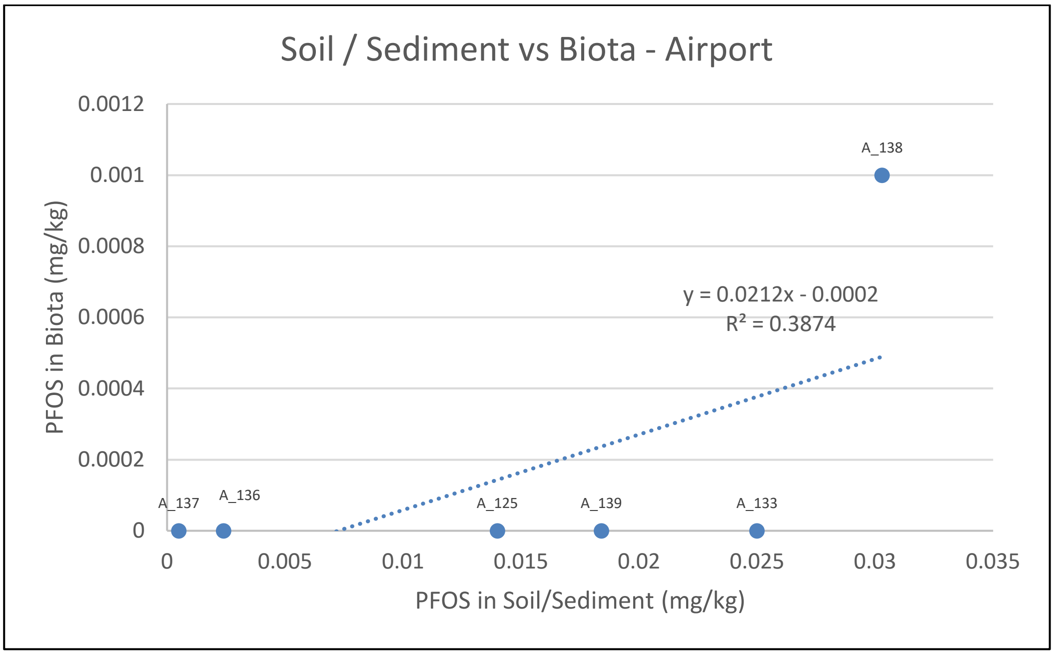

Figure 27: Correlation between Soil / Sediment and Biota Concentrations – Airport

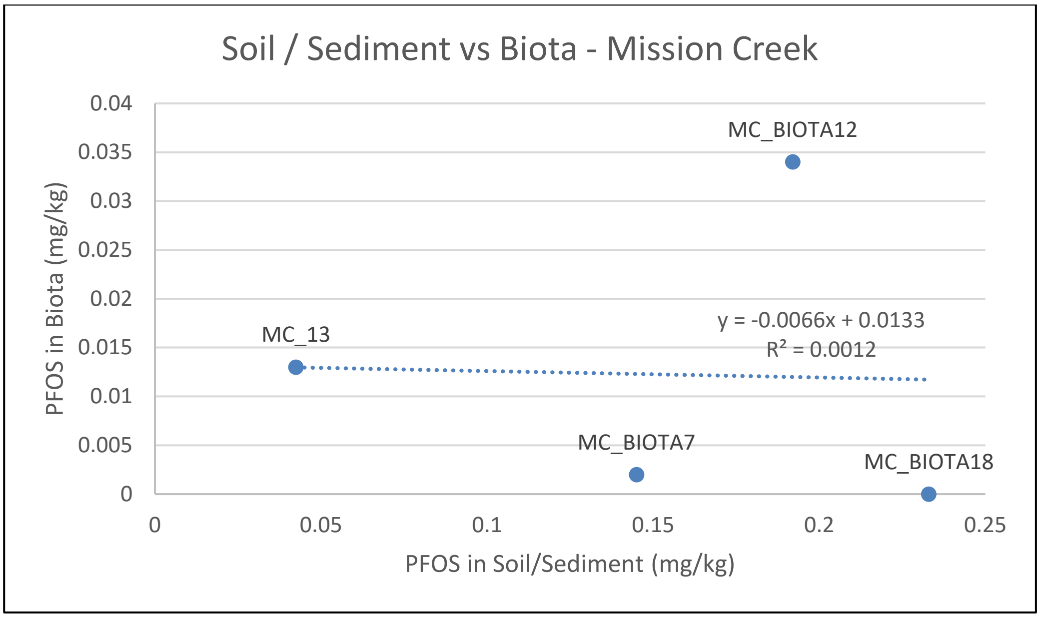

Figure 28: Correlation between Soil / Sediment and Biota Concentrations – Mission Creek

The results indicate that there is no correlation between soil and grass PFAS concentrations based on the four samples obtained. The lack of correlation is considered likely due to the small data set and low level concentrations being assessed.

Egg Analytical Results

The egg sampled as part of this investigation from private property ID013 was from chickens watered with water containing PFAS. Surface water pumped from Mission Creek (which is understood to be used for chicken watering) exceeds ecological, potable and stockwater criteria. The egg was also paired with surface soil sample, which had reported concentrations of PFAS that exceeded Human Health and Ecological (indirect exposure) soil criteria. Water provided to the chickens is understood to be surface water pumped from Mission Creek, which was sampled (ID013_SW01) and found to exceed stock water criteria. A summary of the analytical results for the co-located egg, soil and water samples is presented in **Table 7-12**.

Table 7-12: Comparison of Co-located Egg, Soil and Water Analytical Results

Media	PFOS+PFHxS	PFOA
Water used for chickens (ID013_SW01)	2.84 ug/L	0.05 ug/L
Soil in chicken coop (ID013_SS02)	0.0171 mg/kg	0.0006 mg/kg
Egg from chickens (ID013_BIOTA2)	0.009 mg/kg	<0.001 mg/kg

The results show there is some uptake of PFAS in eggs (this is expected to predominantly from drinking water), however the levels were below the human consumption standard in FSANZ (2017).

It should be noted that the result is marginally below the guideline value, and given the sample size (n=1), potential variance in the concentration reported cannot be assessed. PFOS+PFHxS concentrations reported in eggs can vary significantly, based on the PFAS in the environment in which the chickens are exposed (i.e. stock water, food, soil). Furthermore, the guideline value is based on an assumed egg consumption rate for the 90th percentile (P90); should the actual consumption rate be greater (or when there is potential PFAS uptake through other media), then the exposure would be assumed to be greater.

Fruit, Vegetables and Herbs Analytical Results

All fruit, vegetable and herb samples collected and analysed were below detection limits for all PFAS. The selected biota were known to be currently or historically irrigated with water containing PFAS. All surface soil samples (where paired with biota) detected PFAS, however were below the adopted human health and ecological criteria for soil. The results show there has been no uptake of PFAS into biota irrigation water or soils impacted by irrigation water.

Laboratory certificates of analysis are provided within **Appendix I**.

8.0 Findings

8.1 Nature and Extent of Soil Impacts

8.1.1 On-Site PFAS Source Areas 1 - 6

The interpolated aerial extent of PFAS impacted surficial soils associated with the seven PFAS source areas at the airport is shown in **Figure 29** (further information provided in **Figure A7a** in **Appendix A**) below. The interpolation does not take into account the bitumen runway or aprons, however they are also likely to be impacted by PFAS and potentially represent on-going sources of surface water contamination.

Low level concentrations of PFOS+PFHxS are present across all areas the airport. However, assessment of PFAS concentrations beneath the surface found higher concentrations of PFOS+PFHxS present beneath the surface (at 0.5, 1 and 1.5+ m below ground) where surficial soil concentrations exceed 0.05 mg/kg. Where surficial soil concentrations were less than 0.05 mg/kg, the highest PFAS concentrations are anticipated to be at the surface and therefore soil below this concentration is not anticipated to act as a source of groundwater contamination (and likely be a low level source of surface water contamination at best).

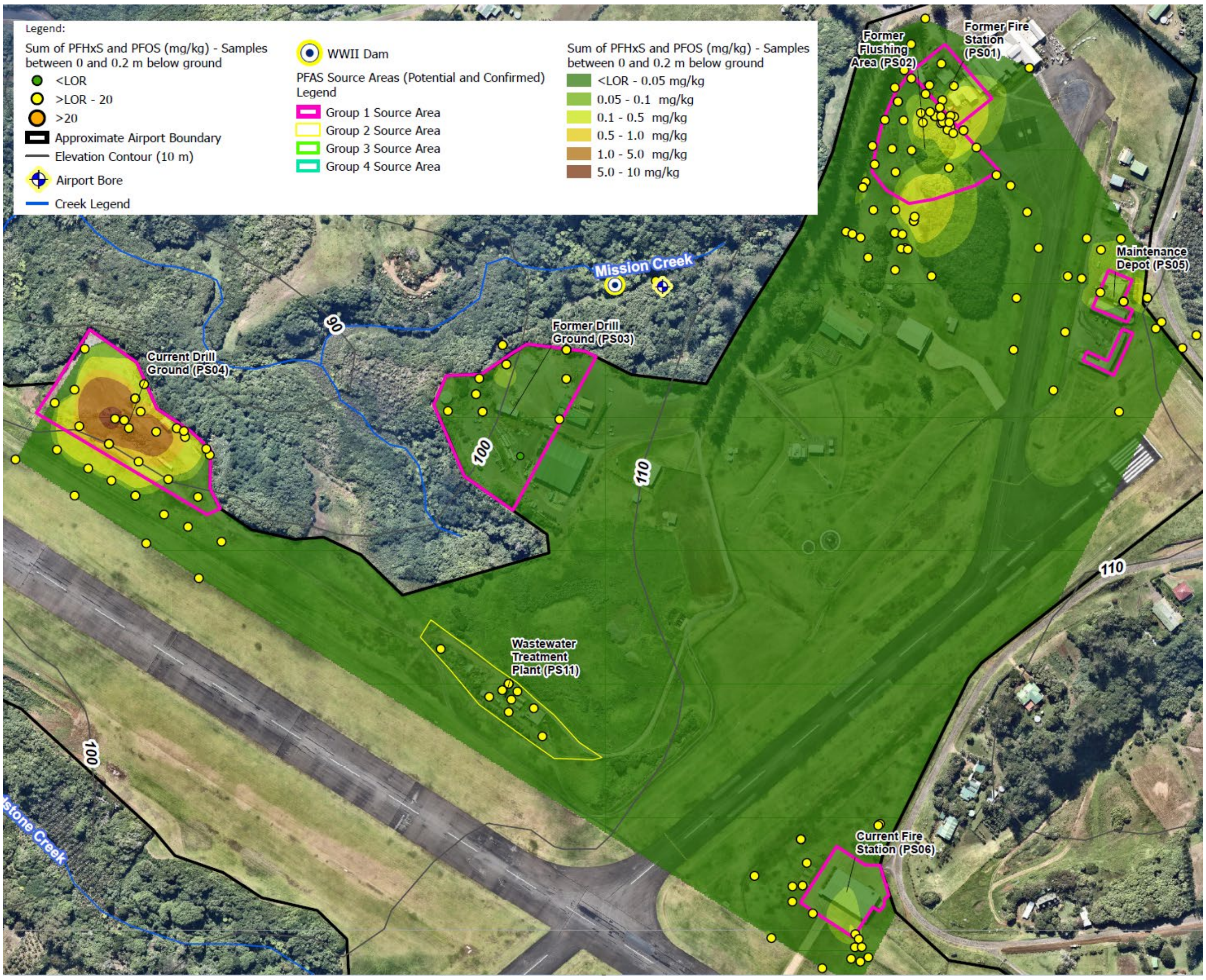

Figure 29: Surficial Soil Concentrations of PFOS and PFHxS

Concentrations of PFOS+PFHxS appear to be highest at Source Area 4 (Current Drill Ground) which is expected as this was where Legacy AFFF was used most recently.

PFAS Sources Areas 1 and 2 are considered to be the primary source of PFAS identified in groundwater at the Airport Bore and within surface water at the WWII Dam. PFAS Source Areas 3 and 4 are likely contributing to PFAS concentrations in surface waters below the WWII dam within Mission Creek.

8.1.2 PFAS Source Area 11 – Wastewater Treatment Plant

PFOS+PFHxS concentrations below 0.05 mg/kg were identified in soil around WWTP located near the middle of the airport. These concentrations were up to three orders of magnitude lower than for other PFAS Source Areas 1, 2 or 4.

Figure 30 below shows the sample locations taken from around the WWTP with the with further information provided in **Figure A6G** (in **Appendix A**).

Figure 30: Wastewater Treatment Plant – Sample locations

PFAS was identified in wastewater at the WWTP, with the concentration of PFOS+PFHxS being 0.24 ug/L.

Based on the known location of the sewer (see **Section 3.6**), as the sewer passes under or near PFAS Source Areas 1, 2 and potentially a portion of 3, there is potential for at least a portion of the PFAS present in the sewer to be derived from infiltration of PFAS contaminated groundwater into the leaking sewer. Alternatively, the potentially leaking sewer may also be acting as a source of PFAS (and other pollutants) contamination to groundwater both up to the airport and between the airport and discharge point south of Headstone Creek.

Other potential sources of PFAS in the wastewater of the Norfolk Island WWTP include:

- Domestic sources of PFAS used in everyday household products (i.e. not legacy AFFF).
- Historical (and potentially current) use of the Airport Bore for water supplies / toilet flushing.

A summary of PFAS-impacted water use is presented in **Table 2-4** in **Section 2.7**.

To assess the makeup of the PFAS in wastewater, the relative percentage of the seven most common PFAS types found on the island was compared with the wastewater sample and 11 PFAS Source Areas in **Figure 31** below.

