RAAF Base Tindal

PFAS MANAGEMENT AREA PLAN REVISION #1

April 2025

ACKNOWLEDGEMENT OF COUNTRY

Defence acknowledges the Traditional Custodians of Country throughout Australia and the Traditional Owners of Country, the Jawoyn, Dagoman and Wardaman peoples of the Katherine region. Defence recognises their continuing connection to traditional lands and waters and would like to pay respect to their Elders both past and present. Defence would also like to pay respect to the Aboriginal and Torres Strait Islander peoples who have contributed to the defence of Australia in times of peace and war.

ABOUT THIS DOCUMENT

This is the Defence PFAS Management Area Plan (PMAP) Revision #1 for RAAF Base Tindal.

This PMAP Revision replaces the PMAP for RAAF Base Tindal dated July 2019.

The purpose of this PMAP is to document Defence's plan to manage potential risks to human health and the environment from PFAS on and from RAAF Base Tindal. It provides an overview of the actions undertaken to date, ongoing and future actions.

The Northern Territory Environment Protection Authority and other relevant state and local agencies have been consulted in the development of this document.

EXECUTIVE SUMMARY

In 2019, Defence published the RAAF Base Tindal PFAS Management Area Plan (2019 PMAP) for managing risks to human health and the environment from per- and poly-fluoroalkyl substances (PFAS) contamination associated with RAAF Base Tindal and surrounding areas.

Since development of the 2019 PMAP for RAAF Base Tindal (the base), Defence has implemented a number of actions set out in the plan and reassessed what is now needed to best manage these contamination risks. This PMAP revision sets out the updated plan to manage risks to human health and the environment from exposure to PFAS contamination at and from the base.

In managing PFAS contamination to reduce risks to human health and the environment, Defence prioritises:

- minimising exposure to PFAS
- preventing or minimising migration of PFAS
- keeping the community informed.

To achieve these priorities, risk management actions have included onsite soil remediation and ongoing water monitoring. Minimising PFAS movement from the base will, in the long term, contribute to the reduction of PFAS concentrations in the surrounding environment. However, the process will take time and therefore other measures will also be implemented to reduce risks to human health and the environment.

A Conceptual Site Model (CSM) is a representation of the biological (uptake by plants and animals), physical (transport through the environment) and chemical (breakdown processes into other forms of PFAS) processes that determine the ways that contaminants move from sources through the environmental media (surface water, groundwater, soil) to the environmental receptors. The contamination originates from a source area, where the majority of PFAS is found on the base, and where most of the PFAS moving off-base is sourced. Whilst no new sources of PFAS contamination or transport pathways have been identified, through review of the PMAP, two minor amendments to the CSM have been considered:

- reduced risk to on-Base workers and the ecology as a result of completed remediation work at key source areas, the Fire Station Area (FSA) and Fire Training Area (FTA)
- westerly movement of PFAS in groundwater, as a result of the seasonal changes, requiring further investigation.

Completed remediation works

Defence has completed a number of remedial actions at the base since 2019:

- financial and technical support for the installation of a permanent Water Treatment Plant (WTP) for the treatment of Katherine Township potable water in collaboration with the Power and Water Corporation
- installation of two on-base groundwater treatment plants at the FSA and FTA. Both WTPs have been in operation since 2019 and have treated over 3.1 billion litres of PFAS-contaminated groundwater as of October 2024
- soil remediation at the FSA, including excavation of 9,000 m^3 of PFAS impacted soils, reducing PFAS movement into groundwater and surface drains between 2022 and 2023

- demolition and management / remediation of all FTA infrastructure (training pad and three concrete evaporation ponds), excavation and treatment of approximately 23,300 m^3 of soils with elevated PFAS concentrations between 2022 – 2024.

Defence has also provided rainwater tanks and associated infrastructure to 80 individual properties that previously used impacted groundwater for domestic purposes.

A number of management actions are still ongoing, or proposed to be implemented:

- in-progress development of a base-wide PFAS groundwater remediation action plan
- in-progress development of a base-wide PFAS groundwater and surface water mass flux study (assessment of volume and flow rate) to understand changes in conditions pre- and post-implementation of remediation actions
- installed a capping layer across the FTA remediation area to finalise the soil remediation
- continue to implement the Ongoing Monitoring Program within the Management Area
- In-progress development of a base-wide Spoil Management Plan.

These proposed actions will build on the works completed to date to further reduce the amount of PFAS leaving the base, and over time will contribute to the long-term reduction of PFAS in the off-base environment.

Defence will provide regular updates to the local community on the Defence website and through community information sessions.

CONTENTS

GLOSSARY

AFFF	Aqueous Film Forming Foam
ASC NEPM	National Environment Protection (Assessment of Site Contamination) Measure, as amended 2013
AST	Above Ground Storage Tank
Base	RAAF Base Tindal
CSM	Conceptual Site Model
CSR	Contaminated Site Register
DSI	Detailed Site Investigation
ERA	Ecological Risk Assessment
HHERA	Human Health and Ecological Risk Assessment
HHRA	Human Health Risk Assessment
ID	Identification
Management Area	The geographical area subject to Defence risk management actions. May include private or Defence owned detached properties beyond the boundaries of the base
Off-site	Off-base (or other Defence property)
OMP	Ongoing Monitoring Plan
On-site	On-base (or other Defence property)
PFAS	Per- and polyfluoroalkyl Substances
PFAS NEMP	PFAS National Environmental Management Plan
PFHxS	Perfluorohexane sulfonate
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
RAP	Remediation Action Plan
Risk management actions	Remediation and management actions to address potential risks to receptors from PFAS contamination.
ROA	Remediation Options Assessment
Risk assessment(s)	The HHERA, HHRA and/or ERA
SFARP	So Far as Reasonably Practicable
Source	A source can be primary or secondary. Primary sources are areas where AFFF was used or stored. Secondary sources may be an accumulation of contamination in the environment, such as in soil, sediments, or surface water bodies.

Unless otherwise defined in this document, definitions provided in the *PFAS National Environmental Management Plan* (NEMP) or the *National Environment Protection (Assessment of Site Contamination) Measure, as amended 2013* (ASC NEPM) apply.

TABLE OF ABBREVIATIONS

kL	Kilolitres
L	Litre
m	metre
mg/kg	Milligrams per kilogram

1 INTRODUCTION

1.1 Background and purpose

In July 2019, Defence published the PFAS Management Area Plan (July 2019 PMAP) for RAAF Base Tindal (the base) describing the actions that would manage risks to human health and the environment from per- and poly-fluoroalkyl substances (PFAS) contamination associated with the base and surrounding areas.

Since the 2019 PMAP was developed, Defence has implemented parts of the plan and reassessed what is needed to best manage risks from PFAS contamination.

This assessment considered:

- progress made in the implementation of the 2019 PMAP
- the outcomes of the mass flux study (the total quantity of a contaminant that flows through a specified area, within a specified time period), which provided a detailed understanding of the volumes and flow rates of PFAS leaving the base, and at which locations
- whether potential risks to human health or the environment from PFAS contamination have changed, based on data collected through the ongoing monitoring plan (OMP) and exploratory studies (groundwater and surface water mass flux estimations, groundwater/surface water interactions, geophysical aquifer mapping)

This PMAP revision sets out the updated plan to manage risks to human health and the environment from exposure to PFAS contamination from RAAF Base Tindal.

The PMAP revision has been developed in accordance with the PFAS National Environmental Management Plan (NEMP) (Heads of EPA, 2020), which provides nationally consistent environmental guidance and standards for managing PFAS contamination. It is also consistent with Defence estate, environmental, and PFAS-specific strategies and guidance.

PMAPs are reviewed and updated periodically to account for changes in circumstances, such as progress in management and remediation, new data, changes in legislation, guidelines and policy, and advances in scientific information.

1.2 Management priorities

In managing PFAS contamination to reduce risks to human health and the environment, Defence prioritises:

- minimising exposure to PFAS
- preventing or minimising migration of PFAS
- keeping the community informed.

1.3 Supporting information

The PMAP revision is based on information from a range of different investigations, human health and ecological risk assessments, and remediation activities. Details of these reports are provided in Appendix A, including web links where available.

The reports identified a range of elevated risks to receptors from exposure to PFAS, which are the focus of the risk management actions outlined in this document.

1.4 Limitations and assumptions

This document has been developed based on the information available at the time of preparation, and the following limitations and assumptions:

- the current state of knowledge regarding PFAS distribution at the time of PMAP revision (refer to Appendix A for the source documents)
- government issued guidance, advisories and policies
- proposed management and remediation options based on current proven technologies available at the time of writing this document, including:
    - management and remedial technologies summarised in the PFAS NEMP
    - additional technologies based on successful trials by Defence and conducted by others within and outside of Australia (based on publicly available information)
- remediation technologies that are not considered viable or feasible for use at the base or Management Area have been excluded (as recommended in PFAS NEMP). However, Defence will regularly review and assess remediation technologies and their applicability to the management of PFAS at the base
- understanding and application of base infrastructure development and access constraints at the time of this report, and
- access to off-base private properties that are granted, where required.

The PMAP will be revised if new information (such as revised guidelines, regulatory requirements, site data or remedial techniques) becomes available and the characterisation of risk changes, requiring a revised management or remediation approach.

