# Appendix B

## Source pathway receptor evaluation (sourced from the PMAP)

# Sampling and Analysis Quality Plan

## PFAS Ongoing Monitoring Plan, RAAF Base Learmonth

Department of Defence

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| | |
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# 1. Introduction

The Department of Defence (Defence) implements a national program to manage the impacts of Per- and Polyfluoroalkyl Substances (PFAS) on, and in the vicinity of, some of its bases around Australia. GHD Pty Ltd (GHD) has been engaged as Lead Consultant to support Department of Defence (Defence) in the management of legacy PFAS impacts and the implementation of the PFAS Management Area Plan(s) (PMAPs) for these sites.

As part of the engagement, GHD has prepared this Sampling and Analysis Quality Plan (SAQP) to support implementation of the PFAS Ongoing Monitoring Plan (OMP) for RAAF Base Learmonth ("the Site"), located approximately 30km south of Exmouth, Western Australia (Figure 1, Appendix A).

The OMP outlines the rationale and scope for the monitoring of the concentrations and extent of PFAS in groundwater, surface water and sediment at and surrounding RAAF Base Learmonth. It applies to not only RAAF Base Learmonth, but also the surrounding areas that, together with the Site, make up the "Management Area". For the purposes of this SAQP and with reference to Figure 1, Appendix A:

– "the Site" was defined as RAAF Base Learmonth; and
– "the Management Area" was defined as comprising the Site, plus the land east of the Base, including the salt pan, drainage channels, Wapet creek and extends to Exmouth Gulf.

***The OMP SAQP is based upon the underlying OMP (Defence, 2019b). It supersedes the previous Stantec (2024a) SAQP document and will be revised as required throughout its implementation in response to the separate OMP Revision process.***

## 1.1 Purpose and objectives

The purpose of this OMP SAQP is to support implementation of the OMP (Defence, 2019b) by detailing the specific monitoring locations, sampling methodologies and quality control / quality assurance measures to be implemented to seek to achieve the objectives of the OMP, which are to evaluate:

– The spatial and temporal (including seasonal) nature and extent of PFAS impact in in the environment associated with Site sources of PFAS derived from legacy use of aqueous film- forming foam (AFFF);
– Changes to the Conceptual Site Model (CSM), which describes the current understanding of PFAS sources, transport pathways and receptors (see Section 2.5);
– Whether current risks to human and ecological receptors require review;
– The influence that risk management activities at the base, as outlined in the PMAP have had on PFAS in the environment; and
– Whether any identified changes trigger an action and/or review.

Outcomes of implementation of the OMP will be drawn upon to review and revise the PMAP actions and to support formation of a supportive base of evidence to either:

– form a PMAP Transition recommendation (for bases where remediation is not required); or
– work through the framework towards Remediation So Far As Reasonably Practicable (SFARP, for bases where remediation is required).

## 1.2 Existing reports and documentation

Table 1 provides a list of all technical reports and documents considered relevant to this OMP SAQP.

*Table 1 Existing reports and documents (chronological order)*

| Report / Document | Citation |
|---|---|
| RAAF Base Learmonth – PFAS Investigations – Preliminary and Detailed Site Investigation Report | (GHD, 2018) |

| Report / Document | Citation |
|---|---|
| RAAF Base Learmonth – PFAS Investigations – Ecological Risk Assessment (ERA) | (GHD, 2019) |
| RAAF Base Learmonth PFAS Management Area Plan (PMAP) | (Defence, 2019a) |
| RAAF Base Learmonth PFAS Ongoing Monitoring Plan (OMP) | (Defence, 2019b) |
| PFAS OMP Biannual Monitoring Event Factual Report | (Cardno, 2020a) |
| OMP First Flush Sampling Event Factual Report | (Cardno, 2020b) |
| PFAS OMP 2020 post-summer Biannual Monitoring Event | (Cardno, 2020c) |
| PFAS OMP 2020 post-winter Biannual Monitoring Event | (Cardno, 2021a) |
| PFAS OMP First Flush Sampling Event Factual Report | (Cardno, 2021b) |
| PFAS OMP 2020 Annual Interpretive Report | (Cardno, 2021c) |
| PFAS OMP Biannual Monitoring Event Factual Report | (Cardno, 2021d) |
| PFAS OMP Biannual Monitoring Event Factual Report | (Cardno, 2022a) |
| PFAS OMP First Flush Sampling Event Factual Report | (Cardno, 2022b) |
| PFAS OMP Biannual Monitoring Event Factual Report | (Cardno, 2022c) |
| PFAS OMP Biannual Monitoring Event Factual Report | (Cardno, 2023a) |
| PFAS OMP 2021 Annual Interpretive Report | (Cardno, 2023b) |
| PFAS OMP Biannual Monitoring Event Factual Report | (Cardno, 2023c) |
| PFAS Ongoing Monitoring Plan Sampling and Analysis Quality Plan (SAQP) | (Stantec, 2024a) |
| Ongoing Monitoring Report (OMR) (October 2021 - September 2023). | (Stantec, 2024b) |
| Site Review Assessment (SRA) Report | (GHD, 2025) |

## 1.3 Regulatory framework

Defence forms part of the Commonwealth of Australia and is not required by law to comply with State legislation. However, Defence Policy states that the Defence shall comply with relevant State laws to the extent that those State laws are not inconsistent with Commonwealth Laws.

This SAQP has therefore been prepared with reference to applicable industry standards and guidelines including:

– National Environment Protection Council (NEPC), 1999, National Environmental Protection (Assessment of Site Contamination) Measure (as amended 2013) (ASC NEPM).
– Heads of Environmental Protection Authority's Australia and New Zealand (HEPA), January 2020, PFAS National Environmental Management Plan (NEMP) 2.0.
– Standards Australia 1998. AS/NZ 5667:1998 Water quality – sampling.
– Australian and New Zealand Guidelines, 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
– Department of Defence, 2021, Defence Contamination Management Manual (DCMM) Annex L Data Management.
– U.S. Environmental Protection Agency (EPA), 2000, Guidance for the Data Quality Objectives Process (EPA QA/G-4).
– USEPA, 2002, Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8).
– Department of Water and Environmental and Regulation (DWER), 2021, Assessment and Management of Contaminated Sites[1].
– National Health and Medical Research Council (NHMRC), August 2019, Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water.

[1] It is noted that Site is located on Commonwealth Land and is regulated under the Commonwealth environmental legislation, the State based DWER guidelines are relevant for the sampling of off-Site waterways.

# 2. Site setting

## 2.1 Site identification

The boundaries of the Site and the Management Area are shown in Figure 1, Appendix A. Key Site identification elements are presented in Table 2.

*Table 2 Site identification summary*

| Information | Details |
|---|---|
| **Street Address** | Minilya-Exmouth Road, Learmonth, WA 6707 |
| **Site Area** | Approximately 2,550 ha |
| **Defence Property ID** | WA_0960 |
| **Local Government Area** | Shire of Exmouth |
| **Traditional ownership and associated information** | The Jinigudera are the Traditional Owners of the land along the Ningaloo Coast in the area of the Exmouth Peninsula in Western Australia (Dive Ningaloo, 2022).<br>The Yamatji Marlpa Aboriginal Corporation (YMAC) is the Native Title Representative Body for the Traditional Owners of the Pilbara region, which includes Exmouth (Dive Ningaloo, 2022). |
| **Current Land Use / Activities** | On-Site land uses include commercial/industrial (aircraft operations, aircraft maintenance, fuel storage, explosives storage and general administration) and residential (base personnel accommodation). |
| **Surrounding Land Use / Activities** | **North:** Kailis Hatchery, Potshot Memorial and pastoral land<br>**East:** Wapet Creek, Solar Observatory, Bureau of Meteorology, Exmouth Gulf and pastoral land<br>**South:** Pastoral land<br>**West:** Various landfills, base supply borefield and pastoral land |

## 2.2 Site description

RAAF Base Learmonth is situated on the North-West Cape in the Pilbara Region of Western Australia. It is located in Learmonth, which is situated approximately 30 km south of the township of Exmouth. It covers an area of approximately 2,550 hectares (ha). The Site boundary and locality is presented in Figure 1, Appendix A.

The key Site features of the RAAF Base Learmonth include:

- Runway, taxi way and aprons
- Aircraft hangars
- Civilian airport terminal
- Maintenance and workshop areas
- General administration
- Domestic housing
- Fuel farm (former and current)
- Explosive storage and preparation area
- Power stations
- Sewage treatment ponds
- Base water borefield

A more detailed description of the Site is provided in the DSI report (GHD 2018).

## 2.3 Site history

Key information relevant to the history of the Site is summarised as follows:

– Aboriginal regional land use in the North-west Cape dates back 25,000 years, however there is no documented evidence of occupation on the Site.
– Prior to acquisition by Defence, RAAF Base Learmonth was Crown pastoral lease.
– The airfield was constructed in 1943. It was used as a support base for Potshot – a US Navy submarine support base located to the north of the Base.
– Most facilities were destroyed by a cyclone in 1945.
– West Australian Petroleum (Wapet) used the area to support oil exploration between 1949 and 1954.
– A fishing company was established near RAAF Base Learmonth in 1951, but this was destroyed by a cyclone. Kailis purchased the area and built a new factory
– The Shire of Exmouth purchased the civil aviation elements of the airfield.
– The airfield was extended in 1974. Further redevelopment occurred in the early 1980s and late 1990s. These later developments were designed to address fuel storage and ordnance storage
– In 2005, the fuel farm was upgraded through replacement of USTs and containment areas.

## 2.4 Environmental setting

The Management Area as depicted in the PMAP (Defence 2019) and in Figure 1, Appendix A is defined as comprising the Site, plus land to the east of the Site extending to the Exmouth Gulf and including the salt pan, drainage channels and Wapet Creek.

Table 3 provides a summary of the environmental setting of the Management Area based on previous reports (as listed in Section 1.2).

***Table 3 Environmental setting of the Management Area***

| Setting | Description |
|---|---|
| Climate | The region has a hot, semi-arid climate with a wet and dry season. The maximum temperatures range between 37.9ºC (January) and 24.2ºC (July) while minimum temperatures range between 11.4ºC (July) and 24.7ºC (February).<br>Rainfall occurs generally between January and July with monsoonal showers between January and Late April. August to December is generally dry. The highest volume of rainfall typically occurs during the month of June with a mean monthly rainfall amount of 43.5 mm. |
| Topography | The Site is located on a coastal plain and is generally flat. The elevation on-Site ranges between 0 and 20 meters relative to the Australian Height Datum (m AHD). To the west of the Site, the elevation at the coastal ranges increases to 220 m AHD. |
| Regional geology | The Site is underlain by quaternary age alluvial, aeolian and littoral sediments superimposed on the coastal plain (Geological Survey of Western Australia 1980).<br>Further inland are Quaternary alluvium and colluvium deposits that have been derived from erosion of the Cape Ranges. The deposits include clays, silts, sands and gravels. The Cape Range forms the highlands to the west of RAAF Base Learmonth and are composed of Tertiary aged Cape Range limestone units.<br>The coastal areas are fringed by Holocene aged beach and sand dunes consisting of quartz and calcarenite sands. An older Quaternary dune unit is located to the south of RAAF Base Learmonth and dune forms are visible. Intertidal flats and mangrove swamps occur immediately west of the coastal sands and are associated with estuarine creeks. |
| Site-specific geology | The DSI (GHD 2018) identified soil conditions that were broadly consistent with the regional geology described above, as follows:<br>On-Site, sands and clays were generally observed at the surface, underlain by colluvium/alluvium, gravels and sands and then weathered limestone rock.<br>To the west of the Site, sub-surface conditions comprised colluvium, sands and sandy clay underlain by limestone rock layer.<br>Within the salt pan area to the east of Base, sands and clays were generally observed at the surface, underlain by alluvium/colluvium and then shallow limestone rock. Outcrops of limestone displaying fossilised coral were observed along the southern reach of Wapet Creek. |