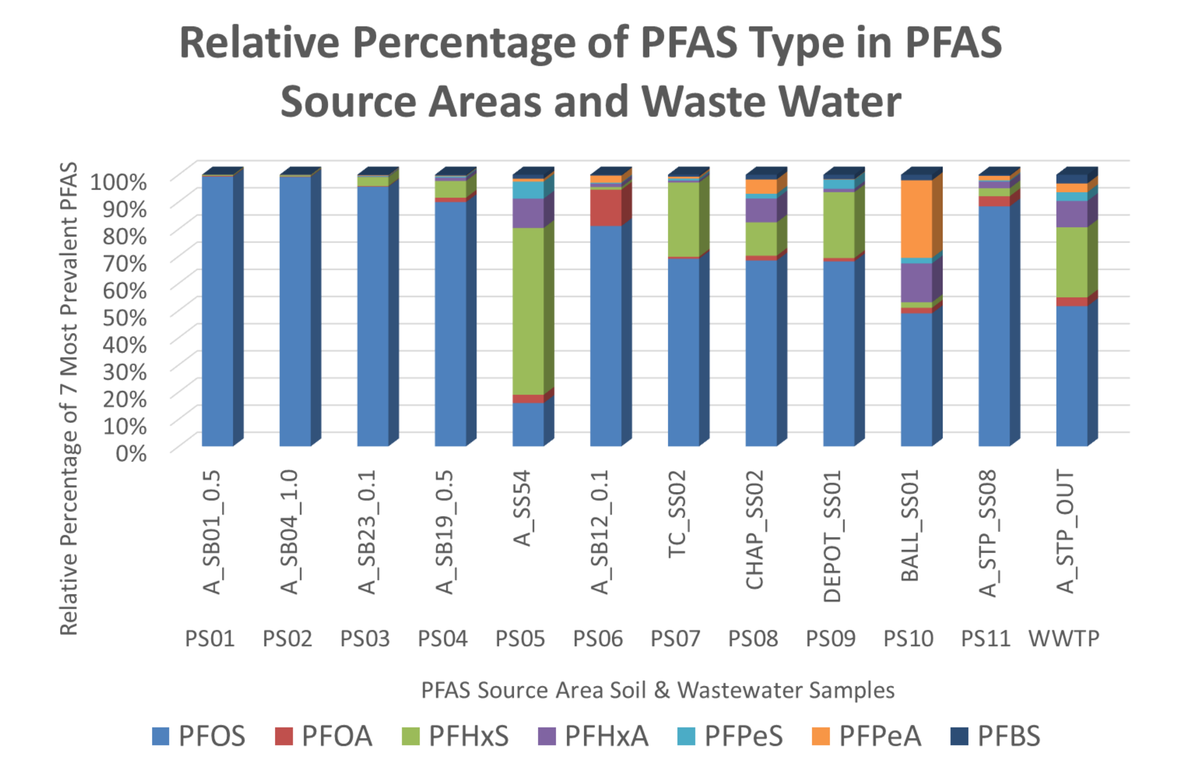

Figure 31: Relative Percentage of PFAS Type in PFAS Source Areas and Wastewater

Review of the relative percentage of PFAS types in wastewater found that it has a much lower level of PFOS that the PFAS source areas (1,2 and potentially 3) that the sewer passes underneath. The PFAS Type ratios appear more similar to Group 2 Source Areas (such as PS07 – PS10) where infrequent application of Legacy AFFF occurred or Airport Bore derived water was utilised.

Therefore, the lower relative concentration of PFOS in wastewater is considered likely to be a result of the higher retardation of PFOS as water migrates through the surficial soil source areas, and / or associated with different sources of PFAS (i.e. domestic products) present in the wastewater.

Concentrations of PFOS+PFHxS in a recent study of 19 Australian WWTPs (Coggan et. Al., 2019) found the following with relation to PFOS+PFHxS concentrations:

- Average PFOS: 0.015 µg/L with a maximum of 0.14 µg/L.
- Average PFHxS: 0.013 µg/L with a maximum of 0.2 µg/L.

Based on this comparison, the reported PFOS+PFHxS concentration in Norfolk Island's wastewater is approximately an order of magnitude higher than the average concentrations reported at the 19 Australian WWTPs. However, the maximum concentration at one of the Australian WWTPs was approximately twice as high than the Norfolk Island WWTP. The presence of PFAS in WWTPs is not uncommon, however the elevated levels reported at Norfolk Island WWTP are likely attributed to uses of impacted groundwater.

The presence of PFAS within wastewater should be taken into account as a part of planned upgrades to the WWTP and potential reuse of wastewater.

8.1.3 Off-Site Source Areas

The DSI investigation confirmed the location of the off-site PFAS source areas identified in the PSI. Based on the assessment undertaken, concentrations in soil and sediments within the potential source areas were found not to represent an unacceptable risk based on their current use. Although, the PFAS in soil still represents a source of PFAS contamination in surface water and groundwaters, the PFAS mass flux associated with these source areas is considered likely to be orders of magnitude less than the mass flux of the seven PFAS source areas identified on the airport, given the total concentrations across the airport were, on average, significantly higher than the offsite source areas. For example, the average PFHxS+PFOS reported for Depot was 0.0215 mg/kg and the Chapel was 0.0027 mg/kg, whilst airport source zones PS01 (0.4428 mg/kg), PS04 (0.7105 mg/kg), PS05 (0.0438 mg/kg) and overall airport concentrations (0.1748 mg/kg) were significantly higher.

Whilst mass flux was not calculated as part of this assessment, based on the assessment undertaken no unacceptable risks to human health receptors associated with off-site source areas were identified.

8.2 Nature and Extent of PFAS in Sediment

8.2.1 Mission Creek Catchment

Sediment samples from the Mission Creek catchment reported the highest PFAS concentrations at adjacent to PFAS Source Zones (PS03, PS04, PS05 and PS08). However, as with the surface water results, sediment samples generally decreased in concentrations at each downstream location within Mission Creek.

The concentration gradients along Mission Creek are shown in **Figure** 32 below.

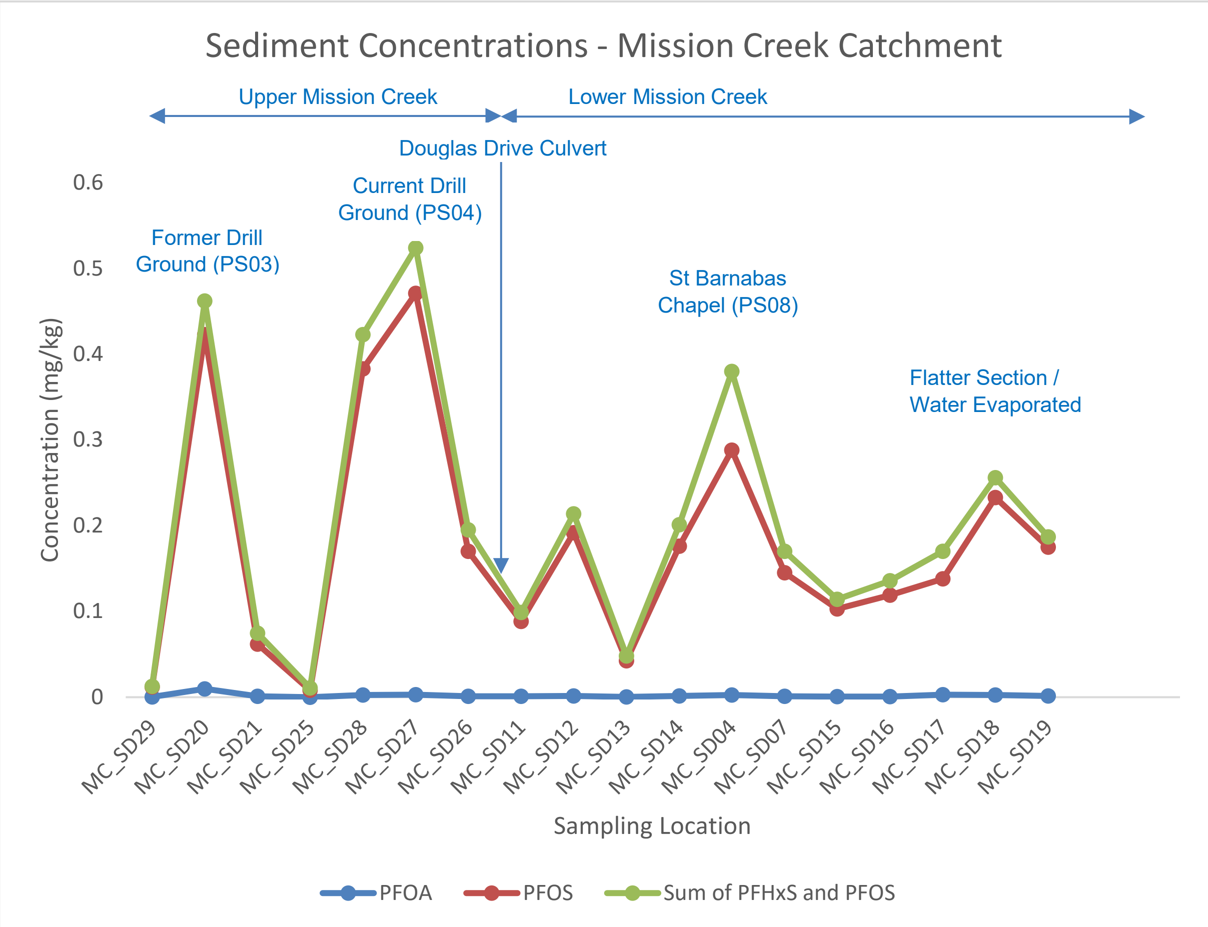

Figure 32: Sediment PFAS Concentrations in Mission Creek

Sediment sample MC_SD11 was collected from Lower Mission Creek (immediately after Douglas Drive Culvert). The next downstream sample MC_SD12 was from a stagnant pond and reported higher concentrations of PFAS than MC_SD11. This indicates shallow stagnant ponds may have resulted in higher rates of deposition of PFAS into sediment after evaporation of the shallow standing water.

Furthermore, sediment samples collected towards the mouth/outlet of Mission Creek (MC_SD17, MC_SD18 and MC_SD19) showed an increase in concentrations following a downward trend from St Barnabas Chapel (PS08). These locations near the terminus of Mission Creek were dry with no surface water noted, which similarly may have resulted in increased deposition of PFAS into sediment after evaporation of the water of the shallow standing water.

8.2.2 Watermill / Town Creek Catchment

Sediment samples from the Watermill / Town Creek catchment generally showed a decrease in PFAS concentrations from upstream to downstream locations. TC_SD02 reported the highest concentrations of PFAS in sediment in Watermill / Town Creek, which is not close to any identified source zones. It is noted this location is after a confluence of two tributaries, and no samples have been collected from the upper reach of the second tributary. The concentration gradients along Watermill / Town Creek are shown in **Figure 33** below.

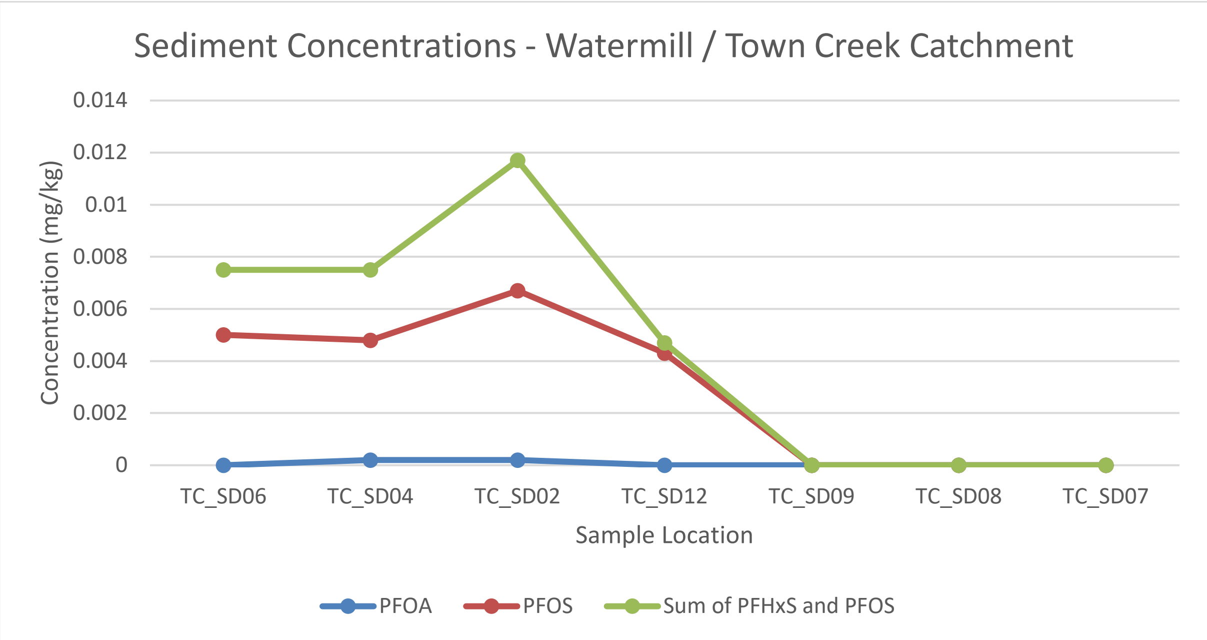

Figure 33: Sediment PFAS Concentrations in Watermill / Town Creek Catchment

8.2.3 Broken Bridge and Cascade Creek

The analytical results show an upper Cascade Creek (ID012_SD04) sample, which is upstream of the Council works depot, had low level detections of PFOS only. A sediment sample (ID012_SD03) downstream of ID012_SD04 and adjacent/downstream of the Council works depot also reported low level concentrations of PFOS+PFHxS only.

One sediment sample (BBC_SD02) adjacent the hospital reported low levels of PFOS. The sediment sample (BBC_SD05 and duplicates) collected from Broken Bridge Creek before the confluence with Cascade Creek was below laboratory LOR for all PFAS.

No sediment was present at cockpit weir, therefore no downgradient sediment data is available after the confluence of Broken Bridge Creek and Cascade Creek.

8.2.4 Headstone Creek

No sediment samples were collected in Headstone Creek as part of the sampling. Surface water was collected from two locations, which were below laboratory LOR for all PFAS.

8.3 Nature and Extent of PFAS in Surface Water

8.3.1 Mission Creek Surface Water Catchment

Surface water samples from the Mission Creek catchment showed the highest concentrations at locations closest to source zones PS01 and PS02 at the airport (World War II Dam and MC_SW21). The pathway of PFAS from PS01 and PS02 into Mission Creek is considered to be both groundwater from source zones and surface water run off over PFAS-impacted soils on the airport through drainage lines, which is supported by the concentration in sediment sample MC_SD20. PFAS concentrations consistently decreased further at each downstream location within Mission Creek (i.e. concentrations decreased with distance away from airport), with the exception of MC_SW25, which reported low levels of PFAS. The decrease in concentrations is shown in **Figure** 34 below.