2 MANAGEMENT AREA

RAAF Base Tindal is a key operational airbase for the Royal Australian Air Force, established in 1988 as a home base for the No.75 Squadron. The base is a hub for training and operational readiness, with a focus on air combat and logistics. It has undergone significant upgrades to enhance its capabilities, including extended runways and facilities to support joint military exercises and operations. Currently large-scale redevelopment and construction programs are underway to modernise and increase capacity of its current facilities and meet Defence alliance requirements.

The base is located within a mixed land use setting, approximately 15km east of the township of Katherine and accessed by Stuart Highway. Current land uses surrounding the base include:

- residential, educational, commercial and recreational areas
- agricultural land uses, predominantly pastoral livestock grazing, grains and fruit crops
- Cutta Cutta Caves Nature Park located directly southeast of the base.

The PFAS Management Area (MA) comprises RAAF Base Tindal and off-base areas, where management actions, including precautionary advice or administrative controls, have been adopted.

Information about the management area environmental setting, such as climate, topography, geology, hydrology and various other aspects is provided in the Detailed Site Investigation (DSI) (Coffey, 2018a).

The MA comprises five key management zones which are monitored for changes in PFAS impact and potential PFAS exposure, extending into the Katherine Township, summarised below and shown on Figure F1 in Appendix B.

- Zone 1: Groundwater PFAS concentrations above drinking water and recreational water criteria.
- Zone 2: Groundwater PFAS concentrations above drinking water criteria.
- Zone 3: Surface Water Management Area comprising Katherine River water downstream of surface water monitoring location surface water (SW) location SW110, shown on Figure F4 in Appendix C.
- Zone 4: Town water supply (Power & Water) that includes treated water from Katherine River (not displayed in figures).
- Zone 5: Groundwater PFAS concentrations below drinking water criteria.

Each zone has tailored precautionary advice for residents to minimise exposure to PFAS, including a precautionary approach to fish and crustacean consumption, released by NT Health. The 2024 OMR (AECOM, 2024a) identified that the extent of PFAS concentrations in groundwater was consistent with historical concentrations reported prior to and including 2020, with the exception of seasonal PFAS fluctuations reported in Cossack. Investigations are in progress to better understand the nature and movement of PFAS within Cossack groundwater to determine if the western extent of Management Zone 2 requires amendment (refer to Table 6).

The NT Government's response to PFAS is being coordinated by the Department of the Chief Minister, through the Interagency Steering Committee (PFASISC). Further information can be found on their website, https://ntepa.nt.gov.au/your-environment/pfas.

Changes to land uses occur over time and future revisions of the PMAP will consider these changes.

3 EXTENT OF PFAS CONTAMINATION

This section provides an outline of the PFAS sources, transport pathways for migration of PFAS from a source area, and potential receptors such as humans and ecosystems that may be exposed to PFAS from the base.

This information is described as a Conceptual Site Model (CSM), which is provided in Figure F7, Appendix C. As part of this PMAP revision, the CSM for RAAF Base Tindal and surrounding areas was reviewed for currency. No new sources of PFAS contamination or transport pathways have been identified. Although, currently, further investigation is underway to understand potential seasonal variability in groundwater in the Cossack area. For more detailed information informing the CSM, refer to the reports listed in Appendix A.

3.1 Source areas

Source areas can be primary or secondary. Primary sources are areas of PFAS contamination where aqueous film forming foam (AFFF) was used or stored, for example, a fire training area. Secondary source areas contain an accumulation of PFAS contamination in the environment, such as in soil or sediment, which has migrated from a primary source area through groundwater or surface water. Key primary source areas are where a majority of PFAS is found on the base and where most of the PFAS migrating off-base is sourced from. Whereas minor source areas contribute to PFAS migration off-base but to a lesser degree. Each source area has an associated Contaminated Site Register (CSR) identification number.

The PFAS source areas that have been identified through previous investigations (Appendix A), each having an associated Contaminated Site Register (CSR) identification number (ID), is provided in Table 1. A map showing these source areas is provided as Figure F6 in Appendix C.

Table 1. Known source areas of PFAS

Source area	CSR ID	Extent of PFAS contamination
Former Fire Training Area (FTA)	CSR_NT_000042	Key primary source area. The most significant PFAS risk is groundwater abstraction by the downgradient Katherine Township for water supply resulting in a complete Source-Pathway-Receptor linkage. PFAS present in soil, groundwater and surface water.
Fire Station Area (FSA)	CSR_NT_000041	Key primary source area. PFAS present in soil, groundwater and surface water.
Mechanical Equipment Operations Maintenance Section (MEOMS)	CSR_NT_000103	Minor primary source area, PFAS present in groundwater and infrastructure including interceptor drains.
Fuel Farm 1	CSR_NT_000084	Minor primary source area. Confirmed minor PFAS present in groundwater and retention pond.
Fuel Farm 2	CSR_NT_000085	Minor primary source area. Confirmed minor PFAS present in groundwater and retention pond.

Source area	CSR ID	Extent of PFAS contamination
Solid wastes in the on-base Sewage Treatment Plant	CSR_NT_000036	Minor secondary source area.

3.2 Transport pathways

PFAS can travel from a source to human and/or environmental receptors via transport pathways, such as surface water, groundwater and stormwater. The transport pathways identified at and surrounding the base is summarised in Table 2.

Table 2. PFAS transport pathways

Source area	Transport mechanisms
Primary source areas: • FSA • FTA	• Vertical migration of PFAS in shallow soils around source areas into groundwater • Migration of PFAS in groundwater through the Tindall Limestone aquifer, flowing to the west, towards Katherine River • Transfer of PFAS between groundwater and surface water via sinkholes and shallow 'daylighting' groundwater (during the wet season) • Discharge of PFAS in surface water into Katherine River via Tindal Creek • Discharge of PFAS in groundwater into Katherine River through springs • Migration of PFAS down-stream in Katherine River • Extraction of groundwater from the Tindall Limestone aquifer via groundwater bores for potable (drinking water) and non-potable (irrigation and recreational) uses
Additional minor source areas: • Fuel Farm 1 and Fuel Farm 2 • Mechanical Equipment Operations Maintenance Section	
Secondary source areas: • Sediments and waters in open base drains and Tindal Creek • Sediments and waters in base closed drainage infrastructure (pits, drains and sewerage) • Surface water runoff from hardstand areas in and around the FSA.	• PFAS impacts in sediments mobilised through influx of surface water runoff in the wet season. PFAS migration through the on-base drainage network into Tindal Creek • Migration of PFAS in surface water along Tindal Creek, into Katherine River • Migration of PFAS in surface water from contaminated concrete and pavement areas surrounding the FSA.

3.3 Receptors and risks

A Detailed Site Investigation (Coffey, 2018a) identified potential pathways through which humans and ecological receptors could be exposed to PFAS sourced from the base. These included:

Humans

- users of extracted impacted groundwater (i.e. bore water used for drinking water, swimming, irrigation, stock watering and consumption of home grown produce)
- users of Tindal Creek and Katherine River (i.e. drinking water, swimming, consumption of aquatic biota), and
- base personnel in impacted areas across the base.

Ecosystems

- aquatic ecological receptors including flora and fauna in and around Tindal Creek and Katherine River
- terrestrial ecological receptors including flora and fauna within the Management Area

3.3.1 Human Health Risks

A Human Health Risk Assessment (HHRA) (Coffey, 2018b) was conducted that measured PFAS exposure risks to people living, working and undertaking recreational activities within the Management Area.

The HHRA concluded that exposure to PFAS impacted water and biota within the Management Area may result in marginal or elevated human health exposure risks (refer to Table 3). NT Health, on behalf of the NT Government, subsequently used this information to issue precautionary advice, tailored to the five zones, to help residents minimise their exposure to PFAS.

A summary of these risks is provided in Table 3.

Table 3. Risks to human receptors

Risk Level	Receptors	Risk Characterisation
Elevated	Residential	• Ingestion of drinking water sourced from groundwater extracted from private bores within Zone 1. • Ingestion of drinking water sourced from groundwater extracted from private bores within Zone 2. • Ingestion of eggs by young children and adults, obtained from poultry fed and watered by PFAS impacted groundwater within Zone 1.
Marginal		• Ingestion of drinking water drawn from the Katherine River down-stream of sample location SW110 (opposite Rapide Street) in Zone 3. • Young children frequently swimming in pools filled with bore water extracted from Zone 1. • Young children ingesting large quantities of home-grown root vegetables irrigated with bore water extracted in Zone 1. • Young children frequently eating beef from cattle watered with bore water extracted in Zone 1. • Young children frequently eating eggs from poultry watered with bore water from Zone 1.
Elevated	Recreational	• Ingestion of a range of fish caught in Katherine River (specifically downstream of sample location

Risk Level	Receptors	Risk Characterisation
		SW110, opposite Rapide Street) by recreational fishers. • Ingestion of crustaceans caught in Tindal Creek or Katherine River (specifically downstream of sample location SW110, opposite Rapide Street) by recreational fishers. • Data gaps exist around the risks associated with the consumption risks associated with consumption include, but are not limited to: turtles, freshwater shrimp, and mussels.
Elevated	Workers (on-base and off-base)	• Ingestion of drinking water sourced from groundwater extracted from private bores within Zone 1 and Zone 2 or river water in Zone 3 by workers. • Incidental ingestion of shallow groundwater within maintenance trenches located in source areas at the base by subsurface workers. • Exceedances of the adopted soil screening criteria for base workers undertaking subsurface or maintenance works were noted in the maximum concentrations reported in the Fire Training Area, which is an identified source area. Soil remediation completed between 2022 and 2023 have treated or removed and destroyed the highest PFAS impacted soils at the FTA that are above 2mg/kg, reducing the potential risk to site workers in this area. PFAS impacted material that was identified above commercial / industrial health criteria have been removed from base. • Exceedances of the adopted human health sediment screening criteria in infrastructure sediments indicated that maintenance workers at the base undertaking repairs or maintenance on infrastructure pits (MEOMS) may be exposed to elevated concentrations of PFAS. Infrastructure sediments have been removed from the FTA and were destroyed at an interstate PFAS impacted soils destruction facility, removing this risk from the FTA.