| Setting | Description |
|---|---|
| Acid Sulfate Soil | A review of the Acid Sulfate Soils (ASS) risk mapping, available on the WA Atlas online database indicates the following:<br>To the north of the Site is classified as having a moderate to low risk of ASS occurring within the top 3 m of natural soil but high to moderate risk of ASS beyond 3m of natural soil surface.<br>The salt pan to the east is classified as having a high to moderate risk of ASS occurring in the top 3 m of natural soil. |
| Hydrology | The Exmouth Gulf is located approximately 600 m east of the Site at its closest point. The Site is also traversed west to east by three ephemeral creeks.<br>RAAF Base Learmonth contains a number of constructed drains that direct surface water towards drainage channels that discharge into Wapet Creek (Central and Southern Channels) or Exmouth Gulf (Northern Channel), summarised as follows:<br>– The Northern Drainage Channel discharges directly to the Exmouth Gulf. It is a constructed drain on-Site but links to a wide natural channel off-Site that cuts through the coastal dunes.<br>– The Central Drainage Channel discharges into the northern reach of Wapet Creek. It is a straight constructed channel for its entire length.<br>– The Southern Drainage Channel discharges into the southern reach of Wapet Creek. It is a constructed drain on-Site but links to a natural channel off-Site that meanders across low lying salt pan topography.<br>Monitoring conducted to date as part of the OMP has found that the water flow in these drains is limited to high rainfall events. The Northern Channel is inundated with seawater during high tides from the coast to the boundary of Base.<br>Wapet Creek is located to the east of Base and is lined with mangroves. Water flows tidally in and out of the creek and low-lying areas around the creek are periodically inundated. |
| Hydrogeology | The Quaternary and Tertiary geology units are hydraulically connected and form a major, unconfined aquifer.<br>Groundwater in the Quaternary units is considered to be perched and discontinuous. The superficial Quaternary layers (dunes, colluvium, alluvium) are considered no more than 20 m in thickness. Coastal dunes may also contain relatively fresh groundwater but of limited extent (lenses). This has not been assessed.<br>The main regional aquifer occurs predominantly within the Tulki Limestone (within permeable beds and the karst system) on the flanks of the range and the Mandu Limestone (within joints and minor permeable beds) on the crest of the range. These units extend to depths of greater than 150 m.<br>The results of the June 2021 OMP monitoring event indicated groundwater was generally brackish to saline in the western wells, with the groundwater becoming more saline closer to the coast (Cardno 2023).<br>The saltwater wedge is expected to extend 5.0 km inland from the east coast (Martin, 1990). The DSI (GHD 2018) identified the water was fresher in the shallow groundwater, likely due to rain infiltration. The salinity distribution in the inferred discharge area to the east is likely to have significant influence on PFAS migration and discharge. |
| Groundwater depth and flow direction | During the June 2021 event depth to groundwater was recorded beneath the Site at levels of between 0.9 m bgl (MW177) and 6.53 m bgl (MW114), with groundwater elevations of between -0.223 m AHD (MW179) and 1.707 m AHD (MW143) calculated.<br>The local groundwater flow pattern at RAAF Base Learmonth was observed to be following the regional flow regime; that is, flowing toward the east. The calculated hydraulic gradient of groundwater across the Site was low and in the order of 0.0003 to 0.0005 m/m (GHD 2018).<br>The groundwater flow direction and hydraulic gradients greatly restricts the flow of contaminated groundwater from RAAF Base Learmonth to Wapet Creek or Exmouth Gulf. Instead, groundwater from RAAF Base Learmonth tends to flow towards an area of groundwater depression with elevated salinity that lies between the Site and the coast, with there being very little net flow to surface waters further to the east.<br>Groundwater levels in wells near the coast are expected to be influenced by tidal pressure.<br>Data obtained through implementation of the OMP to date supports the historical gauging dataset and inferences made regarding groundwater flow direction, with some locations closer to the coast indicating a slight gradient to the coast. |

| Setting | Description |
|---|---|
| Beneficial groundwater use | A potable water supply borefield, comprising ten bores, is located approximately 3 km west of the Base (i.e., inferred hydraulically up-gradient). It was understood that only four of the ten bores were operating at the time of the DSI (GHD 2018). Groundwater is pumped from the Cape Range Group aquifer and is subject to treatment including chlorination and reverse osmosis prior to use on the base.<br>During the DSI (GHD 2018), groundwater was being abstracted from a bore near the Windmill Bore Landfill (approximately 1 km west of the Site) where water was being pumped to a water storage tank and then being discharged to the surface via a hose. Flow rate was estimated to be approximately 9,000 L per day. Sheep were observed drinking this water from the surface.<br>A Water Corporation borefield is present approximately 20 km north of the Site (at its nearest point) that supplies town water to the township of Exmouth. The DSI report notes that Water Corporation sampled the bores for PFAS in 2017 and concentrations were below the LOR (it is unknown what LOR was applied). |
| Environmentally Sensitive Areas | – The Site is located in close proximity to the Cape Range National Park and Ningaloo Reef to the west.<br>– No Threatened Ecological Communities (TECs) with national environmental significance, were identified in the EPBC Act Protected Matters Report generated on November 2, 2017.<br>– Five priority flora species and 36 threatened or priority fauna species are known or expected to be present within 10 km of RAAF Base Learmonth (Stantec, 2024b).<br>– The mangrove wetlands are not listed on the Ramsar Convention on Wetlands of International Importance. It does however constitute a sensitive receptor. |

## 2.5 Conceptual site model

This section provides a summary of the dominant PFAS sources, transport pathways and the identified potential risks to sensitive receptors.

### 2.5.1 Source areas

The DSI (GHD, 2018) identified two source areas where PFAS was detected in soil or groundwater at concentrations exceeding the adopted assessment levels, as follows (also shown in Figure 1, Appendix A)::

– Maintenance Area (Source Area 1)
– Former and Current Fuel Farm (Source Area 2)

It is noted that the DSI also identified PFAS in soil, sediment and/or surface water at concentrations exceeding the adopted assessment levels in the following pathway and receptor areas (also shown in Figure 1, Appendix A):

– Southern Drainage Channel (Pathway)
– Central Drainage Channel (Pathway)
– Northern Drainage Channel (Pathway); and
– Wapet Creek Northern Reach (Receptor).

Concentrations above the adopted assessment levels in these areas are considered likely associated with PFAS transport through/to these areas from the abovementioned source areas (Source Area 1 and/or 2) and as such, these areas are not considered to represent PFAS source areas.

The DSI also investigated a range of other potential PFAS source areas such as the former fire station, former fire training area, a series of underground storage tanks, the sewage treatment plant and aircraft hangers. PFAS was detected in these potential source areas, and other areas, though at lower concentrations (below the adopted assessment levels) and therefore, these areas were not considered to represent significant PFAS source areas.

### 2.5.2 Transport pathways

The DSI (GHD 2018) identified the following credible transport pathways:

– Migration in drainage lines (surface water and sediment) during and/or following heavy rainfall events
– Leaching through the soil profile
– Groundwater migration

### 2.5.3 Receptors

The DSI (GHD 2018) identified the following credible receptors (Table 4).

*Table 4 Receptors*

| Receptor type | Receptor |
|---|---|
| Environmental | Wapet Creek ecosystems<br>Exmouth Gulf ecosystems<br>Terrestrial and estuarine (mangrove) flora<br>Terrestrial fauna<br>Subterranean fauna |
| Human | Off-Site consumers of flora and fauna, particularly those exploiting the biota of Wapet Creek and Exmouth Gulf<br>Traditional harvesting of flora and fauna by Indigenous people<br>Consumers of impacted potable water<br>Residents of houses within the monitoring area with direct access to PFAS contaminated soils in front and backyards |

### 2.5.4 Credible exposure pathways and risk identification

The DSI (GHD 2018) undertook an assessment of the risks associated with the presence PFAS on and in the environment surrounding the Site and concluded that exposure to the identified PFAS concentrations presented a low and acceptable risk to receptors.

Exposure of ecological receptors to PFAS as summarised in Table 4 was quantitatively assessed through an ERA (GHD 2019). The ERA comprised a detailed ecological exposure and toxicity assessment to evaluate the long-term PFAS exposure levels to the identified ecological receptors and inform potential management options to reduce PFAS exposure. The ERA assessed the potentially complete exposure pathways (i.e. the source-pathway-receptor linkages) concerning terrestrial and aquatic ecology that were identified in the CSM developed as part of the DSI. The ERA (GHD 2019) concluded that:

- The risks to lower trophic level terrestrial and aquatic organisms were low and acceptable across the Management Area.
- The risks associated with the bioaccumulation and biomagnification of PFAS in the food chain were low and acceptable across the majority of the Investigation Area, including the terrestrial environments of the Site, the adjacent saltpan and Exmouth Gulf. The risks associated with the bioaccumulation and biomagnification of PFAS in the food chain were also low and acceptable for organisms foraging primarily within the southern reaches of Wapet Creek, which discharges directly into Exmouth Gulf.
- The PFOS plus PFHxS concentrations estimated for fish and benthic infauna in the northern reaches of Wapet Creek marginally exceeded the NEMP (HEPA, 2018) avian wildlife diet guideline. Inherent in this guideline are a number of conservative exposure assumptions and therefore measurable and ecological relevant adverse effects are considered unlikely. The weight of available evidence suggests that shorebirds could source a substantial portion of their diet within Wapet Creek with a low risk of chronic adverse PFOS exposures occurring.

The most recent source-pathway-receptor analysis, sourced from the PMAP (Defence, 2019), is presented in tabular format in Appendix B. The table includes an assessment of whether or not the exposure pathway is complete (i.e. if exposure is actually expected to occur) and the assessed level of risk associated with the potential exposure.

A summary of the exposure scenarios that were considered credible and the assessed level of risk posed by each is presented as Table 5.

*Table 5 Summary of exposure scenarios and risks*

| Receptor type | Exposure pathway | Assessed risk |
|---|---|---|
| Human health | Contact with soil, sediment, concrete surfaces, groundwater and surface water by Site personnel | Low |
| | Consumption of potable water | Low |
| | Consumption of edible species from local waterways | Low |
| Ecological | Contact, uptake and/or ingestion by terrestrial ecology | Low |
| | Contact, uptake and/or ingestion by aquatic ecology | Low |
| | Contact, uptake and/or ingestion by avian predators | Low |

Implementation of the OMP to date has not identified any change to the assessed risk profile of the Management Area (Stantec 2024b).

# 3. Data quality objectives

Development of data quality objectives (DQOs) for the OMP SAQP is based on guidance presented in the ASC NEPM (NEPC 2013) and are consistent with *RAAF Base Learmonth PFAS Investigation PFAS Ongoing Monitoring Plan* (Defence, 2019). The DQO process comprises the following seven steps:

- Step 1: State the problem
- Step 2: Identify the decision/principal study question(s)
- Step 3: Identify the Inputs into the Decision
- Step 4: Study Boundaries
- Step 5: Decision rules
- Step 6: Tolerable limits on decision errors
- Step 7: Optimisation of the data collection process.

The DQOs are detailed in Table 6.

***Table 6 Data Quality Objectives***

| Data Quality Step | Description |
|---|---|
| Step 1: State the Problem | The DSI (GHD, 2018) identified PFAS in groundwater, surface water and sediment within the Management Area at concentrations exceeding the relevant assessment levels. The primary mechanisms by which PFAS has migrated off-Site are considered to be via surface drains, notably the Central Drainage Channel which discharges directly into Wapet Creek.<br>The ERA (GHD, 2019) identified one exposure risk associated with foraging seabirds from the consumption of impacted biota in the northern reach of Wapet Creek. Current data for the majority of sampling locations is limited to one or two sampling events. Whilst the findings of the ERA (GHD, 2019) recognised that an adverse ecological impact is unlikely, a robust dataset is required to assess trends in the nature, extent and magnitude of PFAS concentrations within sediment, surface water, seepage water and groundwater.<br>Ongoing monitoring of PFAS concentrations in relevant media in the Management Area is required to continue to monitor:<br>– Spatial, and temporal (including seasonal) variability of PFAS in the environment.<br>– Changes to sources, transport pathways and/or receptors, described as a Conceptual Site Model (CSM) for the Site.<br>– Whether risks to human and ecological receptors require review.<br>– The influence that risk management activities at the Site, as outlined in the July 2019 PMAP have had on PFAS in the environment, and<br>– Whether the identified changes trigger an action and/or review. |
| Step 2: Identify the decision/principal study question(s) | This OMP is to provide further data to assess the following principal study questions:<br>– What are the changes and trends in the nature, extent and magnitude of PFAS concentrations in the groundwater, surface water and sediment within the Management Area?<br>– Has the nature, extent and magnitude of PFAS concentrations changed significantly to warrant a revision of the ERA?<br>– Has the nature, extent and magnitude of PFAS concentrations changed significantly to warrant refinement of any existing management measures?<br>– Has the nature, extent and magnitude of PFAS concentrations changed significantly or are they likely to change? |
| Step 3: Identify the Inputs into the Decision | The following inputs are required to resolve the principal study questions outlined in Step 2:<br>– PFAS concentrations in groundwater, surface water and sediment from previous and future monitoring events.<br>– Field data (i.e. groundwater levels, physico-chemical parameters) on groundwater and surface water from previous and future monitoring events. |