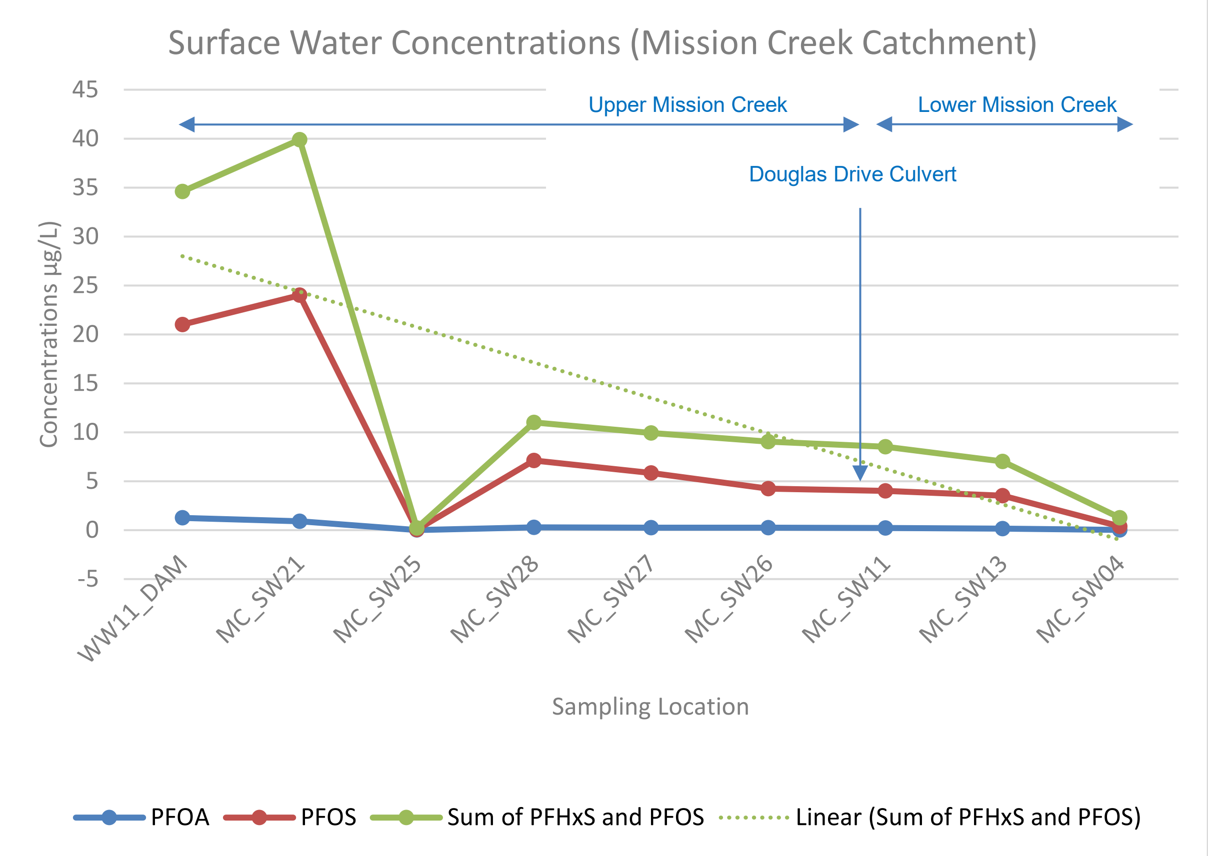

Figure 34: Surface Water PFAS Concentrations in Mission Creek

One surface water sample (MC_SW24) was collected from the upper Mission Creek catchment west of the waste depot (source zone PS03) on a separate Mission Creek tributary branch showed significantly lower PFAS concentrations than the tributary downgradient of PS01 and PS02.

A significant drop in PFAS concentrations was reported in MC_SW25, which is just after the confluence of two tributaries in the upper Mission Creek. There was limited evidence of surface water being further impacted down-gradient of PS04 with Mission Creek, adjacent to where Mission Creek sample MC_SW25 was collected.

It is noted MC_SW25 would be expected to receive run off from PS04, but may not receive flows from both tributaries of Mission Creek after the confluence at the exact sampling point. This is due to the creek bed being large and wide (creek bed and low-lying areas covered in substantial reed beds with moisture noted across most of the low-lying area). Additionally, the surface water sample (MC_SW25) may represent the water coming from upstream, rather than from PS04.

This indicates the highest PFAS impacts are likely to be from the northern tributary and hence from airport sources in the northern portion of the airport (PS01 and PS02).

8.3.2 Watermill / Town Creek Catchment

Within the Watermill / Town Creek catchment, the highest PFAS concentration in surface water (TC_SW06 – PFOS+PFHxS: 1.14 µg/L) was identified downstream of the Maintenance Depot (PFAS Source Zone 5). PFAS concentrations consistently decreased further at each downstream location before being below detection limits at the point of discharge into Emily Bay. The decrease in concentrations is shown in **Figure 35** below.

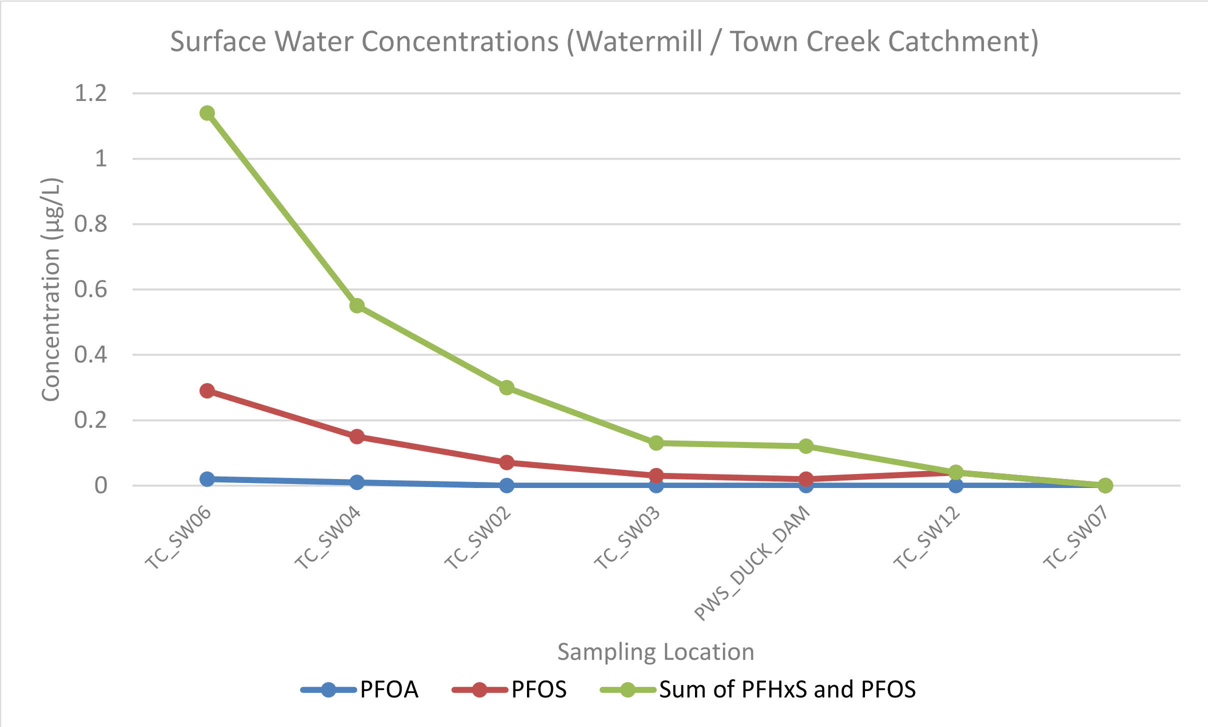

Figure 35: Surface Water PFAS Concentrations in Watermill / Town Creek Catchment

Two surface water samples (TC_SW05 and TC_SW13) were collected in the upper reaches of Watermill / Town Creek Catchment, but were from different tributaries. TC_SW05 was below adopted criteria (95% levels for this catchment) and was collected on a different tributary to TC_SW06; location is in close proximity to the airport boundary, however is not downgradient from any identified source zones. TC_SW13 was also collected from a separate upper reach away from the airport (circa 900 m from airport boundary), but is downgradient of source zone PS14 (perfumery). Concentrations of PFAS in TC_SW13 were above criteria, indicating PS14 is a potential source of PFAS.

8.3.3 Broken Bridge and Cascade Creek

The upper reaches of Cascade Creek are circa 1 km from the airport site. The analytical results show an upper Cascade Creek (ID012_SW04) sample, which is upstream of the Council works depot was below laboratory LOR. The following surface water sample (ID012_SW03) downstream of ID012_SW04 and adjacent/downstream of the Council works depot reported concentrations of PFOS+PFHxS (0.08 ug/L) that marginally exceed stock water / drinking water criteria.

Broken Bridge Creek was dry at locations closest to the airport, and no surface water samples could be collected until before the confluence of Broken Bridge Creek and Cascade Creek. The sample was below laboratory LOR for all PFAS.

The most downstream surface water sample (Cockpit_SW01) collected for this catchment was after the confluence of Broken Bridge / Cascade Creek, and reported a low-level concentration of PFHxS+PFOS (0.04 ug/L), which is lower than upstream sample ID012_SW03 discussed above. The concentrations reported for Cockpit_SW01 were below adopted criteria.

These results indicate the Council works depot is a potential source of PFAS impacts in Cascade Creek.

8.3.4 Headstone Creek

All surface water sampled collecting in Headstone Creek during the DSI were below laboratory LOR for all PFAS.

8.4 Nature and Extent of PFAS in Groundwater

Similar to the reduction seen in surface water at the World War II Dam, concentrations of PFAS in groundwater collected from the Airport Bore in March 2021 (PFOS+PFHxS: 34.7 µg/L) reduced by approximately 20% to 25% of the concentration measured in January 2020. In conjunction with this, a higher reduction in PFAS concentrations in groundwater was measured in private bore (ID015_Bore) sampled in January 2020 and March 2021 within the Mission Creek Catchment, as shown in **Table 8-1**.

Table 8-1 Comparison of PFAS Concentrations in Groundwater between January 2020 and March 2021

Sample ID	PFOS+PFHxS (µg/L)		PFOA (µg/L)		PFOS (µg/L)	
	January 2020	March 2021	January 2020	March 2021	January 2020	March 2021
Airport Bore	44.5	34.7*	0.57	0.73	33.1	22.5*
ID015_Bore	1.09	0.45	0.02	0.01	0.46	0.15

* Duplicate value adopted

The reduction in concentration is considered likely to have been primarily through ‘flushing’, driven by the increase in rainfall (i.e. dilution driven) and therefore may increase in future periods of lower rainfall. However, cessation in the use of the Airport Bore and supply of PFAS free alternative water supplies may also have contributed to this reduction.

PS01 and 02 are considered to be the primary sources of the PFAS present in the Airport Bore (in groundwater) and the WWII Dam (in surface water). PFAS Source Areas 3 and 4 (in particular) were also considered likely to be key contributors to PFAS within Mission Creek, however there is currently no evidence to suggest PS04 (Current Drill Ground) represents a source of PFAS contamination within sampled Mission Creek surface waters. It is noted, the evidence is based on one sample (sediment and surface water) collected from Mission Creek adjacent PS04. Furthermore, there is no groundwater data at or downgradient of PS04, with the exception of ID015_Bore, which is likely impacted by all groundwater moving off the airport.

Groundwater is known to be impacted by PFAS at the airport south of PFAS Source Area 2 (A_Bore1), however higher concentrations of PFAS in groundwater are considered likely to be present beneath and immediately down-hydraulic gradient of the PFAS Source Areas 1 – 6 and potentially also at PFAS Source Area 11. PFAS Source Areas 1 – 4 are considered to be the key sources of groundwater impact that may discharge to surface water within the Mission Creek Catchment, PFAS

Source Areas 1 and 2 considered to be the primary sources of the PFAS present in the Airport Bore (in groundwater) and the WWII Dam (in surface water).

Groundwater is also likely to be impacted beneath PFAS Source Areas 3, 4 and 11, however there is no evidence of an increase in PFAS concentrations within Mission Creek down topographic gradient (surface water pathway) of the source areas. Although the discharge point of groundwater beneath these source areas is not known, given the proximity to the Airport Bore and relatively deeply incised Mission Creek is at this location, it is considered likely groundwater would discharge to Mission Creek.

Other potential points of discharge for PFAS impacted groundwater in this area include:

- Discharge to the main sewer running through PS11 before discharging off-site.
- Groundwater migration to the Headstone Creek catchment, which could be the source of the low level (below adopted drinking criteria) identified at ID003_BORE, within the Headstone Creek Catchment.

A portion of the PFAS concentrations measured in the upper section of Watermill / Town Creek (i.e. at TC_SW02) may be associated with discharge of groundwater impacted by PFAS Source Area 6 (and potentially also PS05) discharging to Watermill Creek. This would be consistent with what was seen on the Mission Creek Catchment side of the airport, where PFAS impacted groundwater was identified at the “Airport Bore” and in surface water inferred to be hydraulically down-gradient (WWII Dam).

Groundwater is known to be also impacted at all bores located in the vicinity of Mission Creek. It is considered likely that transport of the PFAS present in groundwater at the lower levels of the Mission Creek is predominantly through surface water transport in ‘losing’ sections of the creek. It is considered likely that Mission Creek acts as a gaining creek (groundwater predominantly discharges to the creek) in the upper sections near the airport and then losing creek (groundwater is predominately recharged by the creek) in the middle to lower sections of the creek (in particular around Mission Creek).

8.5 Nature and Extent of PFAS in Drinking Water Sources

The investigation of drinking water sources was undertaken in private and public facilities across the island in both the PSI (January 2020) and this investigation (March 2021).

The historical source of PFAS impact in drinking water sources has been identified as being either:

A. PFAS impacted water extracted via the Airport Bore and transported to a holding tank via water carter or pipeline.

B. Extraction of PFAS impacted groundwater from other private bores screened within the Mission Creek Catchment.

Assessment of PFAS concentrations in potable water has been undertaken at the following public facilities:

- PSI Stage: Hospital, Fire Station, Council Works Depot, School and Chapel.
- DSI Stage: Hospital, Fire Station, Council Works Depot, On-Airport Council Office, BOM, Airport Terminal Bathrooms, Airport Mechanical / Maintenance Sheds and Chapel.

Water sampled from these locations and private properties was analysed for PFAS with the result then compared with the drinking water HBGV. Following review of the analytical results, advice in the form a letter was provided to the owner / occupier of each facility or private residence.

During completion of the PSI in early 2020, following confirmation of the analytical results, alternative water supplies were provided to all uses of bore water in the Mission Creek Catchment and all facilities where the ‘Airport Bore’ water was known to have been utilised.

A summary of the assessment and findings at each facility during the DSI is provided below the sections below.

8.5.1 Hospital

The assessment of drinking water sources in the hospital are summarised in **Table 8-2 and** discussed in further below.

Table 8-2: Summary of Hospital Assessment Works

Date	Activity	Discussion
January 2020	The hospital bore, 5 of the on-site tanks and a tap sample from the right-hand side of the filtration system were collected.	The tap sample from the filtration system indicated elevated concentrations of PFAS above drinking water guidelines. All other samples collected in January 2020 were below guideline levels.
February 2020	Accessible carbon filters within the hospital water filtration system were replaced.	
February 2020	The hospital filtration system was resampled at three points and a point of use sample collected from the hospital kitchen tap.	PFAS concentrations for two of the three sample points in the filtration system and for the kitchen tap remained elevated above drinking water guidelines.
Late 2020	The entire hospital water filtration system was replaced.	
February 2021	The filtration system and water from the kitchen taps was resampled. The water system serving the dialysis centre was sampled (post-filtration).	**PFAS was not detected in any of the water samples. Water is suitable for use (both for drinking water and for other domestic uses such as cooking, bathing, laundry and cleaning).**

The Airport Bore was historically used to fill the older water tanks at the hospital (PWS_HOSP_TANK1) and all hospital tanks are filled with rainwater with occasional bore water top up (from PWS_HOSP_BORE). It is understood no bore water top ups have occurred over the past two to three years. All tanks are connected to a master tank (PWS_HOSP_TANK1) with water then transferred directly into the hospital water treatment system in a small building adjacent to the tank. After passing through the water filtration system, water is then circulated through at least some or potentially all hospital buildings. However, the water supply to the hospital laundry is separate, with this water sourced from a bore (PWS_HOSP_BORE) at the rear of the hospital.