3.3.2 Ecological Risks

Potential risks to ecological receptors that were identified as elevated or unacceptable in the Ecological Risk Assessment (ERA) (Coffey, 2018c) are listed in Table 4. The species selected for evaluation were considered to be representative of the environmental values to be protected for the most sensitive and potentially highly exposed species. All the risks were determined to be either negligible, very low or low. There were no scenarios identified that indicated PFAS could result in potential adverse effects to the local ecology.

To further minimise human health and ecological risks Defence continues to implement risk management actions (as provided in Section 4) to reduce PFAS leaving the base.

Table 4. Risks to ecological receptors

Risk Level	Land Based Animals	Location
Negligible	• Birds that eat plants • Mammals that eat plants • Reptiles that eat insects or plants and animals/insects Predatory reptiles	Developed and operational parts of the base and a large buffer zone surrounding the secured boundary. Other settings include the rural residential area of Uralla; woodlands and grasslands in vacant Crown land; and developed commercial and industrial sites down gradient of the base.
Very Low	• Birds that eat insect/aquatic, invertebrates, or plants and animals • Reptiles that eat insects or plants and animals/insects	Developed and operational parts of the base, and a large buffer zone surrounding the secured boundary. Other settings include the rural residential area of Uralla, woodlands and grasslands in vacant Crown land, and developed commercial and industrial sites.
	• Predatory reptiles	Decreased risk of exposure at FSA and FTA due to soil remediation works.
Low	• Birds that eat plants • Birds that eat insect/aquatic, invertebrates, or plants and animals • Predatory birds • Mammals that eat plants • Mammals that eat insects or plants and animals/insects omnivorous • Mammals that eat animals	Decreased risk of exposure at FSA and FTA due to soil remediation works.
Risk Level	**Water Based Animals**	**Location**
Negligible	• Reptiles that eat fish	Upstream and downstream of Katherine River and Tindal Creek off-base.
	• Reptiles that eat insects or plants and animals/insects	Upstream and downstream of Katherine River and Tindal Creek off-base and on-base.
Very Low	• Birds that eat insect/aquatic, invertebrates, or plants and animals	Upstream and downstream of Katherine River and Tindal Creek off-base.
	• Birds that eat fish • Mammals that eat fish	Upstream and downstream of Katherine River
	• Reptiles that eat fish	Tindal Creek on-base

Risk Level	Land Based Animals	Location
Negligible	• Birds that eat plants • Mammals that eat plants • Reptiles that eat insects or plants and animals/insects Predatory reptiles	Developed and operational parts of the base and a large buffer zone surrounding the secured boundary. Other settings include the rural residential area of Uralla; woodlands and grasslands in vacant Crown land; and developed commercial and industrial sites down gradient of the base.
Very Low	• Birds that eat insect/aquatic, invertebrates, or plants and animals • Reptiles that eat insects or plants and animals/insects	Developed and operational parts of the base, and a large buffer zone surrounding the secured boundary. Other settings include the rural residential area of Uralla, woodlands and grasslands in vacant Crown land, and developed commercial and industrial sites.
	• Predatory reptiles	Decreased risk of exposure at FSA and FTA due to soil remediation works.
Low	• Birds that eat plants • Birds that eat insect/aquatic, invertebrates, or plants and animals • Predatory birds • Mammals that eat plants • Mammals that eat insects or plants and animals/insects omnivorous • Mammals that eat animals	Decreased risk of exposure at FSA and FTA due to soil remediation works.
Risk Level	**Water Based Animals**	**Location**
Low	• Birds that eat insects, or plants and animals/insects	Tindal Creek on-base
	• Birds that eat fish • Mammals that eat fish	Tindal Creek on and off-base

4 RISK MANAGEMENT ACTIONS

This section outlines the actions that Defence will take to manage the risks associated with PFAS that are described in Section 3.

4.1 Background

In developing actions to address potential risks to receptors from PFAS contamination, Defence considers:

- whether a remediation option is proportional to risks
- the sustainability and longevity of an option (environmental, economic and social) in achieving an appropriate balance between benefits and effects
- views of the jurisdictional regulator and other stakeholders
- availability of best-practice management systems, treatments and technologies
- site specific issues (including transformation, cross-contamination, and remobilisation)
- logistical and operational constraints
- effectiveness and validation status of technology
- success measures for the treatment or remediation outcomes
- the need for ongoing operations, management, maintenance or monitoring
- the net environmental benefit

Defence prioritises source management and pathway management as preferable to receptor management, but these components may also be progressed concurrently.

4.2 Implementation

Defence takes a risk-based approach to implementing actions under this PMAP and considers value for money in the use of public resources. Defence engages consultants to implement the PMAP.

Key factors for progressing and prioritising PMAP actions include:

Mitigating PFAS migration and protecting human health	Implementation of practicable solutions to prevent or minimise the migration of PFAS beyond the Defence property boundary, and measures to protect the community from exposure to PFAS.
Higher risks	The relative level of risk being addressed, including changes in land use.
Outcomes of completed works	Outcomes from further studies, technology trials or validated remedial works may change the profile or priority of source areas or works.
Linked actions	Whether the implementation of one risk management action is dependent on the implementation of another risk management action.
Use of public resources	Application of the Commonwealth Procurement Rules (issued under the *Public Governance, Performance and Accountability Act 2013*) including the Defence Infrastructure Panel – Environment, Heritage and Estate Engineering Services 2020-2025, to achieve value for money in procurement; and to use public money in an efficient, effective, economical and ethical manner. Cost-effectiveness may be facilitated through: • grouping the implementation of similar risk management actions within one or more Management Areas

	• aligning Defence infrastructure and maintenance plans with a PFAS risk management action.
Mandatory approvals	Timeframes for mandatory approvals and notification processes.
New legislation or policy	Development of relevant legislation, policy, guidelines and whole-of-government positioning.
Science and technology	The availability of new relevant science and technology.
Stakeholder input	Information from stakeholders that may impact a risk profile.

4.3 Completed and ongoing risk management actions

A screening assessment of options to manage the risks presented in Section 3 was undertaken as part of the 2019 PMAP. Based on this assessment, the strategy adopted was to mitigate elevated risks using a combination of source management, pathway management and receptor management. The current status of the 2019 PMAP actions are detailed in Table 5.

Table 5. Status of 2019 PMAP recommended actions

Action	Description	Status	Outcome
Exposure Management	**Alternative Water Supply** Provision of bottled water, rainwater tanks pending long term solution.	Ongoing	The rainwater tank installation, tank top-up and bottled water supply program will continue. Ongoing review of the practicability of implementation of contingency actions (supply of alternative water).
Exposure Management	**Testing of private groundwater water supply bores** Assessment of PFAS impact at the point of use.	Ongoing	Defence continues to test private groundwater bores via the Ongoing Monitoring Program (refer to Section 4.6) or ad-hoc sampling requests from residents.
Exposure Management	**Advisory on consumption** Advisory on consumption; engagement with NT Health and NT EPA to confirm ongoing approach and implementation.	Ongoing	Human exposure from consumption of fish in Katherine River and Tindal Creek, and consumption of home-grown fruit and vegetables watered with contaminated bore water (Zone 1). Supporting ongoing community engagement strategy with NT Government and increasing awareness via community sessions on the potential health risks of frequent consumption of fish, crustaceans, and other aquatic organisms, and/or recreational use of creeks. Defence continues to undertake biota sampling as part of the Ongoing Monitoring Program (refer Section 4.6).