| Data Quality Step | Description |
|---|---|
| | – An appropriate statistical evaluation of the data (e.g. using Mann-Kendall or similar analysis) including short- and long-term trends, in particular for surface water and groundwater concentrations.<br>– Comparison of data sets to relevant endorsed assessment levels (refer to Section 4). |
| Step 4: Study Boundaries | Ongoing monitoring will be generally undertaken within the boundaries of the Management Area (Figure 1, Appendix A) at the groundwater, surface water and sediment monitoring locations outlined in Section 5.1<br>Monitoring will be undertaken twice per year in November and June. Section 5.1.1 provides further detail on the monitoring frequency. |
| Step 5: Develop a Decision Rule | – If a significant change in PFAS concentration (e.g., an increase by one or more orders of magnitude or a first-time guideline value exceedance) and/or distribution (e.g., PFAS is detected at a monitoring location where it was previously not detected), the following initial responses will be considered:<br>• Conduct a more in-depth statistical analysis of the data to assess plume stability and/or variability at the location/s.<br>• Review the CSM to make a qualitative assessment on risks posed to relevant receptors. This should include an assessment of any recent climatic changes, site activities or other factors that might influence the results.<br>– If the initial responses indicate a potentially unacceptable increase in risk, the following responses may be implemented:<br>• Resample the location/s to confirm the changes. This might also involve sampling additional nearby locations.<br>• Conduct further quantitative risk assessment (e.g., consideration to exposure point concentrations and other inputs that informed the current Human Health and Ecological Risk Assessment [HHERA]).<br>• If the risk assessment does not indicate an increased risk then the monitoring would continue as per the OMP.<br>• If the risk assessment does indicate an increased risk then additional contingencies could be implemented, such as additional biota sampling or higher order food chain modelling to support further risk assessment and quantify whether the risk profile has been adversely affected.<br>– If an increase in risk is identified, an appropriate management or remedial response should be selected depending on the level of risk identified in the risk assessment. For example, an immediate unacceptable risk to an environmental receptor or human health (although considered highly unlikely) would require a stronger response than a slight increase in the risk to foraging seabirds. Response actions might include:<br>• Institutional controls to restrict access.<br>• Capping, containment or other treatment of contaminated media.<br>• The appropriate response should be identified with consideration to the PMAP. Revision of the PMAP including the risk identification and remedial options appraisal that informed it may be appropriate. |
| Step 6: Specify Limits on Decision Error | A detailed assessment of potential for sampling and measurement errors will be undertaken. Data quality will be assessed as detailed in Schedules B2 and B3 of the ASC NEPM and the PFAS NEMP. Two types of decision errors are possible:<br>– Sampling errors which occur when the sampling program does not adequately detect PFAS.<br>– Measurement errors which occur during sample collection, handling preparation, analysis and data reduction.<br>To minimise the potential for decision errors, the following data quality indicators (DQIs) will be adhered to; completeness, comparability, representativeness, precision and accuracy (refer to Table 7).<br>Quality Assurance/Quality Control (QA/QC) measures are detailed in Section 6. |
| Step 7: Optimise the Design for Obtaining the Data | The design of the OMP has been made in consideration of historical activities at the Site, historical investigations and findings (i.e. the DSI, ERA), with a view to resolving the principal study questions outlined in Step 2.<br>The OMP scope is outlined in Section 4. The available data will be reviewed and evaluated as part of the OMP Revision process to identify if aspects such as the monitoring network and |

| Data Quality Step | Description |
|---|---|
| | monitoring frequency should be revised to provide better understanding of PFAS concentration fluctuations and potential risks to receptors.<br>To maintain the integrity and reliability of data the following measures will be adopted:<br>– Field and analytical data collected in accordance with the PFAS NEMP (HEPA 2020) and the ASC NEPM (NEPC 2013).<br>– Field personnel trained and have sufficient experience to complete the fieldwork to an acceptable standard, as per the protocols outlined in the SAQP.<br>– Robust field and laboratory quality assurance/quality control protocols are to be adopted.<br>– Use of laboratories that are National Association of Testing Authorities (NATA) accredited for PFAS analysis and ensure laboratory LORs are suitable to meet the relevant adopted assessment levels, where possible |

An assessment of the Data Quality Indicators (DQIs) relating to both field and laboratory procedures will be undertaken with appropriate documentation provided for each environmental element or media assessed. The DQIs to be adopted for the OMP are summarised in Table 7.

*Table 7 Data quality indicators*

| Data Quality Indicator | Detail |
|---|---|
| Documentation and data completeness | All locations that were proposed to be sampled were sampled where possible. Sampling locations accurately described.<br>All field documentation is complete and correct, including chain of custody documentation for samples.<br>Field forms and documentation capture all relevant important information.<br>Field equipment suitably calibrated and supporting documentation provided.<br>Samples were analysed within appropriate holding times.<br>Appropriate laboratory limits of reporting (LOR) for comparison to relevant assessment criteria. |
| Data comparability | Adherence to methodologies presented in this SAQP and relevant guidelines<br>Use of suitably qualified and experienced personnel.<br>Consistent laboratory use with consistent analytical methods used.<br>Climatic conditions consistent and considered representative of region. |
| Data representativeness | Samples were collected in a uniform and consistent manner, therefore representative of the media in the field.<br>Adherence to methodologies presented in this SAQP and relevant guidelines.<br>Use of appropriate techniques for sampling, storage and transport of samples. |
| Precision for sampling and analysis | Sufficient quantities of intra- and inter-laboratory duplicates were collected to enable comparison within and between laboratories (refer to Section 6)<br>Sufficient quantities of internal laboratory duplicates were analysed to enable comparison within laboratories.<br>Relative percentage difference calculations show that a large majority of duplicate sample concentrations are within defined difference limits (refer to Section 6.1.2.<br>Field equipment was calibrated by equipment supplier. |
| Accuracy for sampling and analysis | Sufficient quantities of field blanks and transport blanks were collected and analysed, with no results indicating cross-contamination (refer to Section 6).<br>Sufficient quantities of internal laboratory method blanks, surrogate spikes and laboratory control samples were analysed to determine laboratory accuracy, with the large majority of samples within defined limits. |

# 4. Guideline values

A summary of the current PFAS guideline values considered relevant to the Site is presented as Table 8. The guideline values are largely based upon the PFAS NEMP (HEPA 2020) which presents a consolidated set of health- and ecology-based Australian PFAS guideline values for soil and water that are derived from various guidelines and publications. It is noted that there are currently no Australian regulatory endorsed guideline values for risk posed to ecology or human health by PFAS in sediment.

***Table 8 Relevant PFAS assessment criteria***

| Exposure scenario | Source | Assessment criteria (µg/L) | | |
|---|---|---|---|---|
| | | PFOS | PFOS and PFHxS | PFOA |
| **Groundwater** | | | | |
| Health: potable use of groundwater | PFAS NEMP | 0.07 | 0.07 | 0.56 |
| Health: domestic non-potable use of groundwater (NPUG) | DWER (2021)* | 0.7 | 0.7 | 5.6 |
| **Surface water and pore water** | | | | |
| Health: Recreational water use | PFAS NEMP | NE | 2 | 10 |
| Ecology: aquatic ecosystems (99% species protection) | | 0.00023 | NE | 19 |

Notes:

NE: not established

*Since development of the July 2019 OMP, the WA DWER Assessment and Management of Contaminated Sites (DWER 2021) guideline has been updated and includes clear guidance regarding consideration of PFAS exposure risks from domestic non-potable use of groundwater (NPUG) by applying a factor of ten to the PFAS NEMP drinking water guideline values. The NPUG assessment criteria are of relevance to groundwater abstraction bores near to the site (refer to Section 2.4). DWER (2021) also notes that the drinking water criteria should be adopted as screening criteria in situations where consumption of homegrown produce is a credible exposure pathway.

It is important to note that an ERA (GHD 2019) has been completed for the Site to assess the potential risks to the environment associated with presence of PFAS within the Management Area. While the OMP and any subsequent studies will evaluate PFAS concentration data with reference to the ecology-based guideline values identified in Table 8, decision-making concerning changes to risks posed to ecology within the Management Area should continue to be made with reference to the ERA conclusions and the dataset that informed it.

# 5. Sampling design

## 5.1 Monitoring locations and sampling schedule

### 5.1.1 Monitoring frequency

All monitoring locations will be sampled twice per year. The sampling events will be undertaken in November and June to assess any seasonal fluctuations or trends in PFAS concentrations or extent. The monitoring frequency aligns with the climate of the Management Area, which features the highest volume of rainfall typically between January and July and lower rainfall between September and December.

The May 2019 OMP also included a manual 'first flush' monitoring event conducted immediately (or as close as possible) following the first heavy rainfall event of the wet season. Implementation of the OMP to date has shown that the manual first flush sampling event has had limited effectiveness in achieving the aim of capturing the annual first flush event due to logistical challenges of the region. Due to such challenges, the first flush event is often not captured through the manual sampling method and therefore the representativeness of the data is often uncertain. On this basis and noting that reported outcomes of implementation of the OMP to date (Stantec 2024b) indicate that the Site continues to present a low risk with respect to PFAS exposure, the first flush monitoring event has been removed from the OMP SAQP.

If assessment of data collected through implementation of this OMP SAQP indicates a potential increase to the risk profile for the Site, consideration will be given to re-instating the first flush sampling event.

To the extent practicable, seepage sampling will occur during low, outgoing tides, which is considered the optimal condition for groundwater discharge.

### 5.1.2 Groundwater monitoring locations

The groundwater monitoring locations are presented in Table 9, along with the rationale for their selection, and are shown on Figure 2, Appendix A.

*Table 9 Groundwater monitoring locations*

| Area | Monitoring well /Bore ID | Rationale |
|---|---|---|
| Source Areas | **Source 1 – Maintenance Area:**<br>MW018, MW021, MW112, MW113, MW114, MW115, MW162, MW164, MW165, MW166, MW167, MW168, MW211, MW233.<br>**Source 2 – Fuel Farm:**<br>MW105, MW148D, MW148S, MW151, MW159, MW238 | Assessment of overall changes in PFAS concentration in the source areas to provide temporal data on depletion of the source zone.<br>MW163 was noted to be damaged and was not sampled during the May 2024 monitoring event (Stantec 2024c) and thus has not been included in the monitoring well list. |
| Pathway (northern, central and southern drainage channels) | MW102, MW103, MW104, MW122, MW124, MW126, MW127, MW134, MW135, MW139, MW140, MW143, MW144, MW145, MW146, MW147, MW170, MW172, MW175, MW180, MW181. | Assessment of changes in PFAS concentration and distribution in the main migration pathways. This will also allow for early detection of significant changes in migration so contingencies can be put in place.<br>MW138 was noted to be damaged and was not sampled during the May 2024 monitoring event (Stantec 2024c) and thus has not been included in the monitoring well list. |
| Receptor (Wapet Creek) | MW137*^, MW141*^, MW176*^, MW177*^, MW178*^, MW179*^. | Confirmation of overall PFAS impact identified in the DSI (GHD, 2018). Assessment of changes in PFAS concentration and distribution in the main aquatic receptors. |
| Additional wells | MW132#, MW174#, MW222 (previously MW0124)#, MW227 (previously SMB1)# to MW230 (previously SMB4)# | These wells are positioned in-between the Site and potable water abstraction borefields to the west and north (i.e., hydraulically up and cross-gradient respectively) of the Site. The wells are not part of the May 2019 OMP |

| Area | Monitoring well /Bore ID | Rationale |
|---|---|---|
| | | though were sampled as part of the DSI (GHD 2018). PFOS concentrations were above the lower LOR that was applied (i.e., ranging from 0.001 µg/L to 0.008 µg/L) at the time of the DSI.<br>Given the introduction of draft revised PFAS drinking water guideline values (refer to Section 4) sampling and analysis of these wells is proposed (including analysis to a suitably lower LOR to meet the draft guideline values) is proposed to provide further support in relation to the potential for any Site-derived PFAS to be migrating towards the abstraction borefields (albeit considered unlikely given established groundwater flow direction). |

**Notes:**

*Application of a non-standard LOR (not greater than 0.0003 µg/L for PFOS plus PFHxS and 0.0005 µg/L for PFOA) is to be applied at these locations so that a holistic assessment of potential impacts to identified receptors can be made by comparing PFAS concentrations with the exposure point concentrations (EPC) adopted to inform the ERA (GHD 2019).

^Sampling of all screened intervals at multilevel/nested wells locations at receptor (coastal) locations is to be applied so that an holistic assessment of potential impacts to identified receptors can be made. Multilevel/nested wells outside of the receptor (coastal) areas will continue to have only the shallowest, non-dry well monitored.

#Locations that will be subject to analysis to non-standard ('low level') LOR to provide a preliminary assessment of PFAS concentrations to the draft ADWGs (refer to Section 4**Error! Reference source not found.**).

Construction details for the groundwater wells monitored as part of the OMP are provided in Table 10.