Concentrations of water from the tanks sampled at the hospital in January 2020 were below the health based guidance values for PFAS in drinking water. However, PFAS was detected above the health based guidance values for drinking water in samples collected after filtration (PWS_HOSP_TAP1). The water sampled from the hospital taps in the PSI reported elevated concentrations of PFAS that was not observed in the tank in which the water was sourced. Replacement of the carbon filters (part of the filtration system) was undertaken in February 2020 and PFAS levels remained above the health based guidance values for drinking water in samples collected after filtration. The results indicated that the second filter in the filtration system was the most likely source for the identified PFAS.

The March 2021 DSI assessment included the collection and analysis of six samples following replacement of the whole filtration system in late 2020 from the hospital in the following locations (see **Figure A6h**) with the sample ID in brackets:

- Right-hand side of main filtration system, after filtration. (**PWS_HOSP_TAP1**).
- Left-hand side of main filtration system, after filtration (**PWS_HOSP_TAP3**).
- 'Point of use' sample from kitchen tap (**PWS_HOSP_TAP4**).
- 'Point of use' sample from second kitchen tap (**PWS_HOSP_TAP4a**).
- After entire main filtration system, tap on outside of filtration room (**PWS_HOSP_TAP6**).
- After dialysis system filter, tap on outside of filter room (**PWS_HOSP_TAP10**).

PFAS was not identified at detectable concentrations in water sampled by Senversa from the new filtration system or from the kitchen taps which use this water in March 2021. PFAS was also not identified in water sampled from the water system servicing the dialysis centre.

8.5.2 Fire Station

In January 2020, two samples were obtained from taps (one internal / one external) within the fire station. Review of the analytical results found that both the indoor and outdoor tap samples at the fire station (FRE_TAP1 and FRE_TAP2) exceeded the adopted HBGV for PFOS+PFHxS with concentrations of 8.63 and 22.3 µg/L respectively. The airport bore, which historically fed the fire station, reported PFOS+PFHxS at 44.5 µg/L in 2020. Airport bore water is at least double the concentration reported in the Fire Station taps, indicating that dilution potentially from the installation and testing of new water tanks at the fire station has occurred.

Following receipt of these results, the fire station was made aware of the results and an alternative water supply (and signage) was provided to mitigate the risk posed by use of PFAS-impacted tap water. The source of water to indoor taps within the fire station was the changed through the installation of new rainwater tanks in late 2020 / early 2021 prior to the March 2021 assessment works.

The March 2021 assessment included the collection and analysis of three samples collected from taps in the following locations (see **Figure A6f**) with the sample ID in brackets:

- Kitchen tap at fire station (**FRE_TAP1**).
- Male bathroom tap at fire station (**FRE_TAP3**).
- Female bathroom tap at fire station (**FRE_TAP5**).

Review of the analytical results found concentrations of PFOS, PFHxS and PFOA to be below laboratory detection limits for all three samples.

8.5.3 Council Works Depot

Airport Bore water was historically used to fill water tanks at the Council Works Depot, but recent water supply to the tanks is understood to be through collection of rainwater at the depot (Refer **Table** 2-4).

In January 2020, two tanks and an internal tap (sample ID: DEPOT_TAP) at the off-site Council Works Depot (PFAS Source Area 9) were sampled. Review of the analytical results found identified PFAS concentrations in the internal tap that exceeded the adopted HBGV for PFHxS + PFOS with a concentration of 8.79 µg/L.

This concentration was consistent with the concentrations measured in DEPOT_TANK2 (one of the tanks supplying the facility). A replacement drinking water supply has been put in place at the depot, and tank supplying the council works depot were replaced in late 2020 / early 2021 to mitigate the risk posed by use of PFAS-impacted tap water prior to the March 2021 assessment works.

The March 2021 assessment included the collection and analysis of two samples collected from the kitchen tap and newly installed tank in the following locations (see **Figure A6i**) with the sample ID in brackets:

- Kitchen Tap (DEPOT_TAP1).
- New water tank, south of SW building (DEPOT_TANK3).

Review of the analytical results found concentrations of PFOS, PFHxS and PFOA to be below laboratory detection limits for both samples.

8.5.4 On-Airport Council Offices

The March 2021 assessment of drinking water sources from the on-airport council offices (located in the NW corner) included the collection and analysis of two samples collected from two taps in the following locations with the sample ID in brackets:

- Council tap in kitchen (Council_TAP1).
- Council tap next to fridge. (DEPOT_ TAP2).

Review of the analytical results found concentrations of PFOS, PFHxS and PFOA to be below laboratory detection limits for both samples.

8.5.5 On-Airport Bureau of Meteorology Office

Airport Bore water is understood to have been historically used to supply the Bureau of Meteorology Office, but if understood to be supplied via the new Airport tanks (Refer **Table 2-4**).The March 2021 assessment of drinking water sources from the Bureau of Meteorology included the collection and analysis of two samples collected and one analysed from the kitchen tap and newly installed tank in the following locations with the sample ID in brackets:

- Kitchen tap in Bureau of Meteorology building (A_TAP5).

Review of the analytical results found concentrations of PFOA to be below laboratory detection limits and the concentration of PFOS+PFHxS was 0.04 ug/L. This value is below the health based guideline value for drinking water and for recreational water.

Whilst the result is below health based guideline value for drinking water, there is potential for variability in the reported concentration, given the detection is likely due to residual impacts (in pipework/infrastructure) from historical Airport Bore water use. Confirmatory sampling as a part of a future PFAS management plan would assist in confirming the variability in PFAS concentrations.

8.5.6 Airport Terminal Bathrooms

Airport Bore water was historically used to fill water tanks at the Airport, which supplied the terminal bathrooms, but recent water supply to the tanks is understood to be through collection of rainwater (Refer **Table 2-4**). The March 2021 assessment of drinking water sources from the airport terminal bathrooms included the collection and analysis of two samples collected from two taps in the following locations with the sample ID in brackets:

- Bathroom basin tap in female toilets in departures lounge (prior to security) (**A_TAP1**).
- Bathroom basin tap in male toilets in departures lounge (prior to security) (**A_TAP2**).

Review of the analytical results found concentrations of PFOA to be below laboratory detection limits in both samples, with concentration of 0.02 ug/l (A_TAP1 sample) and 0.01 ug/l (A_TAP2 sample) reported for PFOS+PFHxS.

These values were below the health based guideline value for drinking water and for recreational water.

8.5.7 Airport Mechanical / Maintenance Sheds

The March 2021 assessment of drinking water sources from the airport mechanical / maintenance sheds included the collection and analysis of two samples collected from two taps in the following locations with the sample ID in brackets:

- Kitchen tap in maintenance shed building (near Ferny Lane). (**A_TAP3**)
- Kitchen tap in mechanics shed, adjacent to terminal buildings and Gate 1. (**A_TAP4**)

Review of the analytical results found concentrations of PFOA to be below laboratory detection limits in both samples, with concentration of PFOS+PFHxS also below detection limits in in the A_TAP3 sample.

The reported concentration of PFOS+PFHxS in A_TAP4 was 0.11 ug/L, exceeded the health based guideline value for drinking water and for recreational water. A letter explaining this result was sent to the airport upon receipt of the results.

The source of the PFAS in the kitchen tap in the airport mechanical / maintenance sheds adjacent the airport terminal is anticipated to have been through historical use of Airport Bore in taps at this facility. Given the source of water is now rainwater, there may be remnant PFAS impacts present within current infrastructure (Refer **Table 2-4**).

8.5.8 St. Barnabas Chapel

In January 2020, two samples were obtained from external taps - one on chapel (sample ID: **CHAP_TAP1)** and one on the adjoining chapel cottage (sample ID: **CHAP_TAP1)**. Review of the analytical results found concentrations of PFOS, PFHxS and PFOA to be below laboratory detection limits for both samples.

The March 2021 assessment included the collection of samples from the same two taps and re-analysis. Review of the analytical results from the March 2021 assessment found concentrations of PFOS, PFHxS and PFOA to be below laboratory detection limits for both samples.

The Chapel is understood to be supplied with a combination of bore and rainwater sourced from the residential property across Douglas Drive (Refer **Table 2-4**).

8.5.9 Private Properties

During the DSI assessment works undertaken in March 2021, Senversa sampled drinking water sources from 16 water tanks and taps (point-of-use) from 11 private properties.

The concentration of PFAS in all private drinking water sources assessed on the island were found to be below adopted health based guideline value for drinking water and for recreational water.

8.6 Nature and Extent of PFAS in Irrigation and Stockwatering Water

Based on water use surveys undertaken with a range of private residences both within the Mission Creek catchment and elsewhere on island, it is understood that there are some private properties on which bore water and/or surface water is utilised (or possibly utilised) for stock watering or the irrigation of fruit and vegetables. A summary of the findings of investigations of these water sources is provided below.

8.6.1 Water Used for Irrigation (Fruit and Vegetables) and Chicken Watering

PFAS was historically (in December 2019 and again in January 2020) identified in a private bore (pumped from Mission Creek) used for irrigation of a range of fruit and vegetable produce, and the watering of chickens. Concentrations were elevated in January 2020 (>3 µg/L PFOS+PFHxS) and lower but still elevated (>2 µg/L PFOS+PFHxS) in March 2021.

There are no screening levels which consider a pathway of uptake from water into produce and chicken eggs, and subsequent human consumption. On this basis, samples of produce and chicken eggs were collected from this property to further assess risks via this pathway. These results are discussed in **Section 8.7**, and indicate the risks associated with the consumption of produce and chicken eggs from this property are low and acceptable, however this is based on one sample only.

It is understood that there are other private properties (outside Mission Creek catchment) where water may be used for the irrigation of home produce. There is one private property where PFAS was detected in water used for the irrigation of home-grown produce.

Produce was not sampled from this property, however the PFAS concentrations in water (<0.2 µg/L PFOS+PFHxS in March 2021) were more than ten times lower than those measured in the Mission Creek property. It is therefore likely that risks via this pathway are low, but they cannot be fully excluded based on the available data, and should be further assessed.

There are no other known properties where PFAS-impacted water is used for the watering of chickens.

8.6.2 Water Used for Stock Watering (Cattle)

Norfolk Island's cows (known as Norfolk Blues) are largely permitted to roam around much of the island with the exception of the centre of the Burnt Pine township where cattle grids restrict access. However, there are a number of properties where cows are provided with pasture and water for all or parts of the year. There are several properties in the Mission Creek catchment where water impacted by PFAS is known to be used, or is potentially used, for watering cattle.

Concentrations of PFOS+PFHxS in water used or potentially used for stock watering range up to approximately 7 µg/L. In those locations where multiple monitoring rounds have been undertaken, concentrations were generally lower in March 2021 compared with January 2020.

Additionally, there are properties in the Watermill / Town Creek catchment where surface water impacted by PFAS is potentially used for watering cattle.

There are no screening levels which consider a pathway of uptake from water into stock, and subsequent human consumption. Further assessment of risks via this pathway is discussed within the **Section 9.5**.

8.7 Nature and Extent of PFAS in Biota

8.7.1 Fruit, Vegetables and Poultry Eggs

All six fruit, vegetable and herb samples collected and analysed from a private property where PFAS impacted bore water was used for irrigation were found to be below detection limits for all PFAS. Based on these results, the risks to consumers of fruit and vegetables irrigated with this water is assessed to be low.

PFAS was detected (PFOS+PFHxS: 0.009 mg/kg) in the one egg sample obtained that was known to have been watered by PFAS impacted bore water derived from the Mission Creek Catchment. The PFOS concentration did not exceed the trigger point for poultry eggs derived by FSANZ (2017). Based on this result, the risks to consumers of eggs from chickens drinking this water are assessed to be low, however further assessment of risk recommended to occur.

8.7.2 Grass

Concentrations of PFAS in 17 grass samples taken from inside the airport that is commonly cut and fed to roaming beef cattle were found to below laboratory detection limits with the exception of three low level detections (at or marginally above 0.001 mg/kg detection limit) in the following locations:

- Adjacent the former fire drill ground (PS04).
- Southwest corner of where the two runways intersect.
- Adjacent to the Former Flushing Area (PS02).

Three of four grass samples obtained from the Mission Creek Catchment contained higher concentrations than the airport (PFOS+PFHxS detections ranging from 0.002 to 0.041 mg/kg). Concentrations in paired sediment samples were all greater than three times the concentrations reported in the corresponding grass sample.

Based on these results there is potential for grass grown on the airport and within Mission Creek to accumulate PFAS from PFAS-impacted soil and surface water flow.

There are no screening levels which consider a pathway of uptake of PFAS from grass into stock, and subsequent human consumption. Further discussion of this potential exposure pathway is provided in **Section 9.5.**

It is understood that cut grass may in some instances be diverted to composting. As grass grown in PFAS-impacted areas may accumulate PFAS, there is the potential for composting of this material to present a pathway for the movement of PFAS around the island, potentially into garden soils where PFAS has not currently been identified. While the mass of flora (and therefore the mass of PFAS) is likely to be quite small, where cut grass is collected from PFAS-impacted areas, management (e.g. diversion away from composting) may be warranted to reduce the potential PFAS transport across island to occur.

8.7.3 Aquatic Biota

Aquatic biota (e.g. plants such as reeds, invertebrates, fish) have not been sampled as part of the DSI, although there is noted to be the potential for uptake of PFAS into aquatic biota where there are PFAS impacts in water. Further assessment of risks (to human health and the environment) via the uptake of PFAS into aquatic biota is discussed within the **Section 9.5.**

It is understood that aquatic plants may in some instances be cleared and diverted to composting. As aquatic plants grown in PFAS-impacted water may accumulate PFAS, there is the potential for composting of this material to present a pathway for the movement of PFAS around the island, potentially into garden soils where PFAS has not currently been identified. While the mass of flora (and therefore the mass of PFAS) is likely to be quite small, where aquatic biota is cleared from areas of PFAS-impacted water, management (e.g. diversion away from composting) may be warranted to reduce the potential PFAS transport across island to occur.

9.0 Conceptual Site Model

The following sections outline the key sources, pathways and receptors of the CSM. An illustrative summary of the PFAS CSM is provided in **Figure** 36**36** below.