Action	Description	Status	Outcome
Exposure Management	**PFAS WTP for town water supply** Installation of interim ECT2 Pty Ltd (ECT2) water treatment plant at the Power & Water Corporation (PWC) water treatment plant to manage human exposure through use of extracted groundwater in town water supply.	Ongoing	A new permanent treatment system has been constructed and is currently in operation, currently treating 10ML per day. Implementation steps are: • support PWC in planning and, sourcing of the plant (completed). • confirm commissioning, based on information provided by PWC (completed) • observe performance of the system, based on monitoring data provided by PWC (ongoing).
Source Management	**On-base groundwater remediation** The dominant sources of PFAS impact to off-base groundwater contamination are at the FTA and FSA. Pump and treat of groundwater extracted from these areas commenced to reduce the mass of PFAS leaving these zones.	Ongoing / optimisation	Two groundwater treatment systems are currently operating (commissioned in 2019 by ECT2) on the base to treat PFAS impacted groundwater associated with the FTA and FSA. Ongoing works required to reduce PFAS mass leaving the base in groundwater include: • finalisation of mass flux investigations, assessing the movement of PFAS across the base boundary via both groundwater and also intermittently via surface water in Tindal Creek into downgradient areas / water bodies • identify feasible groundwater extraction and re-injection locations from FTA and FSA • improve understanding of fate and transport to optimise the water treatment systems. This will be conducted by completing a geophysical investigation coupled with additional intrusive works to select favourable well extraction locations. • install and commission long-term treatment system (if required). Monitor pumping

Action	Description	Status	Outcome
			response and system performance to guide improvements. • develop a base-wide Groundwater Remediation Action Plan.
Pathway Management	**Controls on soil movement** Controls on ground disturbance and movement of soil from source areas and transport off-base. Soils at and in the vicinity of the FTA, the FSA, and the Fuel Farms are known to contain elevated concentrations of PFAS, which may present a compliance or exposure risk if transported or handled inappropriately.	Ongoing	Ongoing development of a base-wide Spoil Management Plan, siting a location for long term soil management resulting from on-base construction activities. Implementation of the Defence PFAS Construction and Maintenance Framework to define principles of soil management. Ensuring all base Environmental Certificates of Compliance (ECCs) describe controls on cross contamination and soil movements from source areas, including classification prior to off-base transport. PFAS impacted soils at the FTA and FSA have undergone treatment or have been removed and destroyed at an offsite waste destruction facility and as such no longer represent risk of being transported, although some residual PFAS in soils remains outside of the remediation area footprint and therefore will need to be managed under a Spoil Management Plan.
Pathway Management	**Sediment Management** Implement access restrictions to sediments within MEOMS interceptor pits. Removal of sediments from FTA evaporation ponds.	Completed	The sediments in the FTA evaporation ponds have been removed and destroyed at an offsite waste destruction facility as per the Soil Remediation Action Plan (RAP). The sediments in the MEOMS interceptor pits contain high concentrations of PFAS and may present an elevated exposure risk to maintenance workers in contact with sediments. Controls implemented to limit exposure include: • limit contact with effluent tanks to trained and inducted personnel

Action	Description	Status	Outcome
			• apply mandatory PPE requirements for accessing interceptor pits.
Source Management	**Infrastructure Management** Removal of infrastructure from FTA. Management of effluent and sediments in accordance with the facility management plan.	Completed	All FTA infrastructure has been removed and encapsulated in the nominated remediation area. Concrete from the demolition of the former evaporation ponds #1 to #3 and the former fire pit were crushed, encapsulated in a high-density polyethylene (HDPE) liner and placed within the designed remediation area, which was then capped. All PFAS impacted sediments within the former evaporation ponds at the FTA were removed from base. An environmental management plan is under development to administer control / maintain the integrity of the remediation area and cap and therefore mitigate future exposure.
Source Management	**Soil Management** Remediation of high level PFAS impacted materials at the FSA and FTA has been undertaken. However, low level contaminated soil outside of the FTA and FSA remediation areas and to a lesser extent in localised areas of the base present ongoing, or potential future, sources of PFAS impact to groundwater and surface waters.	Completed	Completed soil remediation works at the FTA include: • excavation and offsite destruction of highly impacted soils. • excavation and treatment and reinstatement of moderately impacted soils. The capping of the FTA remediation area has been completed and hydroseeding is in its growth phase. Completed works at the FSA include: • excavation, treatment, and partial reinstatement of moderately impacted soils. • scraping and treatment of main drainage swale soils or onsite reinstatement. • installation of cap over the remediation area and surface water re-direction earthworks.
Source Management	**Feasibility Study**	Ongoing	Defence undertaking sealant study in collaboration with CSIRO.

Action	Description	Status	Outcome
	Undertake a pilot trial on the sealing of contaminated infrastructure. The concrete may be acting as an ongoing source of impact to surface water during rainfall or washdown events. Where replacement of the concrete surfaces and infrastructure is not scheduled or warranted, sealing of the surface to reduce leaching to run-off may be beneficial.		Options assessment to be undertaken for infrastructure decontamination or sealing. Conduct treatability trials to decontaminate or prevent ongoing leaching of PFAS compounds from drains, hardstand and other infrastructure areas.

4.4 Additional risk management actions

Additional management actions have been identified and implemented since publication of the 2019 PMAP. A description and the status of these actions are set out in Table 6.

Table 6. Status of additional risk management actions

Action	Description	Status / reason / timeframe
Source Management	**Source Area Remediation** Ongoing remediation at FTA and FSA	Almost complete. Further excavation and treatment of source mass at the FTA source area, specifically the residual source material under the former evaporation ponds #2 and #3. A data review, further investigations and 3D geospatial modelling is being conducted to gain a better understanding of the contribution of PFAS through surface water from FSA infrastructure. Outstanding investigative works include washdown tests, sample collection, and leachate testing of different hardstand areas and materials. These investigations are to start in early 2025.
Source Management	**Cleaning of redundant waste foam storage tank (FSA)**	Completed. A decommissioned 2 kL waste foam tank was decontaminated and disposed of off-base.
Source Management	**Minor Source Areas - Remediation**	Ongoing. Additional, targeted investigations around other source areas. Other minor source areas include the MEOMS, Fuel Farms 1 and 2, and the wastewater treatment plant. The need for a RAP for these areas is unlikely although these areas will likely require ongoing

Action	Description	Status / reason / timeframe
		management combined with opportunistic remediation actions such as dealing with potential PFAS contaminated waste during future base upgrades or redevelopment actions in these areas. At MEOMS, limited sampling and data review has been undertaken. Further investigation is required to determine the nature of contamination in this area and infrastructure management requirements, including evaluating whether the concrete is an ongoing source. Investigative works to start in early 2025.
Source Management	**CSIRO trial – concrete treatment**	Ongoing. If the research identifies successful treatment options for concrete, develop a RAP to describe the implementation of full-scale treatment of PFAS impacted infrastructure / hardstand areas, with particular focus on the FSA and MEOMS areas.
Pathway Management	**Passive Water Treatment – Tindal Creek** Seasonally dependent groundwater discharge into surface water (Tindal Creek) from the base.	Ongoing. Further data gap investigations are required to inform potential effectiveness and design of a passive water treatment system at locations where groundwater daylights into Tindal Creek during the end of the wet season / beginning of the dry season. This assessment is currently being conducted, with findings to be reported in late 2024.
Pathway Management	**Mass Flux Investigations**	Ongoing. A Sampling, Analysis and Quality Plan (SAQP) has been developed (AECOM, 2022) and is being implemented to measure pre- and post-remediation mass flux incorporating data from the 2018 DSI. This program commenced in 2022 and has developed a dataset of annualised mass flux estimates leaving the base. Continued data collection will be used to monitor consequential changes in PFAS surface water mass flux from the base boundary, as a result of completed and future remediation efforts. Conduct additional groundwater investigations to refine the conceptual model and groundwater mass flux estimate and to assist in the preparation of a base-wide Groundwater Remediation Action Plan. The scope and direction of the groundwater investigation will be informed by the geophysical surveys of the FSA and FTA. Planned to be completed in 2025.
Receptor Management and Review of Management Area Boundaries	Investigate westerly migration of, or seasonal impact on the PFAS groundwater	Ongoing. Installation of new monitoring wells to monitor changes in groundwater levels and corresponding PFAS concentrations within the Cossack area. This will improve understanding of groundwater movement and recharge within Cossack during wet and dry seasons,

Action	Description	Status / reason / timeframe
	plume in the Cossack area. Consider amendments of the Management Area (Zone # 2).	and to evaluate whether the CSM and risk profile in this area requires amendment. Works pending approval of installation of monitoring wells on Katherine Town Council land, planned installation in late 2024. Observed changes in the locations and concentrations of PFAS within the Cossack area and review whether the Management Area boundary requires modification. To be reviewed following additional wet season data collection near the Management Area western boundary.

4.5 Completed remediation actions

The base has been subject to previous and ongoing PFAS remedial actions, including soil, sediment, infrastructure and groundwater remediation as summarised in the following sections.

4.5.1 0FSA – Soil and Drainage

Soil, infrastructure and sediment remedial works at the FSA were completed in 2023 in general accordance with the 2019 PMAP. The purpose of the remedial works was to reduce, to the extent practicable, the mass of PFAS in soil at the FSA. A total of 9,000 m^3 of soil was treated via stabilisation with powdered activated carbon at amendment dosage of 1%. The treated soils were reinstated following confirmation that leaching had been reduced to the remedial acceptance criteria. The treated material was compacted during reinstatement into the excavation and then covered with a compaction layer that was recontoured so that the final landform diverted runoff away from the treatment area (5,450 m^2). Post remediation modelling will be conducted to estimate the pre- and post-remediation PFAS mass estimates.

The main surface water drain that diverts water from the FSA hardstand areas to the main runway drain was scraped to 300 mm below the surface in 2022. Soils from this scaping activity were added to main excavation soils for treatment and inclusion in reinstatement within the FSA remediation excavation area.

A temporary stormwater drainage pipeline was installed to ensure the FSA excavation area could be kept as dry as practicable with limited impact of water ingress from the upstream flow.

4.5.2 FTA – Soil, Infrastructure and Drainage

Soil, infrastructure and sediment remedial works were completed at the FTA in October 2024.The purpose of the remedial works was to reduce to the extent practicable, the mass of PFAS in soil at the FTA. A total of 44 m^3 of sediments removed from the onsite evaporation pond sediments, 70 m^3 of concrete fines (powder to grain sized concrete), and 475 m^3 of soil from the FTA was shipped to an interstate waste destruction facility.