*Table 10 OMP Groundwater Monitoring Wells Construction Details*

| Well ID | Date Drilled | Easting | Northing | RL TOC (mAHD) | Depth (mbgl) | Screen Interval (mbgl) |
|---|---|---|---|---|---|---|
| MW018 | 2006 | 199251.86 | 7537465.65 | 6.403 | 8.5 | 5.5-8.5 |
| MW021 | 2006 | 199143.14 | 7537433.45 | 6.745 | 8.6 | 5.6-8.6 |
| MW102 | 2018 | 200487.728 | 7538870.392 | 4.6266 | 8.5 | 2.5-8.5 |
| MW103 | 2018 | 199762.727 | 7540965.102 | 2.2785 | 5.8 | 1.0-5.8 |
| MW104 | 2018 | 199946.08 | 7540599.855 | 2.7256 | 6.5 | 1.0-6.5 |
| MW105 | 2018 | 199491.679 | 7540303.158 | 3.7272 | 8.0 | 2.0-8.0 |
| MW112 | 2018 | 199473.4723 | 7537651.252 | 5.1191 | 8.0 | 3.0-8.0 |
| MW113 | 2018 | 199156.14 | 7537686.096 | 7.3165 | 10.0 | 4.0-10.0 |
| MW114 | 2018 | 199037.9871 | 7537512.217 | 7.7467 | 10.0 | 4.0-10.0 |
| MW115 | 2018 | 199604.327 | 7537522.607 | 4.9133 | 8.0 | 3.0-8.0 |
| MW122 | 2018 | 200580.746 | 7537635.452 | 3.9702 | 7.7 | 1.7-7.7 |
| MW124 | 2018 | 200525.625 | 7539636.566 | 2.9183 | 6.0 | 1.0-6.0 |
| MW126 | 2018 | 200301.728 | 7536952.205 | 4.5088 | 8.0 | 2.0-8.0 |
| MW127 | 2018 | 200158.599 | 7536314.042 | 5.6238 | 8.5 | 2.5-8.5 |
| MW134 | 2018 | 200439.185 | 7540598.585 | 2.5155 | 5.7 | 1.0-5.7 |
| MW135 | 2018 | 200867.402 | 7540438.161 | 2.7781 | 3.0 | 2.5-3.0 |
| | | | | 2.7828 | 5.0 | 4.5-5.0 |
| | | | | 2.7858 | 7.0 | 6.5-7.0 |
| | | | | 2.7884 | 9.5 | 9.0-9.5 |
| MW137 | 2018 | 201611.362 | 7539047.314 | 2.1687 | 1.3 | 0.8-1.3 |
| | | | | 2.1691 | 3.0 | 2.5-3.0 |
| | | | | 2.2017 | 5.0 | 4.5-5.0 |

| Well ID | Date Drilled | Easting | Northing | RL TOC (mAHD) | Depth (mbgl) | Screen Interval (mbgl) |
|---|---|---|---|---|---|---|
| | | | | 2.2034 | 7.0 | 6.5-7.0 |
| MW138 | 2018 | 200820.406 | 7538649.357 | 3.3074 | 3.5 | 3.0-3.5 |
| | | | | 3.3166 | 5.5 | 5.0-5.5 |
| | | | | 3.3205 | 7.5 | 7.0-7.5 |
| | | | | 3.3224 | 9.5 | 9.0-9.5 |
| MW139 | 2018 | 201088.954 | 7536832.655 | 4.1386 | 7.0 | 2.0-7.0 |
| MW140 | 2018 | 202004.879 | 7537028.632 | 2.4916 | 2.0 | 1.5-2.0 |
| | | | | 2.5035 | 4.0 | 3.5-4.0 |
| | | | | 2.5081 | 6.5 | 6.0-6.5 |
| | | | | 2.5345 | 9.0 | 8.5-9.0 |
| MW141 | 2018 | 202555.223 | 7537320.681 | 2.7999 | 2.0 | 1.5-2.0 |
| | | | | 2.8073 | 3.5 | 3.0-3.5 |
| | | | | 2.8141 | 5.5 | 5.0-5.5 |
| | | | | 2.8224 | 7.5 | 7.0-7.5 |
| MW143 | 2018 | 200819.408 | 7539420.558 | 2.8174 | 3.5 | 3.0-3.5 |
| | | | | 2.8204 | 5.5 | 5.0-5.5 |
| | | | | 2.8221 | 7.5 | 7.0-7.5 |
| | | | | 2.8273 | 9.5 | 9.0-9.5 |
| MW144 | 2018 | 200691.327 | 7540195.613 | 3.0481 | 3.5 | 3.0-3.5 |
| | | | | 3.052 | 5.5 | 5.0-5.5 |
| | | | | 3.0545 | 7.5 | 7.0-7.5 |
| | | | | 3.0573 | 9.5 | 9.0-9.5 |
| MW145 | 2018 | 201084.426 | 7538337.599 | 3.1416 | 3.5 | 3.0-3.5 |
| | | | | 3.1481 | 5.5 | 5.0-5.5 |
| | | | | 3.1506 | 7.5 | 7.0-7.5 |
| | | | | 3.1519 | 9.5 | 9.0-9.5 |
| MW146 | 2018 | 201126.901 | 7537691.759 | 2.7937 | 3.5 | 3.0-3.5 |
| | | | | 2.8009 | 5.5 | 5.0-5.5 |
| | | | | 2.802 | 7.5 | 7.0-7.5 |
| | | | | 2.8184 | 9.5 | 9.0-9.5 |
| MW147 | 2018 | 201259.369 | 7537322.231 | 2.9123 | 3.5 | 3.0-3.5 |
| | | | | 2.9152 | 5.5 | 5.0-5.5 |
| | | | | 2.9183 | 7.5 | 7.0-7.5 |
| | | | | 2.9209 | 9.5 | 9.0-9.5 |
| MW148D | 2018 | 199536.808 | 7540521.489 | 3.5778 | 20.0 | 14.0-20.0 |
| MW148S | 2018 | 199537.603 | 7540521.649 | 3.6851 | 8.0 | 2.0-8.0 |
| MW151 | 2018 | 199442.761 | 7540459.319 | 4.0631 | 8.0 | 2.0-8.0 |
| MW159 | 2018 | 199164.27 | 7540373.912 | 4.1895 | 9.0 | 3.0-9.0 |
| MW162 | 2018 | 199230.504 | 7537650.674 | 6.856 | 20.0 | 17.0-20.0 |
| MW163 | 2018 | 199232.4874 | 7537569.5756 | 6.7808 | 20.0 | 17.0-20.0 |

| Well ID | Date Drilled | Easting | Northing | RL TOC (mAHD) | Depth (mbgl) | Screen Interval (mbgl) |
|---|---|---|---|---|---|---|
| MW164 | 2018 | 199251.946 | 7537546.874 | 6.7893 | 20.0 | 17.0-20.0 |
| MW165 | 2018 | 199312.5481 | 7537531.6778 | 6.1043 | 9.0 | 3.0-9.0 |
| MW166 | 2018 | 199363.212 | 7537610.565 | 5.7441 | 8.5 | 2.5-8.5 |
| MW167 | 2018 | 199368.445 | 7537673.832 | 6.2094 | 8.5 | 2.5-8.5 |
| MW168 | 2018 | 199390.678 | 7537754.41 | 6.1713 | 8.5 | 2.5-8.5 |
| MW170 | 2018 | 199828.672 | 7536509.856 | 5.639 | 8.5 | 2.5-8.5 |
| MW172 | 2018 | 199755.067 | 7536989.143 | 5.6193 | 8.5 | 2.5-8.5 |
| MW175 | 2018 | 201458.887 | 7540121.278 | 4.7916 | 4.5 | 4.0-4.5 |
| | | | | 4.7982 | 6.0 | 5.5-6.0 |
| | | | | 4.7995 | 7.5 | 7.0-7.5 |
| | | | | 4.8316 | 9.5 | 9.0-9.5 |
| MW176 | 2018 | 201711.745 | 7539606.488 | 2.1274 | 2.0 | 1.5-2.0 |
| | | | | 2.1279 | 4.0 | 3.5-4.0 |
| | | | | 2.1594 | 6.5 | 6.0-6.5 |
| | | | | 2.1712 | 9.0 | 8.5-9.0 |
| MW177 | 2018 | 202130.765 | 7539004.262 | 2.2299 | 2.0 | 1.5-2.0 |
| | | | | 2.2517 | 4.0 | 3.5-4.0 |
| | | | | 2.2531 | 6.5 | 6.0-6.5 |
| | | | | 2.2718 | 9.0 | 8.5-9.0 |
| MW178 | 2018 | 201387.629 | 7539566.48 | 2.1612 | 2.5 | 2.0-2.5 |
| | | | | 2.1614 | 4.5 | 4.0-4.5 |
| | | | | 2.1726 | 7.5 | 7.0-7.5 |
| | | | | 2.1762 | 9.5 | 9.0-9.5 |
| MW179 | 2018 | 201939.471 | 7538448.239 | 2.222 | 1.5 | 1.0-1.5 |
| | | | | 2.2371 | 3.7 | 3.2-3.7 |
| | | | | 2.2653 | 6.4 | 5.9-6.4 |
| | | | | 2.2689 | 9.0 | 8.5-9.0 |
| MW180 | 2018 | 201567.932 | 7537913.284 | 1.9179 | 1.5 | 1.0-1.5 |
| | | | | 1.9226 | 4.0 | 3.5-4.0 |
| | | | | 1.9368 | 6.5 | 6.0-6.5 |
| | | | | 1.9458 | 9.0 | 8.5-9.0 |
| MW181 | 2018 | 201688.497 | 7537372.233 | 2.2333 | 2.0 | 1.5-2.0 |
| | | | | 2.2773 | 4.0 | 3.5-4.0 |
| | | | | 2.2789 | 6.0 | 5.5-6.0 |
| | | | | 2.3122 | 7.5 | 7.0-7.5 |
| MW211* | - | 199199.771 | 7537549.138 | 6.3409 | - | - |
| MW233 | 2015 | 199198.57 | 7537590.67 | 6.262 | 7.0 | 4.0-7.0 |
| MW238 | 2006 | 199446.65 | 7540509.92 | 3.98 | 6.0 | 3.0 – 6.0 |
| Note: * *No bore log available* | | | | | | |

### 5.1.3 Seepage monitoring locations

The seepage monitoring locations are presented in Table 11, along with the rationale for their selection, and are highlighted on Figure 2, Appendix A.

***Table 11 Seepage monitoring locations***

| Area | Seepage location ID | Rationale |
|---|---|---|
| Receptor (Exmouth Gulf) | OTH103*, OTH106*, OTH107*, OTH129*, OTH132*, OTH134*. | To assess changes in PFAS concentration at the inferred groundwater discharge zone along the coast.<br>Includes locations near the mouth of Wapet Creek, the northern Drainage Channel, a low point in the dunes near the southern reach and other locations along the coast of the Exmouth Gulf. |
| **Notes:**<br>*Application of a non-standard LOR (not greater than 0.0003 µg/L for PFOS plus PFHxS and 0.0005 µg/L for PFOA) is to be applied at these locations so that a holistic assessment of potential impacts to identified receptors can be made by comparing PFAS concentrations with the exposure point concentrations (EPC) adopted to inform the ERA (GHD 2019). | | |

### 5.1.4 Surface water and sediment monitoring locations

The surface water and sediment monitoring locations are presented in Table 12, along with the rationale for their selection, and are highlighted on Figure 3, Appendix A.

*Table 12 OMP surface water and sediment monitoring locations*

| Area | Surface water sampling location ID | Sediment sampling location ID | Rationale |
|---|---|---|---|
| Drainage channels (source and pathway) | **Bi-annual and first flush events:**<br>SW108, SW113, SW114, SW121 SW122, SW123, SW124, SW125, SW157, SW166, SW168, SW170, SW174, SW176, SW189, SW190, SW192, SW193*, SW198, SW199, SW200, SW219, SW227, SW231, SW234, SW235, SW243, SW265, SW277, SW278, SW279, SW288, SW291, SW292, SW293, SW298* | **Bi-annual and first flush events:**<br>SD199, SD200, SD219, SD108, SD113, SD114, SD121, SD122, SD123, SD124, SD125, SD157, SD166, SD168, SD170, SD174, SD176, SD189, SD190, SD192, SD193, SD198, SD227, SD231, SD234, SD235, SD243, SD265, SD277, SD278, SD279, SD288, SD291, SD292, SD293, SD298 | The monitoring will assess the PFAS extent and changes in the Central Drainage Channel leading to Wapet Creek. It will also confirm the low risk posed by sediment and surface water in other drainage channels.<br>Monitoring of these locations will provide an indication of any change in the nature or magnitude of PFAS in surface waters and sediments and will help in assessing changes attributable to seasonal fluctuations.<br>Priority will be given to areas where surface water has pooled and to low lying areas where sediment can accumulate. This includes surface water pooling on-Site at the flood gate release point, which if present during wet season monitoring will be sampled. |
| Receptor (Wapet Creek) | **Bi-annual and first flush events:**<br>SW001, SW205, SW207, SW208*, SW209*, SW210*, SW211*, SW300, SW301*, SW302, SW303, SW304, SW305* | **Bi-annual and first flush events:**<br>SD205, SD207, SD208, SD209, SD210, SD211, SD300, SD301, SD302, SD303, SD304, SD305, SD009 | Wapet Creek is the most important receptor with respect to identified risk. Monitoring of these locations will provide an indication of any change in the nature or magnitude of PFAS in surface waters and sediments and will help in determining changes attributable to seasonal fluctuations. |

**Notes:**

*Application of a non-standard LOR (not greater than 0.0003 µg/L for PFOS plus PFHxS and 0.0005 µg/L for PFOA) is to be applied at these locations so that a holistic assessment of potential impacts to identified receptors can be made by comparing PFAS concentrations with the exposure point concentrations (EPC) adopted to inform the ERA (GHD 2019).