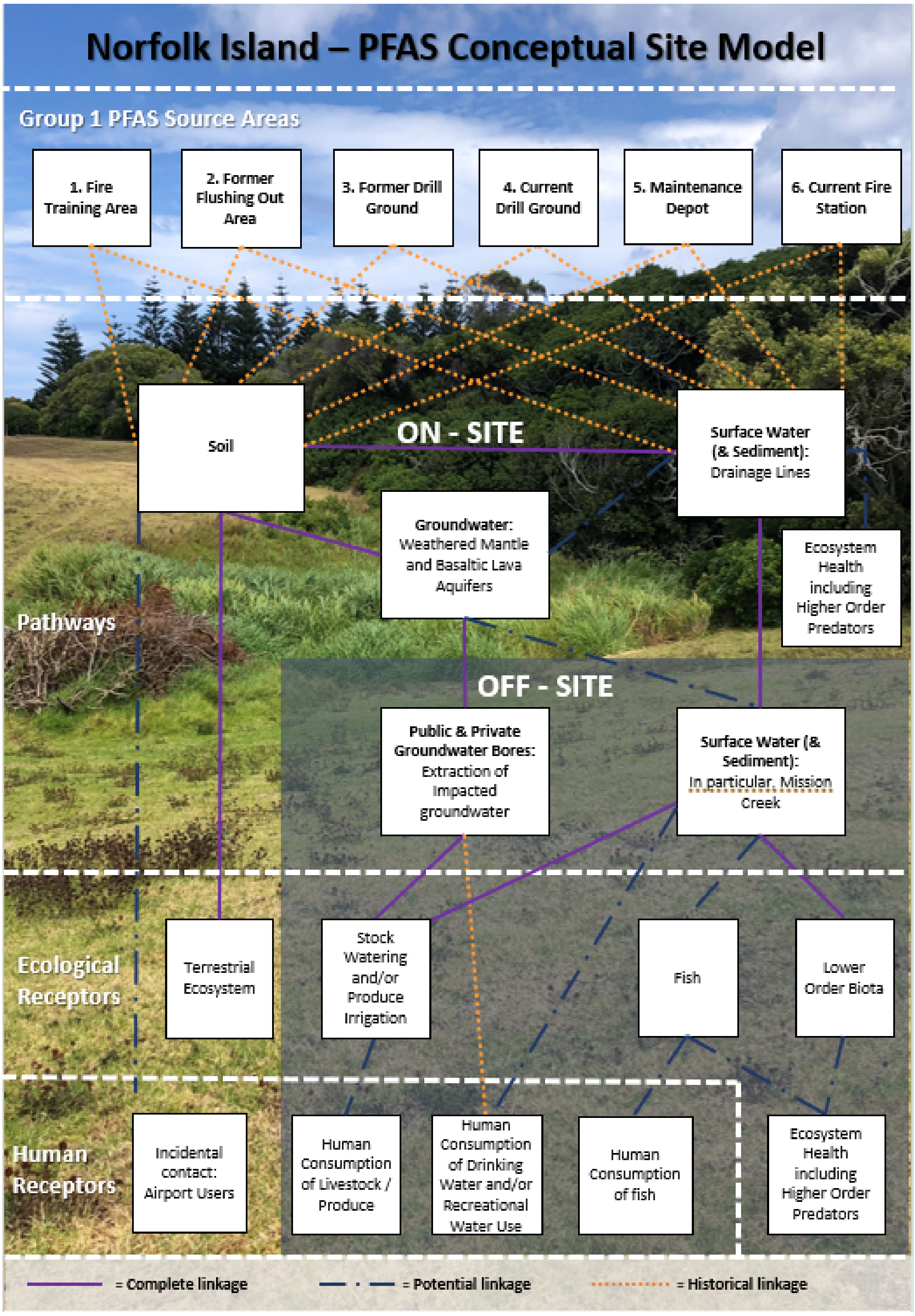

Figure 36: PFAS Conceptual Site Model Flow Chart

9.1 Key PFAS of Interest

The PFAS NEMP 2.0 provides HBGVs for PFOS, PFHxS and PFOA only. Therefore, these PFAS are considered the key PFAS of interest for the purposes of the DSI.

9.2 Sources of PFAS

9.2.1 Primary PFAS Source Areas

A number of PFAS source areas where legacy AFFF was used and introduced into the environment were identified during the site history review and Senversa's on-island investigation. Details on each identified source area are provided in **Table A1** (attached) with their location shown on **Figures A4 - A15.**

Generally, the most significant source areas ('Group 1 Source Areas') were locations where there was repeated application of foams and concentrate.

These Group 1 Source Areas include the following:

Group 1 Source Areas:

- PFAS Source Area 01: The former fire station and foam shed.
- PFAS Source Area 02: Flushing out area in the northeast corner of the site.
- PFAS Source Area 03: The former drill ground south west of the former fire station in the northeast portion of the site. This area is now utilised as the waste management facility, which includes a composting facility.
- PFAS Source Area 04: Current fire drill area along the northern site boundary. This area was most recently utilised by Boral and was unable to be accessed during the PSI, but was accessed for the targeted DSI investigation.
- PFAS Source Area 05: The maintenance depot where general maintenance of fire trucks historically occurred.
- PFAS Source Area 06: The current fire station.

Other source areas that were considered to be less significant based on frequency of AFFF application, were identified and grouped as follows:

Group 2 Source Areas (PFAS Sources Areas 7-11) – Areas where legacy AFFF concentrate and / or foam was used or stored more than once, but with less frequent rates of application than Group 1. Also includes secondary source areas like the wastewater treatment plant on the Airport (PS11), which is considered likely to be higher source of PFAS flux than the other Group 2 Source Areas.

Group 3 Source Areas (PFAS Sources Areas 12-15) – Areas where a single application of foams occurred due to an incident or a one off event.

Group 4 Source Areas (PFAS Sources Areas 16 & 17) – Areas where no AFFF is known to have been used, however water containing elevated concentrations of PFAS used.

Further information on potential PFAS Source Areas 7 through 17 is provided summarised in **Table B1**.

9.2.2 Secondary Sources (Impacted Environmental Media)

Soils

Once released into the environment due predominately to the historical application of legacy AFFF at PFAS Source Area 1 – 6 at the airport, PFAS has migrated into in soils, sediments and surface water both on site and off-site predominately into the Mission Creek Catchment.

The impacted soils associated with PFAS Source Areas 01 – 06 and 11 (WWTP), contain a relatively large mass of PFAS and extend over a wide area of the airport outside of the Primary Source Areas as shown on **Figure A7a**.

Sediments

As shown in **Section 8.2.1**, sediments within the Mission Creek Catchment have detectable PFAS concentrations that are impacted along the extent of the catchment and represent an ongoing secondary source of PFAS to surface waters with Mission Creek.

Sediments of the Town / Watermill Creek also contained detectable concentrations of PFAS along the majority of the catchment, however concentrations were on average one or two orders of magnitude less than the Mission Creek Catchment. Sediments down-gradient of known PFAS source areas in other parts of other catchments were also identified, however the extent of impact was limited.

Surface Water

Mission Creek catchment has the highest PFAS concentrations in surface water, however concentrations consistently decrease the further away from the airport.

Lower concentrations of PFAS (although still exceeding drinking water HBGV in upper portion of the catchment) are present in the upper to mid reaches of the Watermill / Town Creek catchment down-gradient of the airport. However, these concentrations reduce to below detectable concentrations before the point of discharge into Emily Bay.

Groundwater

As per previous investigation, groundwater screened at the Airport Bore has the highest concentrations of PFAS on the island. Portions of groundwater beneath the north western portion of the airport are beneath and down-gradient of PFAS source areas are likely to contain similarly elevated (or potentially higher concentrations) of PFAS. Although still often having PFAS concentrations exceeding the drinking water HBGV water criteria, PFAS concentrations in groundwater down-gradient of the Airport Bore in the lower portion of the Mission Creek catchment is at least two orders of magnitude lower than the Airport Bore.

Groundwater sampled from all other catchments had PFAS concentrations below acceptable drinking water criteria.

Wastewater

PFAS is present in waste water at the WWTP at concentrations exceeding ecological criteria (95% and 99% species protection, where freshwater criteria is also applicable to marine environment) and also exceeded drinking water criteria, however this is not considered a realistic use. The reported concentrations were below recreational water criteria. The source of PFAS has not been confirmed.

9.3 Migration Mechanisms

9.3.1 Key PFAS Migration Pathways

PFAS has predominately entered the Norfolk Island environmental through use of legacy AFFF in PFAS Source Areas 1 – 6.

Key migration pathways considered likely to constitute the majority of the PFAS Mass Flux both historically and currently on the island include the following:

A. Rainwater and runway run-off migrating over PFAS Source Areas 1 – 6 and 11, migrating overland flow into stormwater system or directly into Mission Creek.

B. Rainwater and runway run-off migrating over PFAS Source Areas 1 – 6, migrating through surficial soils into groundwater and discharging predominately to Mission Creek, but also potentially to Headstone and Watermill / Town Creeks.

C. Historical extraction of PFAS impacted groundwater from the Airport Bore and use to refill tanks and provide water to public facilities.

D. Ongoing back-diffusion of PFAS from sediments (particularly in Mission Creek) that were historically directly in contact with historically high concentrations PFAS containing legacy AFFF.

E. Discharge of PFAS containing wastewater from the islands water assurance scheme following treatment at the WWTP to the South Pacific Ocean south of Headstone Creek.

F. Ongoing use of PFAS impacted groundwater historically extracted from the Airport Bore in public toilets.

9.3.2 Exposure Pathways

Exposure pathways by which the above receptors may be exposed to PFAS in environmental media are listed below. The significance of these exposure pathways is dependent on a number of factors, such as the rate of exposure/intake, the concentrations within the impacted media at the point of exposure and characteristics of the receptor group.

Human Health

Human health receptors may be exposed to impacted environmental media through direct contact pathways. Generally, direct contact with soils is limited to the top 0.5 m, although construction or intrusive workers may disturb and be exposed to deeper soils and potentially shallow groundwater. groundwater may also be accessed when extracted for uses such as domestic (non-potable), agricultural (stock watering / crops), or other purposes.

- Incidental ingestion – shallow soil, extracted groundwater, surface water.
- Dermal contact – shallow soil, extracted groundwater, surface water (noting that PFAS have very low/ negligible dermal absorption rates).
- Inhalation of dusts and aerosols.
- Bioaccumulation into consumed products – agricultural (e.g. fruit, vegetables, cattle products, chicken eggs) or aquatic (e.g. fish).

Ecological receptors may be exposed to impacted environmental media through direct contact and uptake pathways. Generally, habitat areas for terrestrial receptors are assumed to extend to approximately 2 m depth (to account for e.g. deep rooted trees), although the majority of exposure (the root zone for most plants, and the exposure depth for invertebrates and other soil-dwelling creatures) is likely to occur in shallower soils.

- Direct uptake from surface water, sediments or soils.
- Bioaccumulation via the ecological food web.

9.4 Receptors

Potential receptors that may be exposed to PFAS on or off the site are divided into two categories, human health and ecological. While these receptors may not be at risk from PFAS impacts (i.e. exposure pathways may be incomplete), the investigation into potential PFAS impacts should ensure that such receptors are considered and the potential for exposure should be appropriately assessed.

9.4.1 Key identified human health and ecological receptors are shown on the cross-section presented as Figure 10 and summarised below. Human Health

Current receptors **on-site** comprise:

- Airport, BOM and Council Office Workers.
- Fire Fighters.
- Waste Management Workers.

- WWTP Workers.
- Intrusive workers (including resurfacing workers).
- Airport visitors / travellers.

Off-site receptors located down-gradient of known source areas in proximity to the site include:

- Residents / Farmers.
- Workers and intrusive workers.
- Recreational users of creeks / dams.
- Council Depot Workers.
- Consumers of produce in which PFAS may accumulate (e.g. meat, eggs, fruit, and vegetables).

9.4.2 Ecological

Potential ecological receptors include the following:

- On-site environments:
  - Grassland surrounding the runway and aprons (and subsequent consumption by cattle).
- Off-site environments:
  - Freshwater aquatic flora and fauna present in surface waters (including Mission Creek, Cascade Creek, Watermill Creek, Watermill Dam, and drainage and irrigation lines).
  - Agricultural Terrestrial flora and fauna, including grasses/pasture, cattle and chickens.
  - Endemic terrestrial fauna, including endangered land snails.
  - Saltwater aquatic flora and fauna present at Mission Creek and sewerage discharge points.
- Higher trophic level organisms (e.g. predatory birds) consuming fauna from on- and/or off-site.

9.5 Interim Management of Identified PFAS Impacts

Following the identification of PFAS in groundwater in late 2019, DITRDC have undertaken a number of management actions aimed at reducing the potential for exposure to the identified PFAS within the on-island environment both on-airport and off-airport, focussing on managing the exposure to PFAS identified in water used (or potentially used) for drinking water or domestic water supply.

These measures have been undertaken incrementally as information has become available on the nature and extent of PFAS on Norfolk Island:

Use of water from the airport bore

- Following the identification of PFAS in the airport bore, residents on Norfolk Island were advised on 14 January 2020 to discontinue use of water from the airport bore. Locks were also placed on the road standpipe (connected to the airport bore) in February 2020 where water had been historically collected for a variety of uses.
- DITCRD has commissioned ECT2 to provide a point of use treatment system (POETS) at the new fire station to remove PFAS and allow water extracted from the airport bore to be safely used for firefighting. Treated water will be tested and provided PFAS levels in the treated water are within the NEMP health-based guidance value (HBGV) for drinking water, the intention is to use the treated water within the fire trucks. The intended use of treated water in the fire trucks is expected to remain in place for the medium term as the Island progresses to becoming reliant on rain water only.

Drinking water and domestic water advisory measures

- Media releases (including includes six fact sheets and five media releases issued by DITRDC) have provided advice not to use water from the following sources for drinking or domestic use:
  - Groundwater from within the Mission Creek catchment.
  - Surface water extracted from Mission Creek or Watermill Creek.
- It is noted that none of these sources have been identified to currently be used for drinking water or domestic use.
- These water sources are variously utilised for other uses (e.g. stock watering, irrigation). No advice has been issued for these other uses; the risks associated with non-domestic uses is the subject of further assessment in the HHERA.

Drinking water at the fire station and other on-airport buildings

- PFAS was identified above the HBGV in domestic water at the fire station and airport maintenance sheds on the airport, assessed to be related to historic use of airport bore water for domestic supply to these buildings.
- Alternate water for domestic use has been supplied to these buildings as well as the airport terminal toilets, on-airport council buildings and the BOM office (where detectable PFAS below the HBGV was reported).
- Two large rainwater tanks have been recently installed adjacent to the fire station. The tanks will supply potable water for use inside the fire station with works proposed to be completed in early 2022.
- New rainwater tanks connected to the roof of the airport terminal and ancillary buildings have been purchased and are currently in the process of being installed.