Three evaporation ponds and the fire training pad were all demolished, with the training pad and evaporation pond #1 demolished in 2022, and evaporation ponds #2 and #3 demolished in 2024. All concrete from the training pad and evaporation ponds will be encapsulated within the FTA remediation area beneath the finished capping layer according to the amended technical specifications (AECOM, 2024b).

A total of 30,500 m^3 of soil was treated via stabilisation with powdered activated carbon at amendment dosage of 1% or was shipped off site to a thermal destruction facility interstate. The treated soils will be reinstated following confirmation that leaching had been reduced to the remedial acceptance criteria. The treated material will be compacted during reinstatement into the excavation and then covered with a compaction layer that was recontoured so that the final landform diverted runoff away from the treatment area. It is estimated that 70% of the modelled mass at the FTA has been remediated and/or managed.

The main surface water drain that ran along the western side of the FTA was scaped to 300 mm below the surface in 2023. Soils from this scaping activity were added to main excavation soils for treatment and inclusion in reinstatement within the FTA remediation excavation area.

4.5.3 Groundwater water treatment plants

ECT2 has operated two WTP's at the base since 2019, one at the FSA and the other at the FTA, both utilising anionic resins. As of August 2024:

- 1,970,488,000 litres of groundwater have been extracted and treated by the FSA WTP, and
- 1,339,660,000 litres of groundwater have been extracted and treated by the FTA WTP.

The treated water is reinjected into the ground or used on-base for construction purposes such as dust suppression. The development of the base-wide Groundwater RAP will consider the efficacy of these WTPs and identify any opportunity to optimise the PFAS mass being extracted.

4.5.4 Decontamination of decommissioned waste foam AST at FSA

A decommissioned 2000 L above ground storage tank (AST), that formerly contained waste foam, was located at the FSA. The subject AST was decontaminated and subsequently removed from the base in 2024. Pipework and other AFFF related FSA infrastructure still requires management to ensure that there are no releases or discharges of PFAS to the environment or sewer. Additional investigation is required to characterise any ongoing contribution of PFSA to surface water. If AFFF related infrastructure becomes redundant to base operations, then an adequate decontamination program is required to be designed and implemented.

4.6 Ongoing monitoring and trigger levels

Defence continues to monitor PFAS concentrations in the environment at the base through an ongoing monitoring program. This allows for the timely identification and management of emerging risks and informs Defence's approach to the management of PFAS. Monitoring requirements are outlined in an Ongoing Monitoring Plan (OMP). The OMP is reviewed annually and, if required, amended to ensure it continues to provide the data needed to monitor important changes in PFAS concentrations and distribution.

The results from the ongoing monitoring program are shared with the NT EPA and are provided in an Ongoing Monitoring Report, available on the Defence website. The Ongoing Monitoring Report provides the PFAS data, and an analysis of what important changes in concentrations may mean to the risk profile of PFAS contamination set out in the CSM, or potential changes to risks to humans or the environment.

Based on the data collected to date, no new sources of PFAS contamination or transport pathways have been identified. However, the Ongoing Monitoring Report (AECOM, 2024b), identified that the CSM for RAAF Base Tindal may require minor modification. Additional investigations (refer to Table 6) will predict better the response of the aquifer beneath Cossack during the wet and dry seasons and

the potential expansion of the PFAS plume further to the west of the current boundaries of the Management Area. Surface water sampling will continue in Katherine River, the Hot Springs and the YMCA, with results to date confirming no changes in PFAS conditions throughout the monitoring period.

Soil remediation performed at the FSA and FTA has reduced / eliminated risk to base workers and ecological receptors (direct contact). In addition, there are on-base preliminary lines of evidence suggesting a reduction of PFAS migration as concentrations in both surface water and groundwater have decreased immediately downgradient of recent soil remediation actions conducted at the FSA and FTA.

The OMP outlines triggers and actions that Defence will undertake if certain results or trends are reported from the ongoing monitoring program sampling. This includes actions to confirm the accuracy of results, notification to the NT EPA and other agencies upon new PFAS detections or increasing trends and implementing additional investigations and risk management actions if the monitoring data indicates changes to the current risk profile. Currently, there are no OMP triggers requiring action or notification.

5 NEXT STEPS

Defence will carry out the risk management actions set out in this PMAP and continue to reassess its actions based on a range of factors, such as the outcomes of remediation, monitoring results, changes to government policy settings, base conditions and scientific methodologies and technologies.

Defence will review, and if required, revise the PMAP at regular intervals to ensure the PMAP remains current, relevant and prioritises the right actions to protect human health and the environment. Defence will continue to engage with the community, the Council, NT EPA, NT Health, Power & Water Corporation and other stakeholders to ensure information is available in an easily accessible form.

It is not possible to remove all PFAS from the environment. Remediation at RAAF Base Tindal will be undertaken so far as reasonably practicable, and unacceptable risks that may remain will be identified through monitoring and be appropriately managed. Removing PFAS completely is currently not achievable within the technical, logistical, environmental, and financial constraints associated with existing remediation technologies, and pursuing such course of complete PFAS removal would not result in a net environmental benefit

In determining what is reasonably practicable, the following range of aspects will be considered:

- level of risk from PFAS to human and ecological receptors
- environmental base setting
- nature and extent of PFAS contamination
- availability of proven technologies suitable for the characteristics of the base
- logistical and operational constraints of the base, and
- financial and sustainability aspects of each technology
- Environmental impacts vs. benefits.

At completion of remediation, an independent professional accredited as a site auditor in accordance with Section 68 of the *NT's Waste Management and Pollution Control Act 1998,* and engaged by Defence, will assess whether remediation has been conducted so far as reasonably practicable. The PMAP will then be updated to reflect a transition to ongoing monitoring, and long-term management of remaining risks.

APPENDIX A REFERENCES

AECOM (2022), Sampling and Analysis Quality Plan Service Package 3: Mass Flux Assessment, 11 August 2022.

AECOM (2024a), RAAF Base Tindal Ongoing Monitoring Report.

AECOM (2024b), Technical Specification Addendum – FTA PFAS Remediation, 29 August 2024

Coffey (2018a) Department of Defence RAAF Base Tindal Supplementary Detailed Site Investigation, 10 September 2018

Coffey (2018b) RAAF Base Tindal Human Health Risk Assessment for PFAS, 18 June 2018.

Coffey (2018c), RAAF Base Tindal Ecological Risk Assessment, 12 November 2018.

Coffey (2022), Remediation Action Plan (RAP) FSA and FTA Soil, 21 January 2022.

Department of Defence (2019), RAAF Base Tindal PFAS Management Area Plan, dated July 2019.

Heads of EPA (2020), PFAS National Environmental Management Plan, Version 2.0, January 2020

National Environment Protection Council (NEPC). (2013). National Environment Protection (Assessment of Site Contamination) Measure Amendment 2013.