## 5.2 Sampling methodology

### 5.2.1 Groundwater monitoring methodology

The groundwater monitoring methodology is detailed in Table 13

*Table 13 Groundwater monitoring methodology*

| Activity | Details |
|---|---|
| Well gauging | Monitoring wells will first be gauged to allow subsequent correction of groundwater levels relative to Australian Height Datum (AHD) prior to groundwater sample collection. All depth measurements will reference the top of casing (TOC) of the monitoring well as an established datum (refer to Table 10). |
| Groundwater Physicochemical Parameters | Groundwater physicochemical parameters will be recorded via a water quality meter from HydraSleeves® or purged water via a peristaltic pump. The following parameters will be recorded:<br>– pH.<br>– Electrical conductivity (EC).<br>– Oxidation reduction potential (ORP).<br>– Dissolved oxygen (DO).<br>– Temperature.<br>The water quality meter will be calibrated by the equipment supplier and daily readings of reference solutions ("bump tests") completed to optimise the accuracy of the measurements taken. |
| Deployment and Retrieval of HydraSleeves® | In compliance with section 18 of the HEPA NEMP, groundwater samples will be collected using bore-dedicated polypropylene HydraSleeves®. The HydraSleeves® will be installed and left in place for a minimum of 24 hours prior to retrieving for sample collection. Where monitoring well construction details are available, the HydraSleeves® will be positioned to target the mid-section of the screened interval. Where construction details are not available, the HydraSleeves® will be placed approximately 1 m from the base of the monitoring well.<br>Samples will be collected via continuous pull method at a rate allowing the water to pass through the check value into the sample sleeve.<br>Samples will be discharged immediately (to seek to minimise changes in chemistry) by piecing the HydraSleeve® in the middle to upper section with a discharge tube.<br>Following sampling, new HydraSleeves® will be deployed in preparation for the next OMP monitoring event using the same string for consistency (same depth of sampling i.e. within screen depth). |
| Alternative sampling methodology (peristaltic pump) | Sampling via low flow micro-purge pump will occur if:<br>a. a HydraSleeve® is retrieved with no or insufficient sample volume; or<br>b. the groundwater well casing is too narrow to accommodate a HydraSleeve® (i.e., multi-level wells).<br>The methodology will comprise:<br>– Post-gauging, each monitoring well will be purged using a low flow micro-purge pump fitted with bore-dedicated inert High-density Polyethylene (HDPE) and silicone tubing. The upper end of the tubing will be connected to the flow cell of a water quality meter positioned to prevent entrapment of oxygen.<br>– The pump intake will be placed approximately 0.5 m below the top of screen (or at least 0.5 m below the top of the water column) to ensure collection of samples representative of groundwater quality beneath the Site.<br>– Measurement of water quality parameters will be undertaken immediately after the flow cell is full and continued thereafter at two to five-minute intervals during the purging process. Field parameters including pH, DO, ORP, EC, TDS and temperature will be measured and recorded on field data sheets during purging until stabilisation is achieved.<br>– Purging will be undertaken until stabilisation of field parameters is achieved after which the well will be subsequently sampled. Parameters will be considered stable when they are within the following range (where practicable within the time constraints of the program):<br>• Temperature: +/- 0.02 °C |

| Activity | Details |
|---|---|
| | • pH: +/- 0.05<br>• EC: +/- 3%<br>• DO: +/- 10%<br>• ORP: +/- 10 mV<br>– Representative groundwater samples will be collected directly from the HDPE tubing into laboratory supplied pre-preserved sample containers. |
| Field records | Field records will include the following information:<br>– Sampling time and date.<br>– Weather conditions.<br>– Sample collection method. Where a HydraSleeve® is used for sample collection, the target interval depth will be recorded.<br>– Stabilised field parameters (three readings required when a bailer is used).<br>– Sampling equipment decontamination procedures where non-disposable sampling equipment is utilised.<br>– Calibration and daily bump test records.<br>– Well gauging records.<br>– Observations such as water colour, turbidity and any obvious visual or olfactory indicators of contamination.<br>All sample documentation including field notes, reporting records, CoC and equipment calibration certificates and procedures will be retained within project files. |
| Decontamination procedure | Dedicated HydraSleeves® will be used at each groundwater bore thus no cross contamination will occur<br>Single use nitrile gloves will be worn during sampling and appropriately disposed of between each sampling location.<br>All re-usable sampling equipment will be thoroughly washed using PFAS-free detergent (mixed per supplier instructions) then double rinsed with clean laboratory supplied rinsate water before the sample collection. |
| Sample identification, preservation transport and holding times | Each sample container will be pre-labelled by the laboratory with a unique barcode for identification.<br>Samples will be collected directly in appropriately preserved laboratory supplied bottles (Teflon-free) and packed in chilled containers for delivery to the laboratory under Chain of Custody (CoC) documentation.<br>Sample containers, preservation procedures, sample storage requirements and holding times will be undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998). |

### 5.2.2 Seepage monitoring methodology

Seepage sampling will be completed be advancing a shallow excavation in the beach sand; just above where inundation by wave action is occurring, using a spade. In-situ water parameters will be measured from water seeping into the excavation using a calibrated water quality meter. Water seeping into the excavation will be purged prior to measuring water quality parameters (using a dedicated syringe or jug). Once the excavation recharges, a seepage sample will be collected directly into sample containers using a ‘grab’ (manual) sample method.

### 5.2.3 Surface water monitoring methodology

The methodology for surface water monitoring is detailed in Table 14.

*Table 14 Surface water monitoring methodology*

| Activity | Details |
|---|---|
| Field parameters | Surface water physiochemical parameters (i.e. pH, electrical conductivity (EC), oxidation reduction potential (ORP), dissolved oxygen (DO), and temperature) will be recorded at the time of sampling using a pre-calibrated water quality meter. |

| Activity | Details |
| --- | --- |
| | Field observations such as flow rate (low/medium/high), odours or sheen presence must also be recorded on field sampling sheets. |
| Sampling method | Where the embankment of the water body is stable and the water body can be safely accessed, surface water samples will be collected by hand, directly into the laboratory supplied sample containers using a 'Grab' (manual) sample method.<br>Where depth permits, the sample container should be positioned at least 10 cm below the surface water level and above the sediment bed and oriented with the capped opening facing downwards to avoid the collection of surface films. Once in position, the container cap will be removed to allow sample collection.<br>Where sampling points cannot be safely accessed, surface water samples will be collected using a long-handled sampler and decanted into the laboratory supplied sample containers.<br>Samples will be collected in accordance with Australian/New Zealand Standards (AS/NZS 5667.1:1998) Water quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples. |
| Sample collection | Water samples will be placed directly into appropriately labelled, laboratory supplied sample bottles and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation. |
| Decontamination | All re-usable sampling equipment will be thoroughly washed using PFAS-free detergent (mixed per supplier instructions), then double rinsed with laboratory supplied rinsate water before the sample collection. Single-use nitrile gloves will be worn during sampling. |
| Sample identification, preservation, transport and holding times. | Each sample container will be pre-labelled by the laboratory with a unique barcode for identification.<br>Samples will be contained in appropriately preserved laboratory supplied bottles (Teflon-free) and packed in chilled containers for delivery to the laboratory under Chain of Custody (CoC) documentation.<br>Sample containers, preservation procedures, sample storage requirements and holding times will be undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998). |
| Field records | Field records will include the following information:<br>– Sampling time and date.<br>– Weather conditions.<br>– Sample Collection method.<br>– Sampling equipment decontamination procedures where non-disposable sampling equipment is utilised.<br>– Calibration and daily bump test records.<br>– Observations such as sediment colour, type and any obvious visual or olfactory indicators of contamination.<br>All sample documentation including field notes, reporting records, CoC and equipment calibration certificates and procedures will be retained within project files. |

### 5.2.4 Sediment monitoring methodology

The methodology for sediment monitoring is detailed in Table 15.

***Table 15 Sediment monitoring methodology***

| Item | Details |
| --- | --- |
| Sample Collection | Sediment samples will be collected at the sediment/water interface (0-0.1 mbgl) using hand tools (e.g. trowel, hand auger, PVC pipe etc.) with samples placed directly into appropriately labelled, laboratory supplied sample containers and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation.<br>At each sampling location, the sediment sample will be visually assessed and observations (including physical description) recorded on field data sheets. |
| Field Records | Field records will include the following information:<br>– Sampling time and date.<br>– Sample description and condition. |

| Item | Details |
|---|---|
| | – Weather conditions.<br>– Sample Collection method.<br>– Sampling equipment decontamination procedures where non-disposable sampling equipment is utilised.<br>All sample documentation including field notebooks, reporting records, CoC and equipment calibration certificates and procedures will be retained within project files. |
| Decontamination | All re-usable sampling equipment will be thoroughly washed using PFAS-free detergent (mixed per supplier instructions), then double rinsed with laboratory supplied rinsate water before the sample collection. Single-use nitrile gloves will be worn during sampling. |

## 5.3 Sample analysis

Groundwater, seepage, surface water and sediment samples will be analysed for the full PFAS analytical suite (see Appendix C).

Laboratory LOR must be selected to achieve the OMP objectives (Section 1.1) and the DQOs. As identified in the monitoring location tables in Section 5.1, non-standard LOR will be applied at:

– Selected pathway/receptor groundwater (Table 9), seepage water (Table 11) and surface water monitoring locations (Table 12). At these locations, a non-standard LOR, not greater than 0.0003 µg/L for PFOS plus PFHxS and 0.0005 µg/L for PFOA, is to be applied to seek to:
  - Enable comparison of OMP data and the DSI data (i.e., baseline data) which included analysis of samples to a lower LOR than what has been adopted throughout implementation of the OMP to date.
  - Enable comparison of PFAS concentrations with the exposure point concentrations (EPC; 0.0022 – 0.0059 µg/L for PFOS plus PFHxS, 0.0005 µg/L for PFOA) adopted to inform the ERA (GHD 2019) and therefore enable robust monitoring of the Site risk profile, as established by the ERA in relation to sensitive ecological receptors. The nominated LOR are approximately one order-of-magnitude lower than the EPC adopted in the ERA.

– Selected off-Site groundwater locations (Table 9) noting that in November 2024, the National Health and Medical Research Council (NHMRC) released draft health based drinking water guideline values for public consultation. Defence is considering how the draft guidelines, if adopted, may affect its PFAS Investigation and Management Program, and communities surrounding the Defence Estate. An initial step to this is the adoption of a lower laboratory LOR to understand any future implications. To this end, selected off-Site groundwater monitoring locations (Table 9) will be analysed at a suitably low LOR. It is important to note however that until the revised PFAS guideline values are finalised and published, the current guideline values remain in effect.

It is proposed to discontinue the May 2019 OMP requirement to analyse samples for major ions (including calcium, magnesium, sodium, potassium, chloride, sulfate etc.) and physicochemical parameters (dissolved organic carbon, total/dissolved solids, pH etc.) on the following basis:

– To date, the recorded concentrations of major ions and physicochemical parameters in the samples have not informed conclusions regarding changes to the nature and extent of PFAS impacts, the CSM or the Site risk profile (Stantec, 2024b).

– Ongoing monitoring of PFAS concentrations paired with groundwater level gauging (and subsequent flow direction interpretation) and in-situ (i.e., field) measurement of physicochemical parameters (e.g., total dissolved solids, pH, electrical conductivity etc) is likely to provide better value as lines of evidence in support of fulfilment of the OMP objectives.

If unexpected PFAS concentration data is identified as requiring further assessment, analysis of selected samples for ions and/or physicochemical parameters could be considered and re-introduced through update of this OMP SAQP.

All analysis will be undertaken by NATA accredited laboratories, as follows:

– Primary analysis will be undertaken by ALS Global Laboratories

– Secondary analysis will be undertaken by Eurofins ARL.

## 5.4 Data Management

All data collected as part of the OMP will be managed in accordance with the DCMM Annex L (Defence, 2021). This includes:

- The location codes, project ID, and sample naming conventions presented in the DCMM Annex L will be followed.
- Laboratory and field data will be uploaded onto the Defence Environmental Data Management Software (EDMS (ESdat)).
- Laboratory data will be reviewed, approved and QA/QC data reconciled in ESdat.

# 6. Quality assurance and quality control

The QA/QC procedures are based on NEPM (2013), HEPA (2020) PFAS NEMP and DWER Assessment and management of contaminated sites (DWER 2021).

QA involves all of the actions, procedures, checks and decisions undertaken to ensure the representativeness and integrity of samples and accuracy and reliability of analytical results (NEPM 2013) QC involves protocols to monitor and measure the effectiveness of QA procedures.

## 6.1 Field program QA/QC

### 6.1.1 Field quality assurance procedures

All field work will be conducted with reference to the DWER (2021) contaminated sites guidelines, HEPA (2020) and GHD’s Standard Field Operating Procedures, which ensures all samples are collected by a set of uniform and systematic methods, as required by GHD’s QA system.