Drinking water supply at the hospital

- PFAS was identified above the HBGV at the point of use (kitchen tap) within the hospital.
- The hospital water supply at the time was from rainwater tanks, which did not contain PFAS above the HBGV.
- The source was traced to the filtration system previously used by the hospital, likely related to to historical supply of PFAS-containing water (e.g. from the airport bore) to the hospital, which resulted in residual PFAS within the filtration system, which subsequently leached into water during filtration (even after switching water supply).
- The filtration system at the hospital has been fully replaced and testing has indicated that it is no longer a source for PFAS into the hospital drinking water supply. Water sampling from hospital taps completed in February 2021 (following replacement of the filtration system in March 2020) indicated PFAS concentrations to be below the HBGV.

Drinking water supply at the council works depot

- PFAS was identified above the HBGV at the point of use (kitchen tap) and one tank within the works depot, assessed to be likely related to the works depot historically utilising airport bore water for domestic supply.
- Alternate water has been supplied to these buildings for domestic use since February 2020.

Drinking water at private residences

- The works completed in the DSI and PSI included investigations of private domestic water supplies (e.g. rainwater tanks, domestic taps) to identify whether PFAS was present above the HBGV.
- While these investigations were proceeding, alternate water supplies were offered to residences within the Mission Creek catchment as a precautionary measure.
- The investigations indicated that these private water supplies were unimpacted with PFAS above the HBGV. However, to date, DITRDC have continued to supply alternative water sources to these residents.

Public toilets

- PFAS has been identified in the water supply at some public toilets, assessed to be likely related to the former carting of water from the airport bore for use in the public toilets.
- Signs have been placed in the toilets indicating the water is not suitable for drinking.

The ongoing implementation of these management measures, together with associated controls, monitoring and assessment of efficacy as required, should be captured within a future PFAS Management Plan.

In addition to these measures focussed on managing the exposure to PFAS identified in water, a number of source management activities have also been undertaken, or are currently being undertaken. These works focus on the reduction of PFAS mass on-island, and will reduce the potential for further PFAS to enter the environment in the future:

Phasing out of use of AFFF containing PFAS

- Fire training commenced on the island in 1942.
- Legacy AFFF (containing PFAS as an active ingredient) used on island includes 3M lightwater and Tyco Ansulite. 3M lightwater is understood to have been introduced to the island in the early 1980s and was used for approximately 20 years until the island changed to AFFF Tyco Ansulite in 2004.
- While some fire trucks still contain Ansulite, which is only used in emergency situations, Legacy AFFF (containing PFAS as an active ingredient) has not been used for training since 2015.
- Historic on-airport training activities with AFFF containing PFAS were identified in the DSI as the primary source for the majority of the identified PFAS impacts; as training with AFFF containing PFAS no longer occurs, this source for PFAS entering the environment has ceased.

Fire-truck cleaning and decontamination programme

- NIFS owns 4 firefighting trucks which have used legacy AFFF (with PFAS as active ingredients) and still contain legacy AFFF in their concentrate tanks.
- DITRDC is organising to have the trucks cleaned and have the legacy AFFF replaced with new AFFF (not containing PFAS as an active ingredient). Additionally, the Department is organising to ensure the water used to re-fill the fire trucks is treated to ensure PFAS levels are within the NEMP HBGV for drinking water.
- DITRDC has engaged GHD to establish a cleaning hub at the fire station to clean the fire-fighting vehicles. This will be undertaken following the installation of required infrastructure (currently underway).
- Legacy AFFF will be removed from the fire trucks and replaced with new AFFF (not containing PFAS as an active ingredient).
- The wash water captured during truck cleaning will be treated using a point of use treatment (POET) filter to remove PFAS, and tested. Provided PFAS levels are within the NEMP HBGV for drinking water the water will be stored for use in the fire trucks.
- All legacy AFFF will then be removed from the island to be disposed on the mainland.

The implementation of these source management measures should also be captured and assessed within the PFAS Management Plan.

9.6 Source – Pathway - Receptor Linkages

9.6.1 Assessment of Potential Source – Pathway – Receptor - Linkages

Potential SPR linkages associated with all PFAS Source Areas (including less significant Group 2, Group 3 and Group 4 sources) are assessed in **Table 9-1**. The assessment of potential SPR linkages is based on current conditions and current management options implemented (as outlined in **Section 2.5).**

Table 9-1: Assessment of Potentially Complete Current Source-Pathway-Receptor Linkages

Area	Media of Potential Concern	Receptor	Exposure pathway	Current exposure?	Further Risk Assessment Required?	Basis
On-Site: Norfolk Island Airport	Soil	Airport and Council Office Workers	Incidental contact (ingestion, dermal contact, dust inhalation)	**No**	**No**	Potential for general worker exposure soil is considered to be low as majority of activities are not likely to involve soil disturbance. Further, reported concentrations are below adopted commercial / industrial criteria indicating low and acceptable risk.
On-Site: Norfolk Island Airport	Soil	Airport Visitors	Incidental contact (ingestion, dermal contact, dust inhalation)	**No**	**No**	Reported soil concentrations are below adopted commercial / industrial criteria indicating low and acceptable risk. Potential for visitor exposure to soil is considered to be low as the publicly accessible portions of the site generally contain hardstand and are not in areas of highest impact. Further, visitors only spend a very limited period of time at the airport, thereby limiting potential exposure.
On-Site: Norfolk Island Airport	Soil	Current Fire Fighters	Incidental contact (ingestion, dermal contact, dust inhalation)	**No**	**No**	Potential for firefighter exposure to soil is considered to be low as majority of activities are not likely to involve soil disturbance. Further, reported concentrations are below adopted commercial / industrial criteria indicating low and acceptable risk.
On-Site: Norfolk Island Airport	Soil	Waste Management Workers	Incidental contact (ingestion, dermal contact, dust inhalation)	**No**	**No**	Waste Management workers may be exposed to dust, however general duties are not likely to involved soil disturbance. Further, reported concentrations are below adopted commercial / industrial criteria indicating low and acceptable risk.
On-Site: Norfolk Island Airport	Soil	Intrusive workers (Incl. resurfacing workers)	Incidental contact (ingestion, dermal contact, dust inhalation)	**Possible**	**Yes**	There is potential for intrusive worker (including resurfacing worker) exposure to soil e.g., during excavations. Reported concentrations are below adopted commercial / industrial criteria indicating low and acceptable risk, however, given the commercial/industrial criteria assumes 8 hours indoors or 1 hours outdoors. As intrusive workers may be exposed over longer periods of time outdoors, the risks have not been entirely excluded and will be further assessed in a HHERA.
On-Site: Norfolk Island Airport	Soil	Terrestrial ecological receptors	Direct contact or bioaccumulation through food web	**Unlikely, but cannot be excluded**	**Yes**	Given the nature of the airport site, the potential for sensitive ecosystems to be present is likely to be low. Additionally, it is unlikely that biota from within the impacted areas of the site would form a significant proportion of the diet of higher order predators, given the limited size of the area, and the limited biota which are likely to be present in these areas. Notwithstanding this, it is noted that that a number of the measured concentrations exceed the most conservative screening levels for terrestrial ecosystems presented in the NEMP, and as such, this pathway should be considered further in the next stages of assessment.
On-Site: Norfolk Island Airport	Soil	Consumers of cattle products	Uptake into grass fed to cattle, subsequent consumption of cattle products	**Potential**	**Yes**	It is understood that grass on-airport is mowed and potentially fed to cattle. Sampling of grass was undertaken to better assess this pathway. PFAS was identified in some grass samples, at low concentrations (close to the LOR). PFAS was also identified in grass samples (which may potentially be eaten by cattle) within Mission Creek catchment,. As there are no regulatory screening levels for comparison with grass concentrations which consider uptake into livestock, risks cannot be excluded based on the available information. Further assessment is required.
On-Site: Norfolk Island Airport	Tap Water (including from bore)	Airport and Council Office Workers	Non-potable water use	**No**	**No**	There is potential for airport and council worker exposure to PFAS in water as the water supplied to buildings across the airport is sourced from Airport Bore (located just outside the airport boundary) which contains elevated concentrations of PFAS. However, this water is not used for potable purposes, with alternate drinking water supplied. Water from the Airport Bore continues to be utilised for other (non-potable) uses, for example the toilet facilities. However, the exposure from hand washing is considered relatively low given the frequency and duration of exposure, and the properties of PFAS meaning the substances are poorly adsorbed through the skin.
On-Site: Norfolk Island Airport	Tap Water (including from bore)	Airport Visitors	Non-potable water use	**No**	**No**	The potential for airport visitor exposure to PFAS is considered to be low as alternative supplies for potable water is provided (for both drinking water and in the café). Water from the Airport Bore continues to be utilised for the toilet facilities. However, the exposure from hand washing is considered relatively low given the frequency and duration of exposure, and the properties of PFAS meaning the substances are poorly adsorbed through the skin.
On-Site: Norfolk Island Airport	Tap Water (including from bore)	Fire Fighters	Domestic use in fire station (e.g. kitchen tap)	**No**	**No**	The potential for fire fighter exposure to PFAS in water within the fire station is considered to be low as the water samples collected from taps within the fire station during the DSI sampling did not detect PFAS. PFAS was historically identified from the kitchen tap, however a new rainwater tank has been constructed to the north of the airport which is understood to supply the fire station kitchen and toilets etc.
On-Site: Norfolk Island Airport	Tap Water (including from bore)	Fire Fighters	Use of hydrant water for fire drills and training	**Unlikely, but cannot be excluded**	**Yes**	It is understood that water from the Airport Bore continues to be utilised for regular testing and maintenance of fire trucks. PFAS has been identified in this water; the potential for exposure will be reduced given the limited potential for PFAS adsorption through the skin.
On-Site: Norfolk Island Airport	Tap Water (including from bore)	Waste Management Workers	Non-potable water use	**Unlikely**	**No**	No water sampling was undertaken at this facility as no water supply points (e.g. taps) were identified. However, if a water supply is present, the potential for waste management worker exposure to PFAS in water cannot be excluded, as concentrations have not been measured at this facility, and the water supply source is unknown (and could be from the Airport Bore which contains elevated concentrations of PFAS).
On-Site: Norfolk Island Airport	Shallow Groundwater – Direct Contact	Fire Fighters	Incidental contact with groundwater	**No**	**No**	Low potential for fire fighter exposure to PFAS in groundwater is considered low as there are no known fire fighter training activities that require excavation on site. Depth to groundwater is >2 mbgl, therefore incidental contact with groundwater is considered unlikely.
On-Site: Norfolk Island Airport	Shallow Groundwater – Direct Contact	Waste Management Workers	Incidental contact with groundwater	**No**	**No**	Low potential for waste management worker exposure to PFAS in groundwater is considered low as there are no known activities that require excavation on site. Depth to groundwater is >2 mbgl, therefore incidental contact with groundwater is considered unlikely.
On-Site: Norfolk Island Airport	Shallow Groundwater – Direct Contact	Intrusive & resurfacing workers.	Incidental contact with groundwater	**No**	**No**	It is considered unlikely that intrusive works will results in exposure to PFAS in shallow groundwater. Depth to groundwater is >2 mbgl, therefore incidental contact with groundwater is considered unlikely unless deep excavations are undertaken.
On-Site: Norfolk Island Airport	Shallow Groundwater – Direct Contact	Terrestrial ecological receptors	Direct exposure (e.g. by deeper rooted plants) and exposure through food chain via bioaccumulation.	**Unlikely, but cannot be excluded**	**Yes**	Given the nature of the airport site, the potential for sensitive ecosystems to be present is likely to be low. Additionally, it is unlikely that biota from within the impacted areas of the site would form a significant proportion of the diet of higher order predators (given the limited size of the area, and the limited biota which are likely to be present in these areas. Notwithstanding this, it is noted that that the potential for PFAS uptake from groundwater via on-site plants has not currently been excluded, and as such, this pathway should be considered further in the next stages of assessment.