APPENDIX B FIGURES

List of Figures

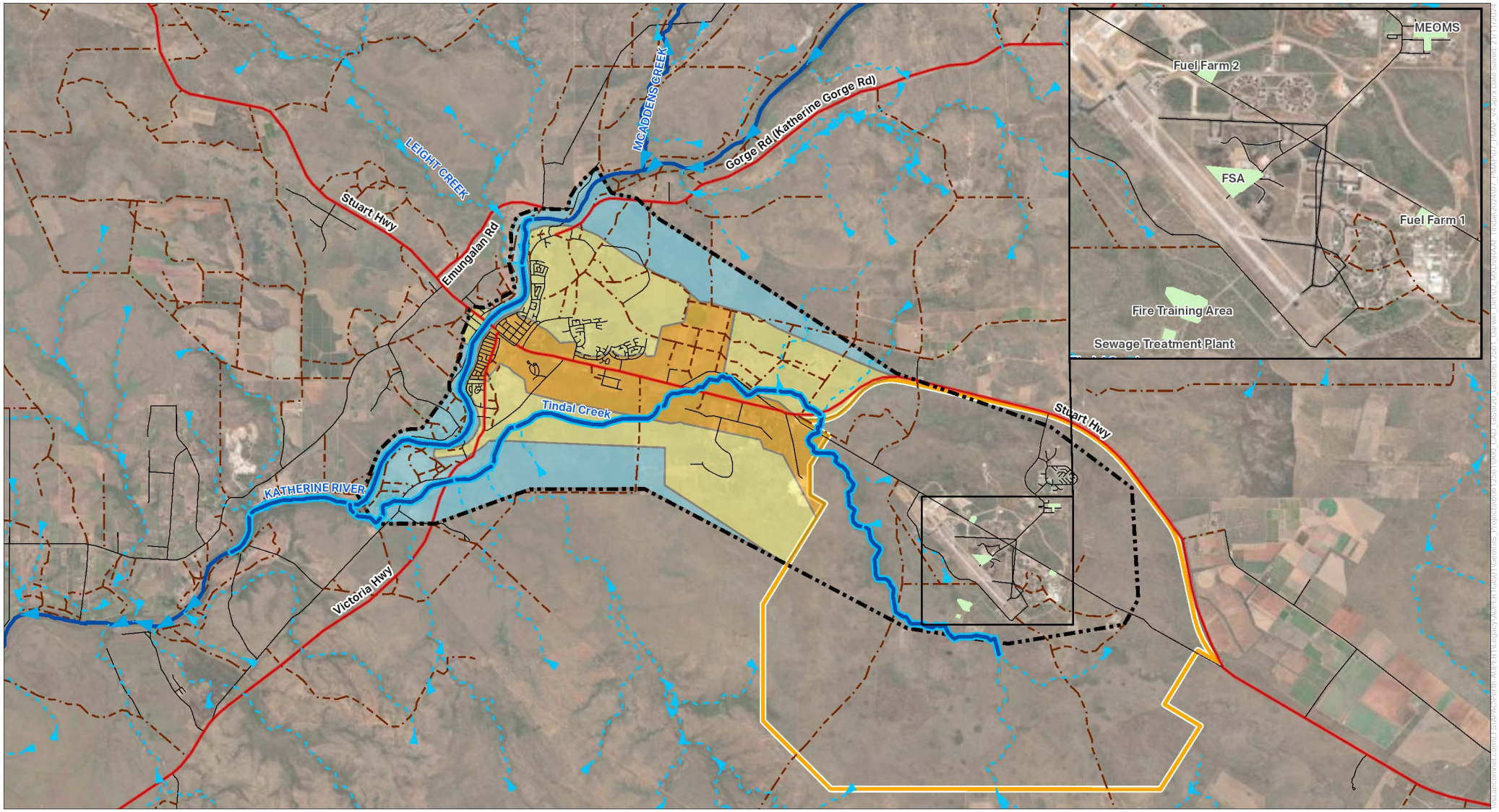

FIGURE F1: PFAS MANAGEMENT AREA

Legend

- RAAF Base Tindal
- Groundwater Management Area
- Zone 3 - Surface Water Management Area
- Highway
- Road
- Track
- Katherine River
- Drainage
- Zone 1 Groundwater > Recreational Water Criteria
- Zone 2 Groundwater > Drinking Water Criteria
- Zone 5 Groundwater < Criteria
- Source Areas

Note:

•FSA - Fire Station Area
•Zone 4 - Treated Town Water Supply - Not shown

N

0 1 2 3 km

AECOM

PROJECT
PFAS Management Area Plan
RAAF BASE TINDAL

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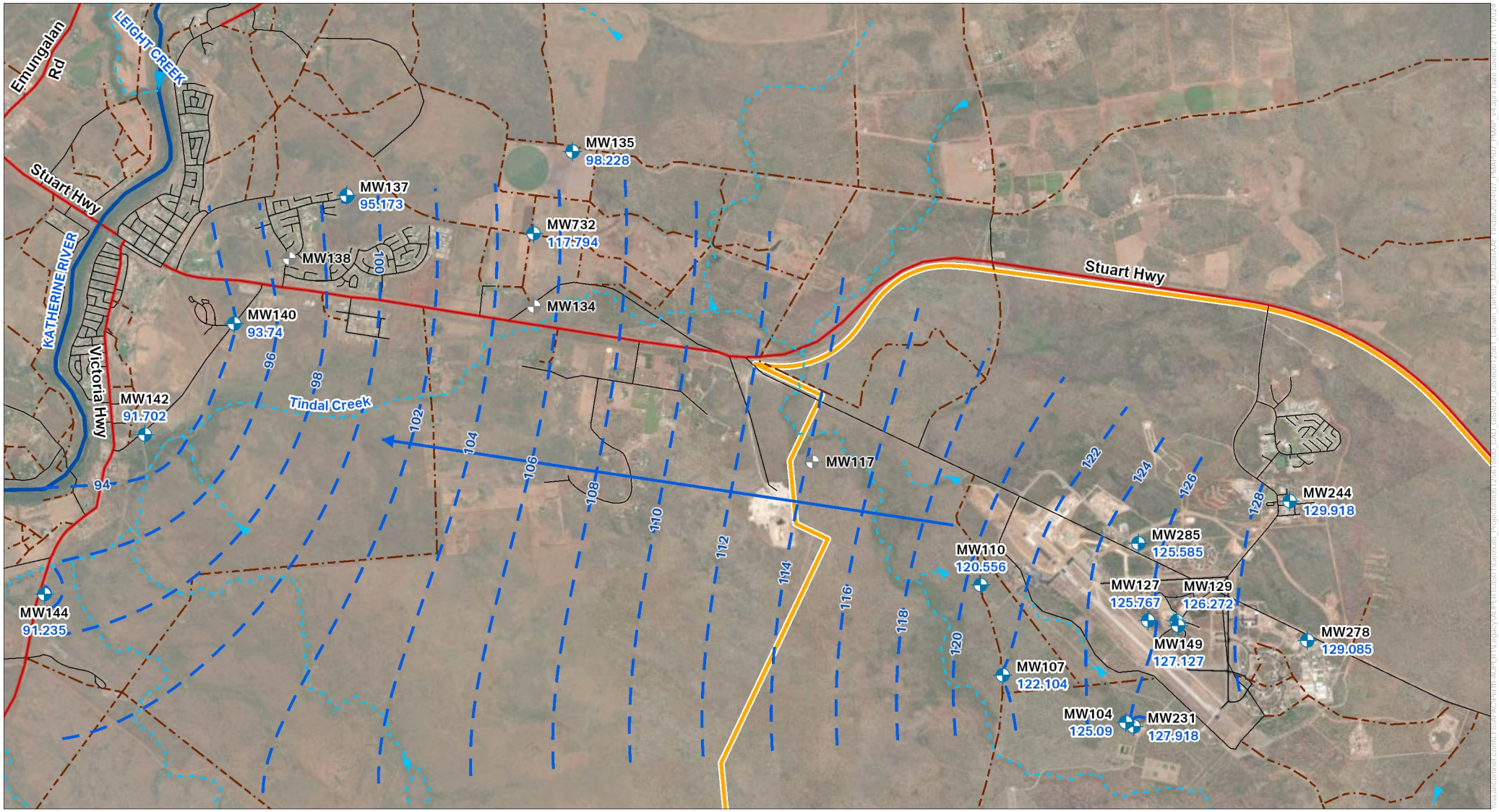

FIGURE F2: SEPTEMBER 2023 INFERRED GROUNDWATER CONTOURS

Legend

- RAAF Base Tindal
- Highway
- Road
- Track
- Katherine River
- Drainage
- Annual Groundwater Locations
- Not Sampled Due To Being Inaccessible, Dry or Blocked
- Inferred Groundwater Level (mAHD)
- Inferred Groundwater Direction

N

0 1 2 km

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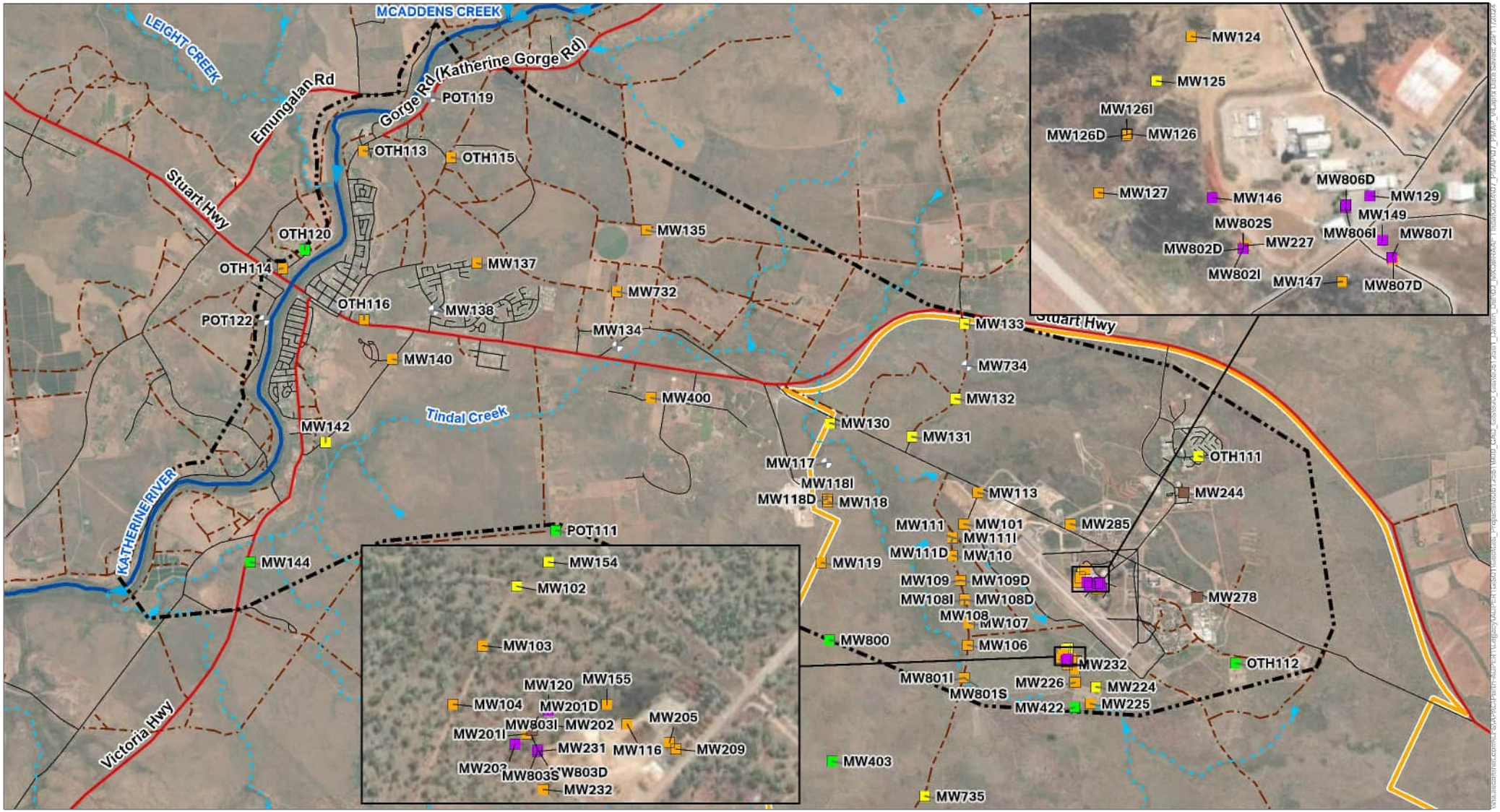