Key requirements of these procedures are listed below. Specific requirements for handling PFAS samples to prevent cross-contamination are detailed in HEPA (2020). These requirements will be complied with during sampling:

– **Sampling team:** The sampling team will follow the methodologies presented within Section 5.2 which are consistent with those adopted during the DSI (GHD 2018). All field staff involved in sampling will be experienced in their respective fields and considered competent in accordance with GHD’s QA system.

– **Sample collection, handling and transport:** Groundwater and surface water samples will be collected using new disposable nitrile gloves for each sample. Specific requirements for handling PFAS samples such as not using water-proofed clothing and having food wrappers on-Site, as per the DER interim PFAS guidelines (DER 2017) and HEPA (2020) guidelines, will be adhered to at all times. Samples will be placed into laboratory provided Teflon-free sample jars/bottles and, once collected, will be placed on ice (contained in plastic bags) in insulated containers. Samples will be delivered to the laboratory within the recommended holding times for the respective analytes.

– **Sample identification procedures:** Each sample will be labelled as per DCMM Annex L with the sample location, date, project identification number and sampler’s initials. Sample details will be entered onto a CoC form that accompanies each batch of samples to the laboratory.

– **CoC information requirements:** A CoC form will be completed and forwarded to the testing laboratory with each batch of samples.

– **Collection of QC samples:** Field QC samples will be collected as detailed in Section 6.1.2.

– **Calibration of field equipment:** Prior to use in the field, all field instruments (i.e. water quality meter) will be calibrated by the equipment supplier to optimise the accuracy of the measurements taken.

### 6.1.2 Sampling and analysis quality control

The ASC NEPM (NEPM 2013), DWER (2021) guidelines and the PFAS NEMP (HEPA 2020) outline a recommended approach to QC sampling. The QC samples to be collected during the investigation are described as follows:

– Blind duplicate: Blind duplicate samples are used to identify the variation in the analyte concentration between samples from the same sampling point.

– Split duplicate: Split duplicate samples provide an indication of the repeatability of the results between laboratories.

– Field blanks: Field blanks are used to estimate contamination of a sample during the collection procedure. Field blanks are collected by pouring laboratory supplied deionised water into laboratory supplied bottles on-Site.

– Rinsate blanks: Rinsate blank samples are used to estimate the amount of contamination introduced by the re-use of sampling equipment. They are obtained by pouring laboratory supplied deionised water over decontaminated sampling equipment (e.g. interphase probe) into laboratory supplied bottles.

The QC sample collection frequency, and the nominated acceptance criteria for data quality evaluation, is presented in Table 16. In the instance that acceptance criteria listed above are not met, further assessment of the data will be required to determine the impact that this has on the interpretation of the data.

*Table 16 Sampling and analysis QA/QC analytical program*

| Sample type | Analysis | Rationale | Acceptance criteria |
|---|---|---|---|
| Blind duplicate samples | Standard PFAS suite | One blind duplicate sample for every 10 samples | 0 – 30% relative percentage difference (RPD) |
| Split duplicate samples | Standard PFAS suite | One split duplicate sample for every 10 samples | |
| Field and rinsate blanks | Standard PFAS suite | One field blank and one rinsate blank per day per piece of reusable equipment. | <LOR |

Blind and split duplicate samples will be assessed by calculating the Relative Percentage Difference (RPD) between the primary, blind and split samples in accordance with the procedure described in the ASC NEPM. Calculation of RPDs provides a quantitative measure of the accuracy of the analytical results reported.

RPD results will be considered acceptable if they are less than or equal to 30%. The only exception to this is when concentrations within the primary and blind or split sample are less than ten times the laboratory LOR. In this case, a greater RPD value may be considered acceptable.

# 6.2 Laboratory QA/QC

## 6.2.1 Laboratory analytical programs

Laboratory methods to be used by the primary and secondary laboratories will be suitable for environmental contaminant analysis and are based on established internationally recognised procedures. Each of the laboratories is NATA accredited for the proposed analysis.

## 6.2.2 Laboratory quality control procedures

The following laboratory QC procedures will be used during the investigation.

### 6.2.2.1 Laboratory duplicate samples

Laboratory duplicate sample analysis is the analysis of a laboratory derived duplicate sample from the process batch, at a rate equivalent to one in 10 samples per analytical batch, or one sample per batch if less than 10 samples are analysed in a batch. A laboratory duplicate provides data on the analytical precision and reproducibility of the analytical results.

The permitted ranges for the RPD of laboratory duplicates are dependent on the magnitude of the results in comparison to the level of reporting as shown in Table 17.

*Table 17 Acceptable laboratory RPD ranges*

| Magnitude of result | Acceptable RPD range |
|---|---|
| < 10 x LOR | No defined limit, to be qualitatively evaluated |
| 10 - 20 x LOR | 0% - 50% |
| > 20 x LOR | 0% - 20% |

#### 6.2.2.2 Method blank samples

Method or analysis blank sample analysis are the analysis of a sample that is as free as possible of the analytes of interest, but has been prepared the same as the samples under investigation. The analysis is to ascertain if laboratory reagents, glassware and other laboratory consumables contribute to the observed concentration of analytes in the process batch. If below the maximum acceptable method blank (20% of the practical quantitation limit), the contribution is subtracted from the gross analytical signal for each analysis before calculating the sample analyte concentration. The method blank should return analyte concentrations as ‘not detected’.

#### 6.2.2.3 Laboratory control samples

Laboratory control spike analysis is the analysis of either a reference material or a control matrix fortified with analytes representative of the analyte class. The purpose of laboratory control spike samples is to monitor method precision and accuracy independent of the sample matrix. Typically, the percentage recovery of the laboratory control spike sample is compared to the dynamic recovery limits based on the statistical analysis of the processed laboratory control spike sample analysis. Recoveries should lie between 70% and 130%.

#### 6.2.2.4 Matrix spike samples

Matrix spike sample analysis is the analysis of one or more replicate portions of samples from the batch, after fortifying the additional portion(s) with known quantities of the analyte(s) of interest. The percentage recovery of target analyte(s) from matrix spike samples is used to determine the bias of the method in the specific sample matrix. Recoveries should lie between 70% and 130%.

#### 6.2.2.5 Surrogate spike samples

Surrogate spike samples are samples with known additions of known amounts of compounds, which are similar to the analytes of interests in terms of extractability, recovery through clean-up procedures and response to chromatographic or other measurement. Surrogate compounds may be alkylated or halogenated analogues or structural isomers of analytes of interest. The purpose of surrogate spikes, which are added immediately before the sample extraction step, is to provide a check for every analysis that no gross processing errors have occurred, which could have led to significant analyte loss or faulty calculation. Recoveries should lie between 50% and 150%.

#### 6.2.2.6 Internal standards

Internal standards are known additions of known amounts of compounds which are not found in real samples, will not interfere with quantification of analytes of interest and may be separately and independently quantified. The purpose of internal standards in instrumental techniques is to provide independent signals, which serve to check the consistency of the analytical step. Internal standards are often used for organic compounds and some inorganic compounds.

# 7. Reporting

## 7.1 Factual and interpretive reporting

After each monitoring event, information, field and laboratory data will be documented in a factual report.

At the end of a specified monitoring period (typically 12 months but may vary) the whole data set (including the current and historic data) will be reviewed, and an interpretive Ongoing Monitoring Report (OMR) prepared. The OMR will report on the objectives of the OMP as outlined in Section 1.1.

## 7.2 Deviations from the OMP

This OMP SAQP supersedes the previous SAQP (Stantec 2204a) which was revised in response to various factors and/or changes throughout its implementation from 2019 to 2024. Those deviations/changes are described within the previous Stantec SAQP (Stantec 2024a). Moving forward, changes and/or deviations to this SAQP will be captured in a revised SAQP and identified in deviations register.

# 8. References

## 8.1 General references


- Australian Standard AS 4482-2005 Guide to the investigation and sampling of sites with potentially contaminated soils, Part 1 – Non-volatile and semi-volatile compounds.
- *Contaminated Sites Act 2003*, Western Australia.
- Department of Defence, 2021, Defence Contamination Management Manual (DCMM) *Annex L Data Management*.
- Department of Defence, May 2021, *PFAS OMP Factual Report Guidance*, Version 0.2.
- Department of Defence, October 2022, *PFAS OMP Annual Interpretive Report Guidance*, Version 0.4.
- Department of Water and Environmental Regulation (DWER), 2021, *Assessment and Management of Contaminated Sites*.
- The Heads of EPAs Australia and New Zealand (HEPA; 2020) *PFAS National Environmental Management Plan (NEMP) 2.0*, January 2020.
- National Environment Protection Council (NEPC), 1999, *National Environmental Protection (Assessment of Site Contamination) Measure* (as amended), registered May 2013.
- National Health and Medical Research Council (NHMRC) (2011 – updated 2022) *National Water Quality Management Strategy Australian Drinking Water Guidelines 6*, September 2022.
- NHMRC, August 2019, *Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water*.
- Standards Australia/Standards New Zealand (1998) AS5667.1:1998 Water Quality – *Sampling, Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples.*
- U.S. Environmental Protection Agency (EPA), 2000, *Guidance for the Data Quality Objectives Process* (EPA QA/G-4).
- USEPA, 2002, *Guidance on Environmental Data Verification and Data Validation* (EPA QA/G-8).


## 8.2 Site specific references


- Cardno, April 2020, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Base Learmonth*.
- Cardno, May 2020, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*.
- Cardno, December 2020, *PFAS OMP 2020 post-summer Biannual Monitoring Event RAAF Base Learmonth*.
- Cardno, February 2021, *PFAS OMP 2020 post-winter Biannual Monitoring Event RAAF Base Learmonth*.
- Cardno, April 2021, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*.
- Cardno, June 2021, *PFAS OMP, 2020 Annual Interpretive Report – RAAF Base Learmonth*.
- Cardno, August 2021, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
- Cardno, April 2022, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
- Cardno, September 2022, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*
- Cardno, October 2022, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
- Cardno, January 2023, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
- Cardno, April 2023, *PFAS OMP 2021 Annual Interpretive Report – RAAF Base Learmonth*
- Cardno, September 2023, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
- Department of Defence, May 2019a, *RAAF Base Learmonth PFAS Management Area Plan*.
- Department of Defence, May 2019b, *RAAF Base Learmonth PFAS Ongoing Monitoring Plan*.
- GHD, December 2018, *RAAF Base Learmonth – PFAS Investigations – Preliminary and Detailed Site Investigation Report*.
- GHD, April 2019, *RAAF Base Learmonth – PFAS Investigations – Ecological Risk Assessment*

– Stantec, May 2024a, *PFAS Ongoing Monitoring Plan Sampling and Analysis Quality Plan (SAQP) RAAF Base Learmonth*
– Stantec, August 2024b, *Ongoing Monitoring Report (October 2021 - September 2023)*. 5 August 2024.
– Stantec, June 2024c, *PFAS OMP Biannual Monitoring Event Factual Report*. May 2024

# 9. Disclaimer

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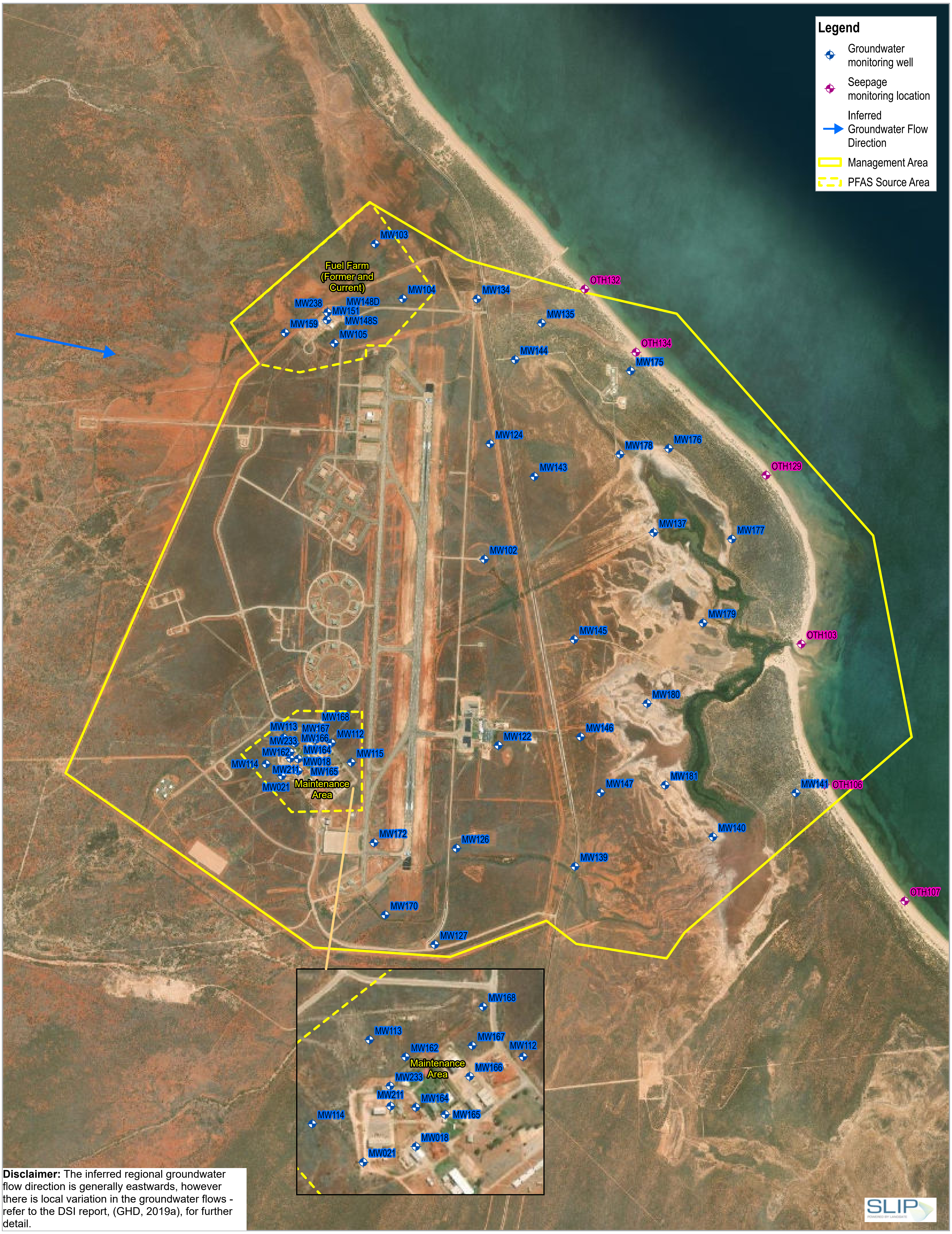
If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

# Appendices

# Appendix A

## Figures




**Disclaimer:** The inferred regional groundwater flow direction is generally eastwards, however there is local variation in the groundwater flows - refer to the DSI report, (GHD, 2019a), for further detail.