Area	Media of Potential Concern	Receptor	Exposure pathway	Current exposure?	Further Risk Assessment Required?	Basis
Off-Site: Wider Norfolk Island	**Soil**	Residents / Farmers	Uptake into produce and subsequent consumption; incidental soil exposure	**No**	**No**	One offsite private residential property (ID013) reported PFAS in one sample at a concentration exceeding Human Health Residential criteria (HIL-A). The soil impacts are considered associated with current and historical irrigation of the land using a combination of bore water and surface water from Mission Creek. Where produce is grown, risks can be further assessed through consideration of biota concentrations. This has been undertaken on this property where the measured produce concentrations were found to be below laboratory LOR and hence acceptable levels, and the risks are therefore assessed to be low. The soil samples collected from other private properties were below HIL-A, therefore the risks are considered to be low.
		All Workers	Incidental soil exposure	**No**	**No**	Potential for exposure if impacted groundwater used for irrigation of crops or gardens results in PFAS impacts to soil. However, the risk is considered low and acceptable as results below the commercial industrial level in all surficial soils.
		Recreational	Incidental soil exposure	**No**	**No**	All soil results from the common oval were below criteria for reactional use (HIL-C), therefore the risk is considered low and acceptable.
		Terrestrial ecological receptors	Direct contact	**No**	**No**	There were no exceedances of the ecological direct contact criteria, as such, the risks to terrestrial ecological receptors directly exposed to soils is assessed to be low.
			Bioaccumulation through food web	**Unlikely, but cannot be excluded**	**Yes**	There were no exceedances of the ecological direct contact criteria, however a limited number of concentrations (mainly in commercial areas) exceeded the criteria considering indirect contact (i.e. bioaccumulation through the food chain). Given the general nature of the areas in which these impacts were identified, the potential for sensitive ecosystems to be present is likely to be low. Additionally, it is unlikely that biota from within the impacted areas of the site would form a significant proportion of the diet of higher order predators (given the limited size of the areas, and the limited biota which are likely to be present in these areas). Notwithstanding this, it is noted that that the potential for PFAS uptake from soil off-site has not currently been excluded, and as such, this pathway should be considered further in the next stages of assessment.
	Sediment	Residents / Farmers	Uptake into produce and subsequent consumption; incidental sediment exposure	**Unlikely, but cannot be excluded**	**Yes**	Sediment samples in Mission Creek and Watermill / Town Creek exceed residential criteria, however these samples were collected from drainage lines and creek beds where the potential for the growing of home grown produce is considered to be low. Exposure to impacted sediment creek beds is considered to be lower than that of residential backyards, and as the sediment sampled were below recreational criteria, incidental contact risks are considered likely to be low. Notwithstanding this, it is noted that that the potential for PFAS uptake into produce from sediments off-site has not currently been excluded, and as such, this pathway should be considered further in the next stages of assessment.
		All Workers	Incidental sediment exposure	**No**	**No**	Potential for incidental exposure to sediments, however general duties are not likely to involve significant disturbance of sediment. Concentrations were below adopted commercial / industrial criteria and risks therefore assessed to be low.
		Recreational	Incidental sediment exposure	**No**	**No**	This use is considered unlikely to be realised. All sediment results were below criteria for reactional use (HIL-C), therefore the risk is considered low and acceptable.
		Terrestrial ecological receptors	Direct contact	**No**	**No**	There were no exceedances of the ecological direct contact criteria, as such, the risks to terrestrial ecological receptors directly exposed to sediment is assessed to be low.
			Bioaccumulation through food web	**Unlikely, but cannot be excluded**	**Yes**	Several sediment samples from Mission Creek and a private property on Broken Bridge Creek reported PFAS exceeding indirect exposure screening levels. It is unlikely that biota from within these impacted areas of the site would form a significant proportion of the diet of higher order predators (given the limited size of the areas), and the land uses (e.g. agricultural) within some of these areas. Notwithstanding this, potential risks have not been fully excluded and should be considered further, including consideration of endangered and sensitive species in the impacted area, in the next stages of assessment.
	Surface Water / Shallow Groundwater	Residents / Farmers	Use of water for drinking	**No**	**No**	Exceedances of drinking water criteria were reported for surface water samples in Mission Creek. However, investigations to date have indicated that surface water is unlikely to be used for drinking, and this pathway is therefore assessed to be inactive.
			Uptake into home-grown produce (fruit and vegetables) and subsequent consumption	**Unlikely, but cannot be excluded**	**Yes**	PFAS impacts were reported in water from Mission Creek, Broken Bridge Creek and Watermill / Town Creek catchments, where water is potentially used for irrigation of home-grown produce and some properties. The pathway has been assessed further through biota (home-produce) sampling at a private property on Mission Creek where water was known to be used for irrigation; all biota were below laboratory LOR, therefore the risk is considered to be low and acceptable at this property. PFAS concentrations in water known to be used for irrigation at other properties was lower, however the risks have not been entirely excluded and should be further assessed.
			Uptake into chicken eggs and subsequent consumption	**No, but based on limited data**	**Yes**	PFAS impacts are present in water in Mission Creek, Broken Bridge Creek and Watermill / Town Creek catchments. However, there is only one property (in Mission Creek catchment) where water impacted by PFAS is known to be used for watering chickens. At this property, risks have been assessed through sampling of chicken eggs, where chickens were known to be watered with surface water. The risks are assessed to be low, however, given they are based on a limited data set (one sample), potential risks have not been fully excluded and will be considered further within the HHERA.
			Uptake into cattle watered with water and subsequent human consumption	**Potential**	**Yes**	PFAS impacts were reported in water from Mission Creek, Broken Bridge Creek and Watermill / Town Creek catchments. There are several properties in the Mission Creek catchment and Watermill / Town Creek catchment where water impacted by PFAS is known to be, or is potentially used for watering cattle. There is no available regulatory screening level specifically for these pathways; the presence of PFAS in this water does not necessarily indicate potential risks, but does indicate that further assessment of these pathways is required. It is noted that where e.g. cattle source their water from a variety of sources (i.e. not all of the water they drink is from the PFAS impacted source) this will reduce the potential exposures via this pathway.

Area	Media of Potential Concern	Receptor	Exposure pathway	Current exposure?	Further Risk Assessment Required?	Basis
Off-Site: Wider Norfolk Island	**Surface Water** **Shallow Groundwater**	Workers incl. Intrusive	Incidental water contact in creeks and drains	**Unlikely, but cannot be excluded**	**Yes**	Exceedances of reactional criteria were reported for surface water samples in Mission Creek. These criteria are considered conservative to assess risks to workers (e.g. farmers) incidentally contacting this water, as the potential for exposure will be much less than assumed in the derivation of the recreational criteria. Notwithstanding this, the risks have not been entirely excluded and should be further assessed.
		Recreational creek users	Water contact during recreation	**Unlikely, but cannot be excluded**	**Yes**	Exceedances in reactional criteria were reported for surface water samples within Mission Creek. Potential contact with surface water bodies for recreation purposes is considered to be low in Mission Creek, given the ephemeral nature of Mission Creek and that any recreation exposure is likely to be occasional. Investigations to date have indicated that surface water is unlikely to be used for swimming, and the potential for PFAS exposure will be much lower for other recreational uses when compared with swimming exposure. Therefore, the risks are likely to be low, however, potential risks have not been fully excluded and should be considered further.
		Freshwater aquatic ecological receptors	Direct contact Bioaccumulation through food web	**Yes**	**Yes**	PFOS has been identified in off-site surface waters at concentrations exceeding NEMP screening levels for the protection of ecosystems. Further assessment of this potential pathway is required to assess the potential for sensitive freshwater ecosystems (including endangered species) to be present, and to understand the potential for exposure to different receptors.
		Saltwater aquatic ecological receptors	Direct contact Bioaccumulation through food web	**Unlikely**	**No**	A pathway of PFAS migration into the marine environment is potentially active at the sewer outfall and Mission Creek discharge point, However, given the relatively low flow rate along the creeks the mass of PFAS entering the marine environment will be relatively small. Additionally, the level of dilution which will occur in the marine environment will be very large. As such, PFAS concentrations will be rapidly reduced to negligible concentrations within the marine environment. On this basis, the potential for measurable PFAS impacts to be present within the marine environment is very low, and any such impacts would be very localised in extent. With the potential exception of marine benthic fauna (not listed as endangered), most risks posed by PFAS at island discharge points (i.e. Mission Creek, sewer outfall) are likely to be short lived due to PFAS concentrations being quickly diluted in the South Pacific Ocean. The potential for the marine ecosystem to be exposed to PFAS will therefore be very small, and in particular, the potential for bioaccumulation within the marine environment will be negligible. As such, it is qualitatively concluded that the risks to the marine environment are low, and further investigation and assessment is not considered warranted.
		Airport bore end users; off-site groundwater (impacted with the use of Airport Bore water)	Use of airport bore water (historically wide usage on island via water carters, now restricted)	**No**	**No**	This pathway was historically complete but is now considered to be inactive due to lock and restrictions put in place on the bore. A POET filter (see **Section 2.5)** to enable Airport Bore water to be safely used by the fire station for non-potable purposes (i.e. fire training) is currently being installed on the island. At public toilets across the island, water historically carted from the Airport Bore is still likely to be present. However, the potential for exposure during hand washing will be relatively low given the frequency and duration of exposure, and the limited potential for PFAS adsorption through the skin. Signage is understood to be at place at toilet facilities across the island to indicate the water should not be drunk. These measures will effectively manage potential exposures to PFAS. It is understood that a number of the toilet facilities run septic systems; there is therefore the potential for the use of PFAS impacted water at these facilities to pose a secondary source of PFAS impacts to groundwater, although it is noted that the mass and concentrations of PFAS associated with these uses is likely to be very small when compared with primary sources associated with the on-site direct use of AFFF. Testing of soils near septic systems has not indicated significant PFAS impacts associated with this pathway.
		Residents / Farmers	Incidental contact associated with groundwater extraction for domestic uses Potential use of extracted water for drinking	**Yes**	**No**	Alternative water for domestic use has been supplied where accepted within the Mission Creek Catchment. Domestic water supplies have been tested and found to not be impacted with PFAS above drinking water guidelines. Exceedances of potable criteria were reported in bore water, however it is understood the bore water is not used for drinking purposes. The potential for ongoing direct contact with PFAS impacted extracted groundwater in the Mission Creek Catchment and consumption of bore water during future dry periods should tank water run out. The future extraction of groundwater for domestic uses should be managed.
		Workers inc.. Intrusive	Incidental groundwater contact	**No**	**No**	Potential for direct contact with extracted groundwater, noting preliminary results from public bores off-site were below criteria or <LOR. Potential for incidental contact with shallow groundwater in excavations.
		Terrestrial ecological receptors	Direct contact (deep rooted plants) and uptake by plants and bioaccumulation through food chain	**Unlikely, but cannot be excluded**	**Yes**	Potential for direct contact with extracted groundwater, or exposure to occur within the plant root zone and then uptake by higher order receptors is considered to be low given the depth to groundwater is likely to be >2 m. Groundwater was measured at greater than 6 m below ground in January 2020 at an old well (approx. 1 m in diameter) south west of large Baynan Tree (sample ID A_Bore1) on the airport, is likely to be less than 2 m below ground closer to Mission Creek. It is unlikely that plants taking up PFAS impacted groundwater would form a significant proportion of the diet of higher order predators (given the limited size of the areas). Notwithstanding this, potential risks have not been fully excluded and should be considered further, including consideration of endangered and sensitive species in the impacted area, in the next stages of assessment.
	Foodstuffs (fruit, vegetables, chicken eggs, livestock (cattle) products, fish)	Consumers of fruit & veg.	Uptake into fruit and vegetables and subsequent human consumption	**Unlikely, but cannot be excluded**	**Yes**	PFAS impacts were reported in water from Mission Creek, Broken Bridge Creek and Watermill / Town Creek catchments, where water is potentially used for irrigation of home-grown produce and some properties. The pathway has been assessed further through biota (home-produce) sampling at a private property on Mission Creek where water was known to be used for irrigation; all biota were below laboratory LOR, therefore the risk is considered to be low and acceptable at this property. PFAS concentrations in water known to be used for irrigation at other properties was lower, however the risks have not been entirely excluded and should be further assessed.
		Consumers of eggs	Uptake into eggs and subsequent human consumption	**No, but based on limited data**	**Yes**	PFAS impacts are present in water in Mission Creek, Broken Bridge Creek and Watermill / Town Creek catchments. However, there is only one property (in Mission Creek catchment) where water impacted by PFAS is known to be used for watering chickens. At this property, risks have been assessed through sampling of a chicken egg, where chickens were known to be watered with surface water. There is a limited data set (one sample), therefore, the risks have not been entirely excluded and should be further assessed, with consideration of whether the eggs from this property are only home consumption and or are provided to other residents.

Area	Media of Potential Concern	Receptor	Exposure pathway	Current exposure?	Further Risk Assessment Required?	Basis
Off-Site: Wider Norfolk Island	**Foodstuffs (fruit, vegetables, chicken eggs, livestock (cattle) products, fish)**	Consumers of cattle products (meat, offal, bone, tallow)	Uptake into livestock products and subsequent human consumption	**Potential**	**Yes**	PFAS impacts were reported in water from Mission Creek, Broken Bridge Creek and Watermill / Town Creek catchments. There are several properties in the Mission Creek catchment where water impacted by PFAS is known to be used for watering cattle. There is no available regulatory screening level specifically for these pathways; the presence of PFAS in this water does not necessarily indicate potential risks, but does indicate that further assessment of these pathways is required. It is noted that where e.g. cattle source their water from a variety of sources (i.e. not all of the water they drink is from the PFAS impacted source) this will reduce the potential exposures via this pathway.
		Fishing	Uptake into fish and subsequent human consumption	**Unlikely**	**No**	Considered a relatively low exposure potential due to minimal fresh water recreational fishing understood to be undertaken in terrestrial surface water bodies. This is likely due to the ephemeral nature of many creeks and abundance of marine fishing opportunities. A pathway of PFAS migration into the marine environment is potentially active at the sewer outfall and Mission Creek discharge point, However given the relatively low flow rate along the creeks the mass of PFAS entering the marine environment will be relatively small. Additionally, the level of dilution which will occur in the marine environment will be very large. As such, PFAS concentrations will be rapidly reduced to negligible concentrations within the marine environment. On this basis, the potential for measurable PFAS impacts to be present within the marine environment is very low, and any such impacts would be very localised in extent. The potential for the marine ecosystem to be exposed to PFAS will therefore be very small, and in particular, the potential for bioaccumulation will be negligible. As such, it is qualitatively concluded that the risks of uptake through human consumption of fish are low, and further investigation and assessment is not considered warranted.

9.6.2 Source – Pathway – Receptor Linkages Requiring Further Assessment

As shown in the above **Table 25**, the majority of the identified exposure pathways are not of concern, based on comparison to Tier 1 assessment criteria / screening levels.

Those pathways requiring further assessment where unacceptable risks cannot be excluded due to exceedance of adopted screening criteria (or because no relevant screening criteria are available), that will be further evaluated in the HHERA are the following (in no particular order):

Consumers of cattle products

- Consumption of cattle products (potentially including beef, tallow, offal and bones) from cattle watered with water containing PFAS, or fed grass containing PFAS.
- The risks to livestock health will also be assessed.

Consumers of produce (fruit and vegetables)

- Consumption of fruit and vegetables irrigated with water containing PFAS.
- It is noted that PFAS was not detected in sampled fruit and vegetables watered with PFAS impacted water, so risks are likely to be low, but will be further assessed on additional properties where concentrations in irrigation water were lower, but where produce was not sampled.

Consumers of chicken eggs

- Consumers of chicken eggs where chickens are watered with water containing PFAS.
- It is noted that PFAS concentrations in chicken egg were measured to be below the acceptable levels (FSANZ tigger), however data is limited and the uncertainties associated with this limited data will be furhter assessed in the HHERA.
- There is only one known property where PFAS impacted water is used to raise chickens; risks will therefore be assessed for this property.

Firefighters

- Exposure to PFAS impacted water during testing, training and drills.

On-airport intrusive workers

- Exposure to PFAS in soils.
- Concentrations in soil are below the screening level for commercial/industrial workers (HIL-D), but this pathway will be further assessed in the HHERA as the HIL-D is not directly applicable to intrusive workers.

Off-site residents (farmers) or recreational users of creeks

- Dermal contact with and incidental ingestion of surface water in open drains during work or recreation.

Terrestrial ecological receptors

- Exposure to PFAS impacted soil, groundwater and sediments (while creeks are dry), or via bioaccumulation of PFAS through the food web.

Freshwater aquatic ecological receptors

- Exposure to PFAS impacted surface water and sediments, or via bioaccumulation of PFAS through the food web.

It is noted that in **Table 9-1** and the above list of pathways to be considered in the HHERA are relevant to the current land use scenario. There is the potential for land use changes to result in other pathways becoming relevant, e.g. changing agricultural uses, etc. These have not been included in the above discussion, but will be considered in the HHERA to the extent possible.

In accordance with the risk assessment process recommended in the NEPM, the HHERA will further detail the above Tier 1 screening evaluation and associated conclusions on risk, and will provide a detailed evaluation of risks to receptors via the pathways requiring further assessment due to exceedance of adopted screening criteria (or because no relevant screening criteria are available).

9.7 Areas of Uncertainty

9.7.1 Nature and Extent of Impact

Soil Assessment

Based on the adopted soil screening levels, the soil investigation is considered to have adequately assessed the nature and extent of PFAS impacts to assess risks to human health and the environment, thereby achieving the objectives of the assessment. The uncertainty associated with the adopted soil screening levels for the Norfolk Island terrestrial ecosystem / endangered flora and fauna and the impact of this on the conclusions of the assessment, is discussed further for relevant receptors in **Section 9.6.2**.