FIGURE F3: Sum of PFOS + PFHXS concentrations for on and off base groundwater locations September 2023 Sampling Event

Legend

- RAAF Base Tindal
- Groundwater Management Area
- Highway
- Road
- Track
- Katherine River
- Drainage

PFOS + PFHxS (µg/L)

- > 50
- > 10 - 50
- > 0.07 - 10
- > Limit of Reporting - 0.07
- < Limit of Reporting
- Groundwater Monitoring Location (Not Sampled)

N

0 1 2 km

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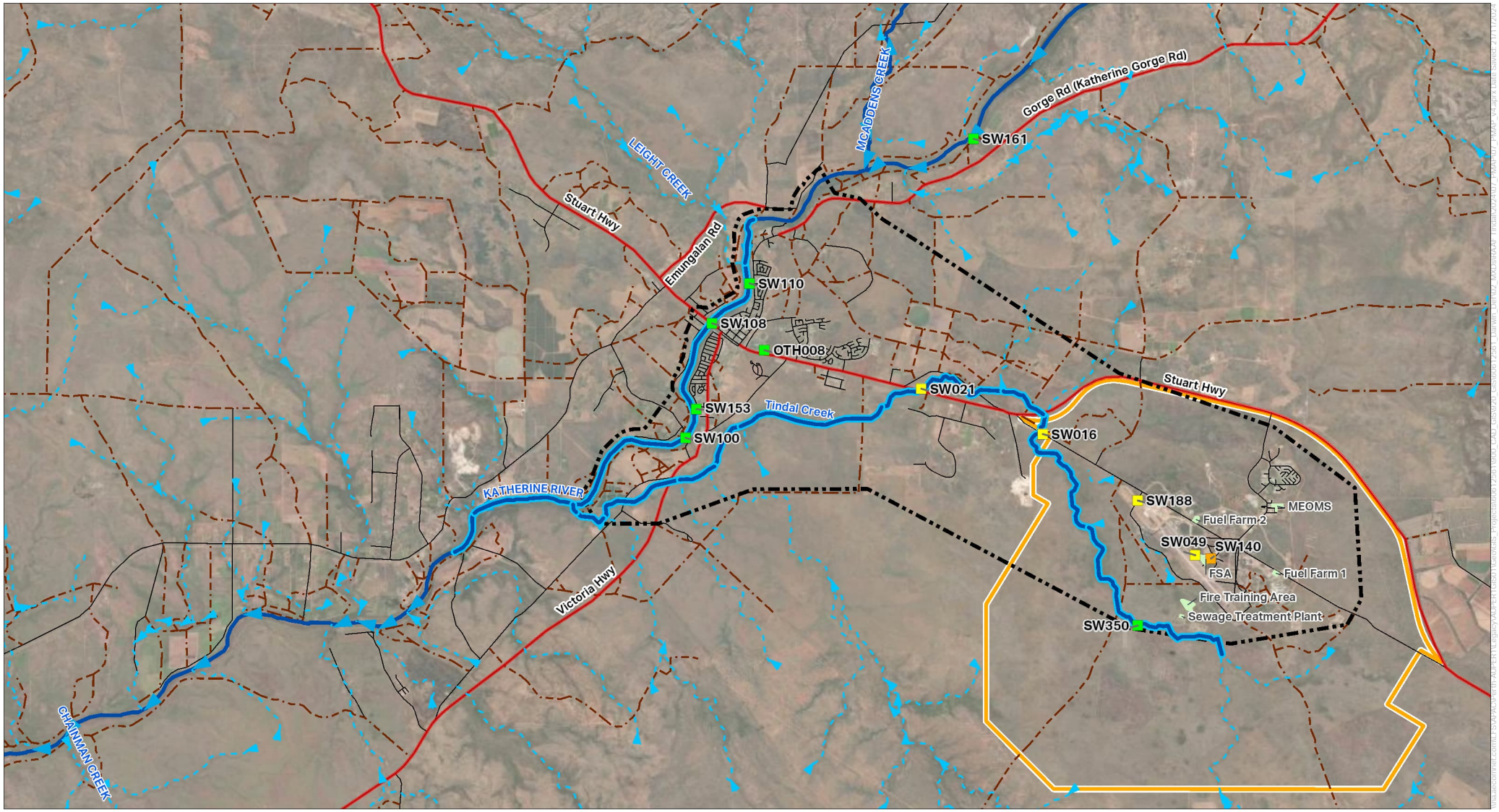

FIGURE F4: SUM OF PFHXS + PFOS CONCENTRATIONS FOR ON AND OFF-BASE SURFACE WATER LOCATIONS MARCH 2024 SAMPLING EVENT

Legend

- RAAF Base Tindal
- Groundwater Management Area
- Zone 3 - Surface Water Management Area
- Highway
- Road
- Track
- Katherine River
- Drainage
- Source Areas

PFOS + PFHxS (µg/L)

- > 50
- > 10 - 50
- > 2 - 10
- > Limit of Reporting - 2
- < Limit of Reporting
- Surface Water Location (Not Sampled)

Note:

- FSA - Fire Station Area
- SW108, SW153 and OTH008 quarterly sampling results Jan 2024

N

0 1 2 3 km

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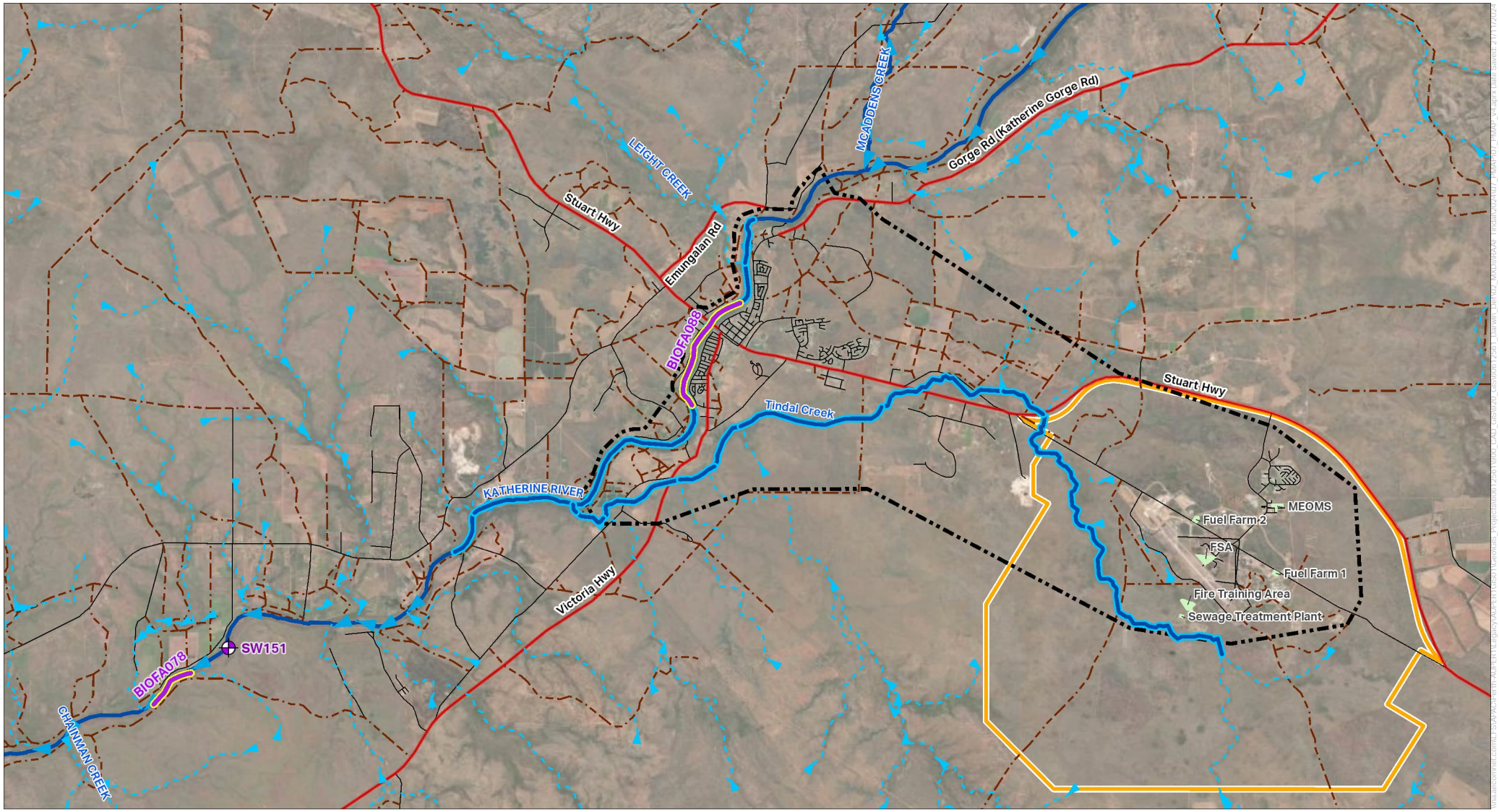