Paper Size ISO A3

0 0.25 0.5 0.75 1

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 50

**Department of Defence**
**PFAS Ongoing Monitoring Plan**
**Sampling and Analysis Quality Plan (SAQP)**
**RAAF Base Learmonth**

**Groundwater and Seepage Monitoring Locations**

Project No. **12641234**
Revision No. **0**
Date **27/03/2025**

**FIGURE 2**

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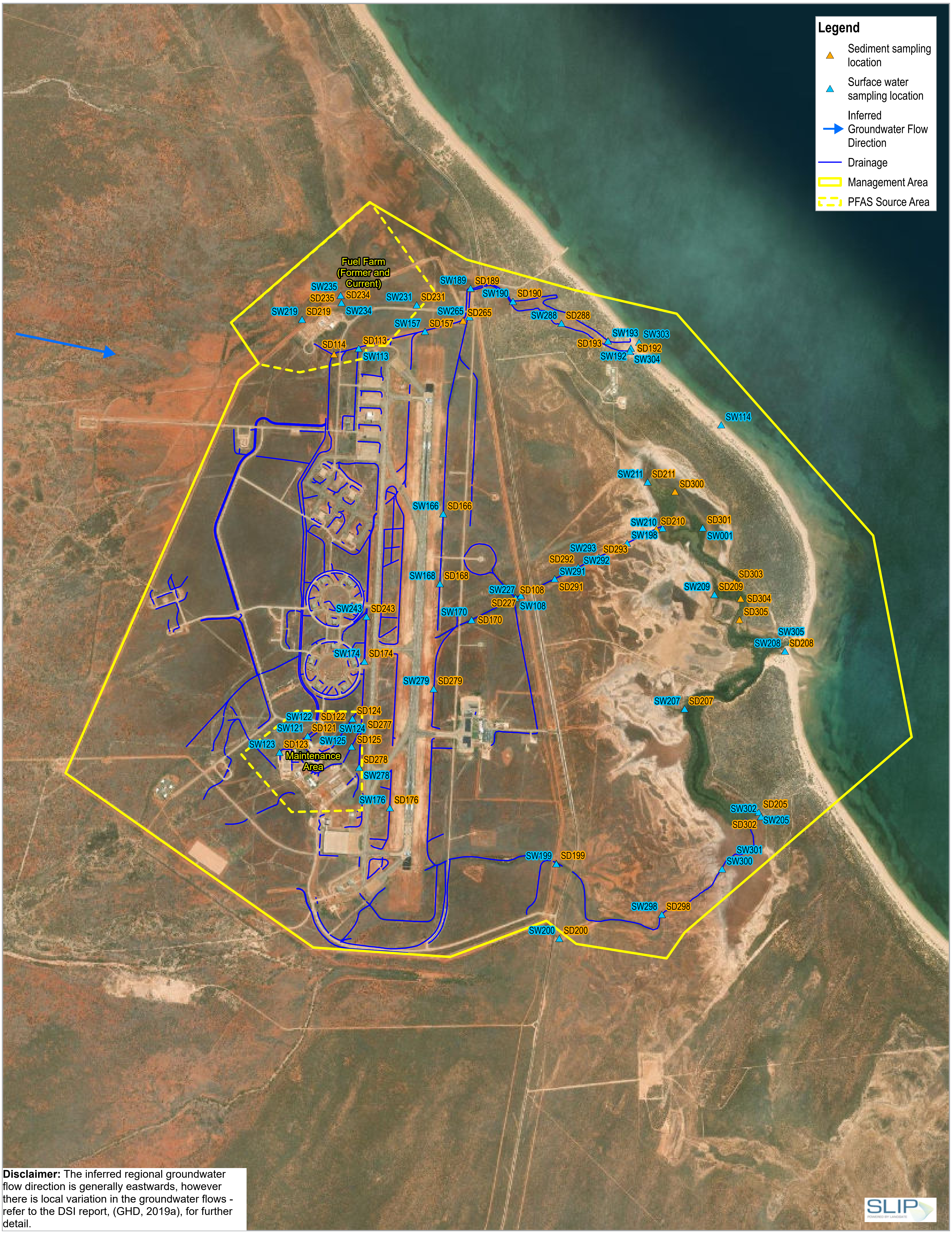
Print date: 27 Mar 2025 - 11:51

Data source: World Imagery: Maxar. Created by: shart2

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 50

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GHD

Department of Defence
PFAS Ongoing Monitoring Plan
Sampling and Analysis Quality Plan (SAQP)
RAAF Base Learmonth

**Surface Water and Sediment Monitoring Locations**

| | |
|---|---|
| Project No. | 12641234 |
| Revision No. | 0 |
| Date | 27/03/2025 |

**FIGURE 3**

\\ghdnet\ghd\AU\Perth\Projects\61\12641234\GIS\Maps\Working\12641234LearmonthSAQP\12641234LearmonthSAQP.aprx\12641234_LearmonthSAQP_004_SurfaceWaterSedimentMonitoringLocations_Rev0
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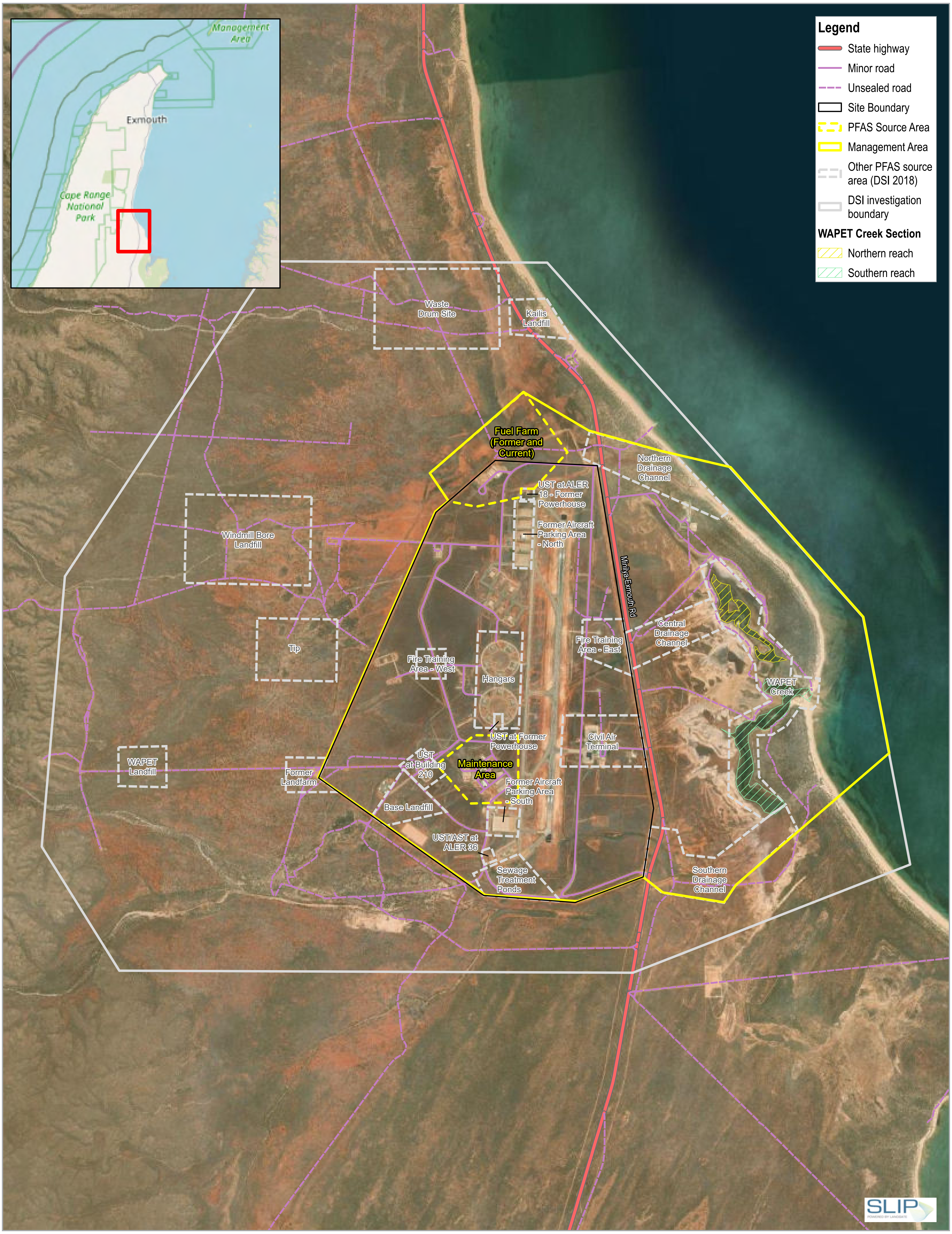


Paper Size ISO A3

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 50

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GHD

**Department of Defence**
**PFAS Ongoing Monitoring Plan**
**Sampling and Analysis Quality Plan (SAQP)**
**RAAF Base Learmonth**

## Site Layout and Management Area

Project No. **12641234**
Revision No. **0**
Date **27/03/2025**

## FIGURE 1

\\ghdnet\ghd\AU\Perth\Projects\61\12641234\GIS\Maps\Working\12641234LearmonthSAQP\12641234LearmonthSAQP.aprx\12641234_LearmonthSAQP_005_SiteLayoutManagementArea_Rev0
Print date: 27 Mar 2025 - 11:51

Data source: OpenStreetMap: © OpenStreetMap (and) contributors, CC-BY-SA
World Imagery: Maxar. Created by: shart2

# Appendix B

## Source pathway receptor evaluation (sourced from the PMAP)

*CSM for the two main source areas – Fuel Farm and Maintenance Area*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Fuel Farm** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Stockpiles | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However, the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Water is ephemeral and not likely to be sourced for consumption<br>Opportunity for exposure is low and manageable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake and accumulation in plants and animals however, water is ephemeral and therefore only periodically available for animal consumption<br>Can discharge eventually into Wapet Creek or Exmouth Gulf, however this is likely to occur in high rain events and result in significant dilution. Sampling results indicated only very low levels of PFAS in receptors. | Possible | Low |
| | Groundwater | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>HIL for drinking water and recreational use<br>Groundwater not abstracted in this area for any use.<br>Generally not potable<br>Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients so primary contact recreation may not be realised | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients.<br>Potential PFAS mass in groundwater is low. | Possible | Low |
| | Edible produce | Human Health | No | No | Ingestion | Edible produce grown in areas where PFAS has impacted the soil can take up PFAS and therefore constitutes a possible risk to human health through consumption. Sampling of bananas and mangos on RAAF Base Learmonth indicated no detectable PFAS | Possible | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Maintenance Area** | Soil | Human Health | Yes (residential)<br>No (industrial / commercial) | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS less than the HILs for the main use of the site (industrial) and residential areas are limited.<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Low |
| | | Ecosystems | Yes (one only) | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals that consume soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface Water | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Water is ephemeral and not likely to be sourced for consumption<br>Opportunity for exposure is low and manageable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake and accumulation in plants and animals however, water is ephemeral and therefore only periodically available for animal consumption<br>Can discharge eventually into Wapet Creek via the Central Drainage Channel. However, this is likely to occur in high rain events and result in significant dilution. Sampling results indicated only very low levels of PFAS in Wapet Creek. | Possible | Low |
| | Groundwater | Human Health | Yes (drinking water) | Yes | Ingestion<br>Dermal contact | Groundwater not abstracted in this area for any use.<br>Generally not potable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients so primary contact recreation may not be realised<br>Deeper aquifer (limestone) not directly assessed but groundwater at 20 m was impacted, so it is likely the deeper limestone will be impacted. | | |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients.<br>Potential PFAS mass in groundwater is low. | Possible | Low |
| | Edible produce | Human Health | No | No | Ingestion | Edible produce grown in areas where PFAS has impacted the soil can take up PFAS and therefore constitutes a possible risk to human health through consumption. No sampling of edible biota has been completed on RAAF Base Learmonth. However sampling of mangos on HEH B indicated no detectable PFAS | Possible | Negligible |