The assessment of nature and extent in soil (and concrete waste) is not likely to provide adequate certainty and delineation of the nature and extent (in particular, vertical distribution) for development of management or remediation options should these be required in future.

Groundwater Assessment

The assessment of groundwater conditions has been limited to the samples of water supply bores already present on the site.

There is little information on groundwater conditions beneath on site PFAS source areas, likely areas of discharge and concentrations trends. The source(s) of PFAS in the sewer needs further investigation, including whether the sewer is below groundwater on the airport or in other areas of the site.

Surface Water and Sediment Assessment

The nature and extent of surface water and sediment impacts and concentrations trends may require further investigation within the Mission Creek Catchment, potentially including at the discharge point of Mission Creek and the WWTP. However, the requirement for further assessment will be dependent on the findings of nature of risk to receptors within the ecological risk assessment.

Biota Assessment

Produce (fruit, vegetables and chicken eggs) have been sampled at a private property which utilises PFAS-impacted water for watering chickens and irrigating produce. While other properties may use water for these purposes, the sampled property has the highest PFAS concentrations in water known to be used for this purpose, and therefore this testing is assessed to be adequate.

For pathways of uptake into cattle, no cattle serum data was collected as part of this investigation, and therefore, the cattle assessment will be initially undertaken on the basis of PFAS concentrations in stock water. The requirement for testing of cattle will be assessed based on the results of this assessment.

Material Assessment

The extent to which bitumen and concrete adjacent to PFAS Source Areas 1 – 6 may act as ongoing sources of surface and groundwater contamination has not been investigated.

9.7.2 Assessment of Risk to Human Health and the Environment

As presented in the CSM presented above, there are a number of potentially complete SPR linkages at the site and surrounds, which have predominately arisen from the site's historical use of legacy AFFF.

As indicated in the SPR linkages table in **Section 9.5**, further assessment of a number of these pathways is proposed to be undertaken as part of a site-specific human health and ecological risk assessment (HHERA).

9.7.3 Summary of PSI Data Gaps

Data gaps identified in in the SPR linkages table are provided in **Table 26** below. Data Gaps 1 – 8 were previously identified within the PSI, with discussion provided on what further information (if any) is required.

Table 9-2: Historical PSI Data Gaps

Data Gap ID	Site Area / Catchment	Data Gap	Importance to Achieving Objective
DG1	On-site and off-site	Extent of Potential PFAS Source Areas. Understanding of aerial extent much improved. Depth of impact not confirmed for all source areas. Further assessment likely required if management is required in the future.	Low
DG2	On-site and Off-site	Extent of PFAS in Water Supplies. **Adequately Assessed - No longer a data gap**	-
DG3	Mission Creek Catchment	Off-Site: PFAS Concentrations in Biota / Soil and Grass in Mission Creek **Adequately Assessed - No longer a data gap**	-
DG4	Mission Creek Catchment	Off-Site: PFAS in Groundwater. Further assessment and sampling of existing bores in Mission Creek catchment was undertaken to confirm PFAS impacts. Uncertainty regarding groundwater flow rate and connection with Mission Creek. Particularly around PFAS Sources Areas 3 and 4.	Low
DG5	Mission Creek, Watermill Creek and Headstone Creek	Off-Site: PFAS in Surface Water. **Adequately Assessed - No longer a data gap**	-
DG6	Mission Creek Catchment	Off-Site: Confirmation of CSIRO Results. **Adequately Assessed - No longer a data gap**	-
DG7	Mission, Watermill & Cascade Creek Catchments	Off-Site: PFAS Concentrations in Saline Sediment. Partially assessed at Watermill / Town Creek only.	Low
DG8	On-Site, Mission, Watermill & Cascade Creek Catchments	On & Off-Site: Consideration of Ecological Receptors. Investigations to date have not considered impacts to the sensitive ecological receptors that may be present in the areas identified as being impacted.	Medium

10.0 Conclusions

Through completion of this DSI, Senversa was able to achieve the objectives outlined in **Section 1.2** and draw the following conclusions:

PFAS Source Area Identification

- Six PFAS primary source areas (Group 1 Source Areas) were confirmed within the Airport, with Primary Sources 1 (Former Fire Station and Foam Shed) and 2 (Former Flushing Out Area) considered to represent the main sources of PFAS identified within Mission Creek surface water. All six sources were associated with the training, storage and / or maintenance of fire trucks that historically used Legacy AFFF.
- The nine other lower risk PFAS source areas identified outside of the Airport within the PSI are still inferred to be present, with one additional Group 3 Source Area identified on Selwyn Rd, where legacy PFAS was used to extinguish a house fire in September 2021.
- Concentrations of PFOS+PFHxS were highest in soils within Source Area 4 (Current Drill Ground) which is expected as this was where Legacy AFFF was used most recently. However, there was limited evidence of surface water impacted down-gradient of Source Area 4 within Mission Creek.
- Assessment of sub-surface conditions within PFAS source areas found higher concentrations of PFAS were generally present at depth (between 0.5 and 1.5+ m) when surficial soil concentrations exceed 0.05 mg/kg, indicative of vertical washing into the soil profile and/or surface removal by rainfall flushing.
- PFAS was identified in wastewater at the WWTP, with a PFOS+PFHxS concentration of 0.24 µg/L (A_STP_OUT). The source of the PFAS in WWTP wastewater has not been confirmed, however it is likely to be a combination of different domestic sources and potentially a portion of inflow from identified airport source areas. The presence of PFAS within wastewater should be taken into account as a part of planned upgrades to the WWTP.

Impact to Utilised Water

- All privately owned drinking water sources that were sampled by Senversa reported PFAS (PFOS+PFHxS) concentrations below the adopted HBGV.
- Concentrations of PFAS in internal water taps at three public facilities (hospital, works depot and fire station) that were previously found to be above the adopted HBGV in January 2020 were all found to be below adopted HBGV in March 2021.
- Concentrations of PFAS exceeded the HBGV in one sample collected from a kitchen tap at airport mechanical/maintenance building in the former fire station (A_TAP4; PFOS+PFHxS: 0.11 µg/L). Reticulated water in this facility was known to have been historically connected to the Airport Bore. The supply of alternate drinking water and signage is considered to mitigate this risk.
- Historically extracted "Airport Bore" water is still present in tanks servicing public toilets within two locations on the island (Cascade Toilets - PFOS+PFHxS: 32.3 µg/L; Headstone Toilets - PFOS+PFHxS: 31.5 µg/L), however the potential for exposure during hand washing is considered relatively low given the frequency and duration of exposure, the limited potential for PFAS adsorption through the skin and the non-volatile nature of PFAS.
- Extracted bore and surface water used for stock watering and irrigation with the Mission Creek Catchment in March 2021 were lower than January 2021 but still elevated, with concentrations of PFOS+PFHxS ranging up to approximately 2 µg/L.

PFAS in Surface Water Catchments

- Concentrations of PFAS in surface water and groundwater generally decreased by between a half and one third between January 2020 and March 2021.
- This reduction in concentration is considered likely to have been primarily through ‘flushing’, driven by the increase in rainfall post January 2020 (i.e. dilution driven) and therefore PFAS concentrations may rebound in future periods of lower rainfall. However, cessation in the use of the Airport Bore, supply of PFAS free alternative water supplies and further time since legacy PFAS containing AFFF was last used and may also have contributed to this reduction.
- The surface water assessment represents the PFAS impacts in January 2020 and March 2021, however, long-term trends and fluctuations have not been assessed.

Mission Creek Surface Water Catchment

- Surface water in Mission Creek was found to have the highest concentrations in the World War II Dam (PFOS+PFHxS: 34.6 µg/L) located in the upper southern portion of the catchment close to source areas PS01 and PS02 at the Airport. However, PFAS concentrations had decreased by approximately half at this location when compared to January 2020.
- PFAS concentrations generally decreased with distance at the eight sample location downstream of the World War II Dam, with the lowest reported concentration of PFOS+PFHxS (1.26 µg/L) reported up-stream of the Mission Pool at MC_SW04. No further down-stream water samples were able to be collected past this point.
- Sediment samples from the Mission Creek catchment reported the highest PFAS concentrations at adjacent to identified on and off-site PFAS Source Areas (PS03, PS04, PS05 and PS08). Sediment concentrations down-gradient of the Mission Pool are higher than those immediately up-gradient; this may be associated with increased cycles of pooling and evaporation in this area, contributing to higher PFAS mass within the sediments.

Watermill / Town Creek Water Catchment

- All water samples obtained from within the KAVHA World Heritage Area were found to be below the drinking / stock watering water HBGV.
- PFAS concentrations were below detection limits at the point of discharge into Emily Bay.
- Within the Watermill / Town Creek catchment, the highest PFAS concentration in surface water (PFOS+PFHxS: 1.14 µg/L) was identified downstream of the Airport Maintenance Sheds (PFAS Source Area 5) at TC_SW06.
- PFAS concentrations consistently decreased at each downstream location away from the airport, however they generally exceeded drinking / stock watering water HBGV until after the “Watermill / Duck Dam”.

Other Surface Water Catchments

- Concentrations in surface water were below the drinking / stock watering water HBGV in all other catchments with the exception of one marginal exceedance (PFOS+PFHxS: 0.08 µg/L) at ID012_SW03 downstream of the Council works depot in Cascade Creek.

PFAS in Groundwater

- As per the PSI targeted assessment undertaken in January 2020, the highest reported PFAS concentration in groundwater was in the ‘Airport Bore’, located near the top of the upper south branch of Mission Creek.
- Similar to the reduction seen in surface water at the World War II Dam, concentrations of PFAS in groundwater collected from the Airport Bore in March 2021 (PFOS+PFHxS: 24.9 µg/L) reduced by between one half to a third relative to the concentration measured January 2020 (PFOS+PFHxS: 44.5 µg/L).
- DITRDC propose to install a point of entry (commonly known as POET) filtration system on the Airport bore to ensure this valuable resource can continue to provide water to the community for non-potable sources.

- A similar level of reduction in PFAS concentrations in groundwater was measured in private bores sampled in January 2020 and March 2021 within the Mission Creek Catchment.
- Based on the findings of the PSI, this investigation did not include extensive investigation into the extent of PFAS in groundwater, as it was considered unlikely to influence the assessment of risk / management measures that may be put in place. As such, this may result in conservative management options for groundwater use.

PFAS in Produce

- No PFAS was detected in fruit and vegetables assessed.
- PFAS reported in egg produce sample ID013_BIOTA2 (PFOS+PFHxS: 0.009 mg/kg) was below adopted criteria for the human consumption of eggs.
- Marginal (at detection limit) concentrations of PFAS were detected in grass on the airport that is commonly cut and fed to cattle.

Risk Assessment and Future Management

The works undertaken as part of the DSI and PSI have allowed a good understanding of the ways in which people and wildlife on-island might be exposed to PFAS. Based on this information, it has been possible to determine that risks are now low and acceptable for many of the ways in which people might be exposed to PFAS in the environment. This includes drinking water; drinking water is often (on other sites) the most significant PFAS exposure pathway, but on Norfolk Island, concentrations of PFAS in the water people currently drink is below the HBGV, and the risks are therefore assessed to be low.

While it has been possible to rule out potential risks for many of the pathways by which people might be exposed, there are a small number of pathways for which further assessment is required to better assess potential risks. Completion of a human health and ecological risk assessment (HHERA) is recommended to further assess the risks and confirm potentially complete source-pathway-receptor linkages.

Furthermore, to address the identified risks in complete pathways, a PFAS Management Plan (PMP) plan should be prepared and approved, which details all physical and administrative preventative measures required to reduce or eliminate exposure to PFAS. The PFAS Management Plan will detail the ongoing management which is required for each identified source area, and for identified potential exposure pathways (both those pathways which are currently managed, and those for which additional management is identified to be required within the HHERA).

11.0 Principles and Limitations of Investigation

The following principles are an integral part of site contamination assessment practices and are intended to be referred to in resolving any ambiguity or exercising such discretion as is accorded the user or site assessor.

Area	Field Observations and Analytical Results
Elimination of Uncertainty	Some uncertainty is inherent in all site investigations. Furthermore, any sample, either surface or subsurface, taken for chemical testing may or may not be representative of a larger population or area. Professional judgment and interpretation are inherent in the process, and even when exercised in accordance with objective scientific principles, uncertainty is inevitable. Additional assessment beyond that which was reasonably undertaken may reduce the uncertainty.
Failure to Detect	Even when site investigation work is executed competently and in accordance with the appropriate Australian guidance, such as the National Environmental Protection (Assessment of Site Contamination) Amendment Measure ('the NEPM'), it must be recognised that certain conditions present especially difficult target analyte detection problems. Such conditions may include, but are not limited to, complex geological settings, unusual or generally poorly understood behaviour and fate characteristics of certain substances, complex, discontinuous, random, or heterogeneous distributions of existing target analytes, physical impediments to investigation imposed by the location of services, structures and other man-made objects, and the inherent limitations of assessment technologies.
Limitations of Information	The effectiveness of any site investigation may be compromised by limitations or defects in the information used to define the objectives and scope of the investigation, including inability to obtain information concerning historic site uses or prior site assessment activities despite the efforts of the user and assessor to obtain such information. Information received during preparation of this report from third parties or anecdotal sources, such as the sources of PFAS identified, was not able to be independently verified by Defence records.
Chemical Analysis Error	Chemical testing methods have inherent uncertainties and limitations. Senversa routinely seeks to require the laboratory to report any potential or actual problems experienced, or non-routine events which may have occurred during the testing, so that such problems can be considered in evaluating the data.
Level of Assessment	The investigation herein should not be considered to be an exhaustive assessment of environmental conditions on a property. There is a point at which the effort of information obtained and the time required to obtain it outweigh the benefit of the information gained and, in the context of private transactions and contractual responsibilities, may become a material detriment to the orderly conduct of business. If the presence of target analytes is confirmed on a property, the extent of further assessment is a function of the degree of confidence required and the degree of uncertainty acceptable in relation to the objectives of the assessment.
Comparison with Subsequent Inquiry	The justification and adequacy of the investigation findings in light of the findings of a subsequent inquiry should be evaluated based on the reasonableness of judgments made at the time and under the circumstances in which they were made.
Data Useability	Investigation data generally only represent the site conditions at the time the data were generated. Therefore, the usability of data collected as part of this investigation may have a finite lifetime depending on the application and use being made of the data. In all respects, a future reader of this report should evaluate whether previously generated data are appropriate for any subsequent use beyond the original purpose for which they were collected, or are otherwise subject to lifetime limits imposed by other laws, regulations or regulatory policies.
Nature of Advice	The investigation works herein are intended to develop and present sound, scientifically valid data concerning actual site conditions. Senversa does not seek or purport to provide legal or business advice.

12.0 References

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