FIGURE F5: BIOTA SAMPLING LOCATIONS

Legend

- RAAF Base Tindal
- Groundwater Management Area
- Zone 3 - Surface Water Management Area
- Highway
- Road
- Track
- Katherine River
- Drainage
- Biota Sampling Surface Water Locations
- Biota Sampling Locations
- Source Areas

Note:

•FSA - Fire Station Area

N

0 1 2 3 km

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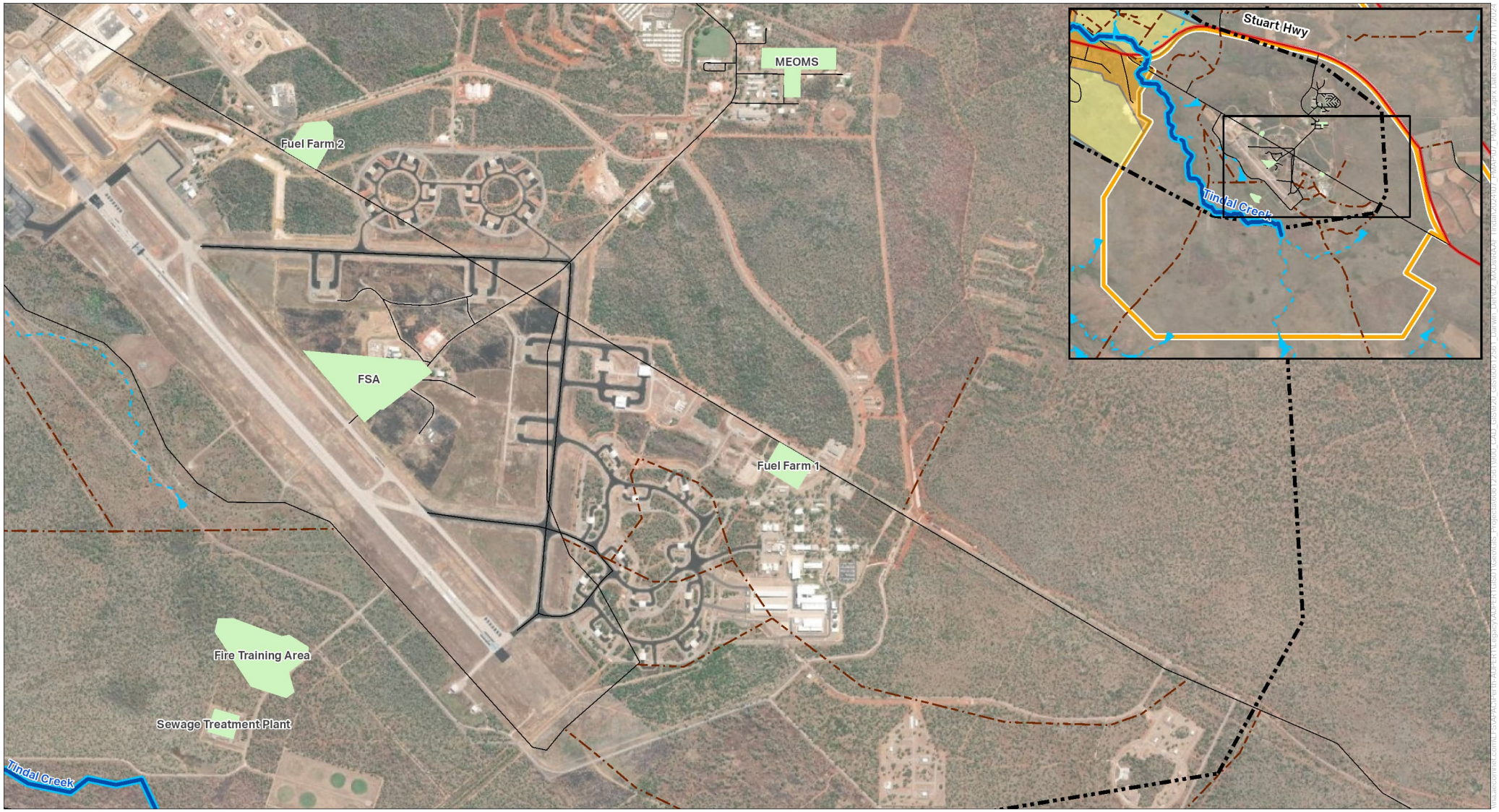

FIGURE F6: PFAS SOURCE AREAS

Legend

- RAAF Base Tindal
- Groundwater Management Area
- Zone 3 - Surface Water Management Area
- Highway
- Road
- Track
- Drainage
- Source Areas

Note:

•FSA - Fire Station Area

N

0 200 400 600 m

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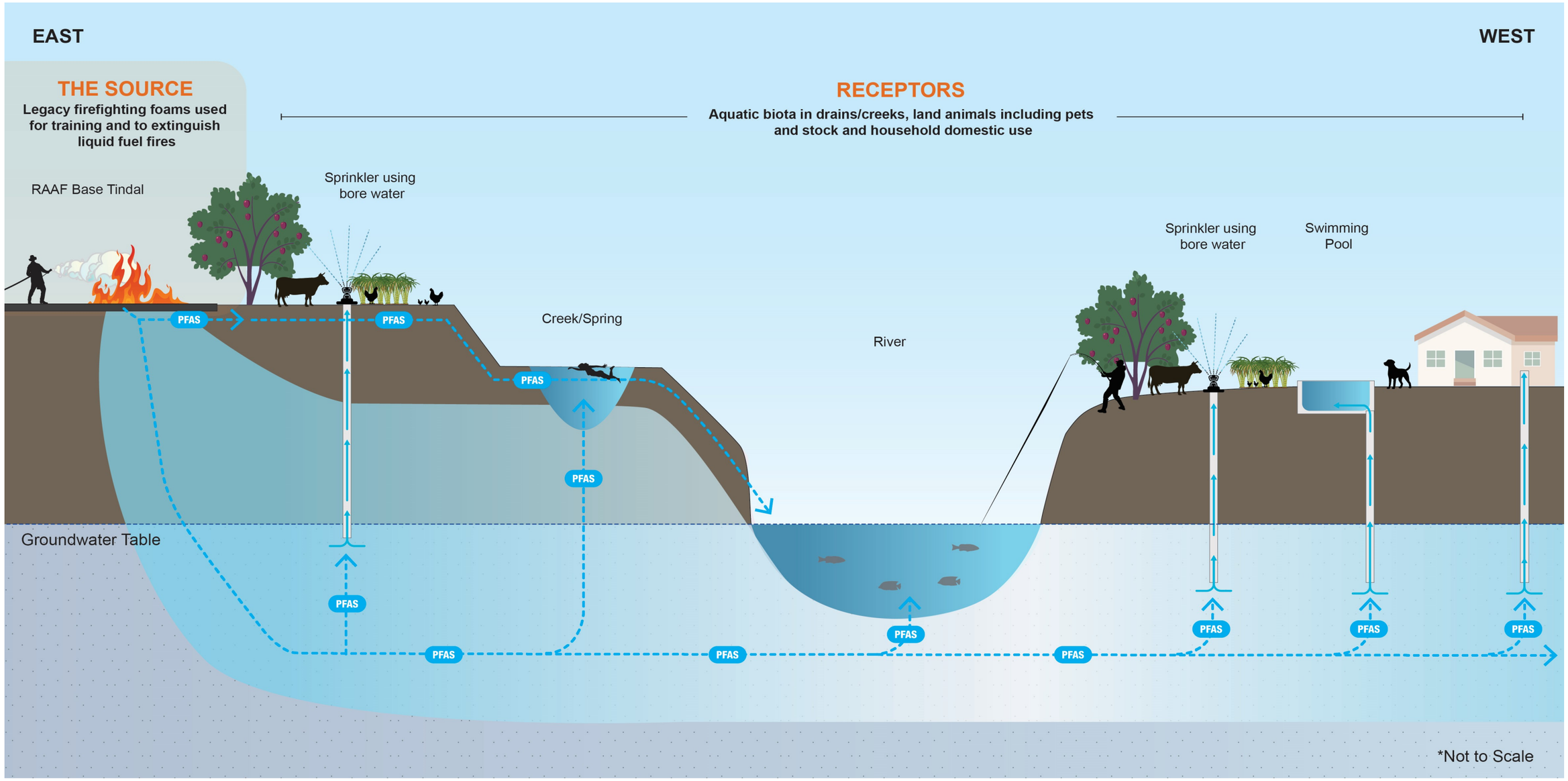
APPENDIX C CONCEPTUAL SITE MODEL

This Appendix provides visualisations of the source – pathway – receptor relationships in the form of a Conceptual Site Model.


EAST
WEST
THE SOURCE
Legacy firefighting foams used for training and to extinguish liquid fuel fires
RECEPTORS
Aquatic biota in drains/creeks, land animals including pets and stock and household domestic use
RAAF Base Tindal
Sprinkler using bore water
Creek/Spring
River
Sprinkler using bore water
Swimming Pool
PFAS
Groundwater Table
*Not to Scale