*CSM for Sewage Treatment Ponds*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **STP** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Water is ephemeral and not likely to be sourced for consumption<br>Opportunity for exposure is low and manageable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Exceeds Marine Water EIL but is some distance from the Gulf. May impact Wapet Creek although there were not surface water detects in the southern reach of Wapet Creek.<br>Potential for uptake and accumulation in plants and animals however, water is ephemeral and therefore only periodically available for animal consumption | Possible | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Groundwater | Human Health | Yes (drinking water) | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater not abstracted in this area for any use.<br>Generally not potable<br>Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients so primary contact recreation may not be realised | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients.<br>Potential PFAS mass in groundwater is low. | Possible | Low |

*CSM for solid waste disposal areas (landfills, drum area, tip)*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Base Landfill** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | Groundwater | Human Health | Yes (drinking water) | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater not abstracted in this area for any use and is not potable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors. | | |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **Wapet Landfill** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the number of detections were low and PFAS mass is likely to be very low | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | Potential for uptake from soils and accumulation in predatory animals that consume soil-dwelling animals or plants. However the number of detections were low and PFAS mass is likely to be very low | Possible | Low |
| | Surface Water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Groundwater not abstracted in this area for any use and not potable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **Windmill Bore Landfill** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the number of detections were low and PFAS mass is likely to be very low | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the number of detections were low and PFAS mass is likely to be very low | | Low |
| | Surface Water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Groundwater abstraction bores are up gradient of this area | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Kailis Landfill** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Low potential for uptake from soils and as detects were not at surface (2 and 3 mbgl) | Possible | Negligible |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < LOR | No | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < LOR | No | Negligible |
| | Surface Water | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | Seepage samples <LOR | No | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | Seepage samples <LOR | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>No groundwater abstraction in this area | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion | Groundwater exceeds EIL for marine water protection but there are no detectable seepage samples on the coast | Possible but unlikely | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Dermal contact<br>Inhalation | | | |
| **Tip** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Low potential for uptake from soils and only one low detect | Possible | Negligible |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Low potential for uptake from soils and only one low detect | Possible | Negligible |
| | Surface Water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed | No | Negligible |
| | | Ecosystems | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact | PFAS <HILs<br>No groundwater abstraction in this area | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | Groundwater exceeds EIL for marine water protection but the area is considerable distance from the coast | Possible but unlikely | Negligible |
| **Waste Drum Area** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < EILs<br>Low potential for uptake from soils and only one low detect | Possible | Negligible |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < LOR | No | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS < LOR | No | Negligible |
| | Surface Water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed | No | Negligible |
| | | Ecosystems | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <LOR | No | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <LOR | No | Negligible |

*CSM for Former Fire Training Areas*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Former fire training areas - west** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact | PFAS <HILs<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | | Ecosystems | Yes (one only) | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **Former fire training areas - east** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | Groundwater | Human Health | Yes (drinking water) | Yes | Ingestion<br>Dermal contact<br>Inhalation | <LOR | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | <LOR | No | Low |

*CSM for other fuel storage areas*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **UST/AST at ALER 36** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | Not assessed | Not assessed | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | | Ecosystems | Not assessed | Not assessed | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | Groundwater | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >HILs for drinking water<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **UST at Former Powerhouse** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | Yes (one only) | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for Interim Ecological Indirect Exposure Commercial/Industrial<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs for<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, with no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | Groundwater | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >HILs for drinking water<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **UST at ALER 18** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | Not assessed | Not assessed | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | | Ecosystems | Not assessed | Not assessed | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs for drinking water<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **UST at Building 210** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, with no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – no drainage channels directly associated with this AEC | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs for drinking water<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |

*CSM for other minor sources*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Hangars** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact | PFAS <HILs<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **Former landfarm** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs but one detect of PFOA<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Negligible |
| **Former Aircraft parking - north** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Inhalation | | | |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | Groundwater | Human Health | Not assessed | Not assessed | Ingestion<br>Dermal contact<br>Inhalation | Not assessed | No | Negligible |
| | | Ecosystems | Not assessed | Not assessed | Ingestion<br>Dermal contact<br>Inhalation | Not assessed | No | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Former Aircraft parking - south** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS > EIL for Marine Water protection.<br>Potential for uptake and accumulation in plants and animals however, water is ephemeral and therefore only periodically available for animal consumption | Possible | Low |
| | Groundwater | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >HILs for drinking water and recreational use<br>PFAS>HIL for drinking water and recreational use<br>Groundwater not abstracted in this area for any use and is not potable | Possible but unlikely | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients so primary contact recreation may not be realised | | |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **Civil air terminal** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Surface water | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | No water to sample - Suggests this transport pathway is ephemeral and insignificant | No | Negligible |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |
| **Additional onsite and grid samples** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Low level PFAS across a significant area of RAAF Base Learmonth. Opportunity for exposure is low and manageable | Possible | Low |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EIL Interim Ecological Indirect Exposure Commercial/Industrial (one location only)<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However, there are few areas of natural, undisturbed ecosystems making exposure limited. | Possible | Low |
| | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. | Possible | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | Surface water | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>HIL for drinking water and recreational use<br>Surface water is ephemeral and not a viable potable or recreational resource. | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EIL for marine water ecosystem protection<br>Not likely to discharge to sensitive receptors given the distance to the receptors. | Possible but unlikely | Low |
| | Groundwater | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >HIL for Drinking water<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |
| | | Ecosystems | Yes (one only) | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EIL for marine water ecosystem protection<br>PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients.<br>Potential PFAS mass in groundwater is very low. | Possible but unlikely | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Additional offsite and grid samples** | Soil | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable | Possible | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. | Possible | Low |
| | Sediment | Human Health | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – covered by other AECs | No | Negligible |
| | | Ecosystems | Not assessed | No | Ingestion<br>Dermal contact<br>Inhalation | Not assessed – covered by other AECs | No | Negligible |
| | Surface water – beach seepage | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS<HILs | No | Negligible |
| | | Ecosystems | Not assessed | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS >EILs for marine water ecosystem protection<br>Risk is considered low as the concentrations in beach seepage samples are low (close to the LOR). | Likely | Low |
| | Groundwater | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Groundwater not abstracted in this area for any use and is not potable | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion | PFAS >EILs for marine water ecosystem protection | Possible | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | | Dermal contact<br>Inhalation | PFAS Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients and the distance to the receptors. However, coastal wells have minor impact a low PFAS mass could potentially discharge into Exmouth Gulf. | | |

*CSM for drainage channels*

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Northern Channel** | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. | Possible | Low |
| | Surface water | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>HIL for drinking water<br>Surface water is too saline to form a potable use | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>EIL for marine ecosystem protection<br>Risk is considered low as Biota from Exmouth Gulf have shown no impact from PFAS. | Likely | Low |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Central Channel** | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Low |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. | Possible | Low |
| | Surface water | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>HIL for drinking water<br>Surface water is too saline to form a potable use | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>EIL for marine ecosystem protection<br>Discharges into the northern reach of Wapet Creek where impact to biota is reported<br>Discharge is likely to be sporadic and discharged mass will be low. Northern reach of Wapet Creek is often isolated from the rest of the creek and Exmouth Gulf so impact likely to be localised<br>The ERA concluded that the potential for elevated food chain exposures to shorebirds foraging primarily within the northern reaches of Wapet Creek (where the central drainage channel discharges) cannot be ruled out | Likely | Medium |

| Area of environmental concern | Impacted media | General Receptor | Exceeds HIL/EIL | Tier 1 risk | Potential exposure route | Comment | S-P-R Link complete? | Residual Risk |
|---|---|---|---|---|---|---|---|---|
| **Southern Channel** | Sediment | Human Health | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <HILs<br>Opportunity for exposure is low and manageable as sediments are confined to drains where access is limited | Possible but unlikely | Negligible |
| | | Ecosystems | No | No | Ingestion<br>Dermal contact<br>Inhalation | PFAS <EILs<br>Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. | Possible | Low |
| | Surface water | Human Health | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>HIL for drinking water<br>Surface water is too saline to form a potable use | No | Negligible |
| | | Ecosystems | Yes | Yes | Ingestion<br>Dermal contact<br>Inhalation | PFAS>EIL for marine ecosystem protection<br>Discharges into the southern reach of Wapet Creek where impact to biota is not reported<br>Discharge is likely to be sporadic and discharged mass will be low. | Likely | Low |

# Appendix C

## PFAS analytical suite

| Group/Analytes | Water Std level (µg/L) | Water Std level (µg/L) | Water Low Level (µg/L) | Water Low Level (µg/L) | Super Trace (µg/L) | Super Trace (µg/L) | Super Ultra Trace (µg/L) | Super Ultra Trace (µg/L) |
|---|---|---|---|---|---|---|---|---|
| Method Code | **EP231** | **EP231X** | **EP231-LL** | **EP231X-LL** | **EP231-ST** | **EP231X-ST** | **EP231-SUT** | **EP231X-SUT** |
| Sample Volume Requirement | **2x 20 mL** | **2x 20 mL** | **2x 20 mL** | **2x 20 mL** | **2x 120 mL** | **2x 120 mL** | **2x 120 mL** | **2x 120 mL** |
| Perfluoroalkyl Sulfonic Acids | | | | | | | | |
| Perfluoropropane sulfonic acid (PFPrS) | | 0.02 | | 0.01 | | 0.002 | | 0.002 |
| Perfluorobutane sulfonic acid (PFBS) | 0.02 | 0.02 | 0.002 | 0.002 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Perfluoropentane sulfonic acid (PFPeS) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorohexane sulfonic acid (PFHxS) | 0.01 | 0.01 | 0.002 | 0.002 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Perfluoroheptane sulfonic acid (PFHpS) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorooctane sulfonic acid (PFOS) | 0.01 | 0.01 | 0.002 | 0.002 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| Perfluorononane sulfonic acid (PFNS) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorododecane sulfonic acid (PFDoDS)* | | 0.25 | | 0.25 | | NA | | 0.005 |
| Perfluorodecane sulfonic acid (PFDS) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| **Perfluoroalkyl Carboxylic Acids** | | | | | | | | |
| Perfluorobutanoic acid (PFBA) | 0.1 | 0.1 | 0.01 | 0.01 | 0.002 | 0.002 | 0.002 | 0.002 |
| Perfluoropentanoic acid (PFPeA) | 0.02 | 0.02 | 0.002 | 0.002 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Perfluorohexanoic acid (PFHxA) | 0.02 | 0.02 | 0.002 | 0.002 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Perfluoroheptanoic acid (PFHpA) | 0.02 | 0.02 | 0.002 | 0.002 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Perfluorooctanoic acid (PFOA) | 0.01 | 0.01 | 0.002 | 0.002 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| Perfluorononanoic acid (PFNA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorodecanoic acid (PFDA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluoroundecanoic acid (PFUnDA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorododecanoic acid (PFDoDA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorotridecanoic acid (PFTrDA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| Perfluorotetradecanoic acid (PFTeDA) | | 0.05 | | 0.005 | | 0.0005 | | 0.0005 |
| Perfluorohexadecanoic acid (PFHxDA) | | 0.05 | | 0.005 | | NA | | NA |
| **Perfluoroalkyl Sulfonamides** | | | | | | | | |
| Perfluorooctane sulfonamide (FOSA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| N-Methyl perfluorooctane sulfonamide (MeFOSA) | | 0.05 | | 0.005 | | 0.001 | | 0.001 |
| N-Ethyl perfluorooctane sulfonamide (EtFOSA) | | 0.05 | | 0.005 | | 0.001 | | 0.001 |
| N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE) | | 0.05 | | 0.005 | | 0.001 | | 0.001 |
| N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE) | | 0.05 | | 0.005 | | 0.001 | | 0.001 |
| N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA) | | 0.02 | | 0.002 | | 0.0005 | | 0.0005 |
| **(n:2) Fluorotelomer Sulfonic Acids** | | | | | | | | |
| 4:2 Fluorotelomer sulfonic acid (4:2 FTS) | 0.05 | 0.05 | 0.005 | 0.005 | 0.001 | 0.001 | 0.001 | 0.001 |
| 6:2 Fluorotelomer sulfonic acid (6:2 FTS) | 0.05 | 0.05 | 0.005 | 0.005 | 0.001 | 0.001 | 0.001 | 0.001 |
| 8:2 Fluorotelomer sulfonic acid (8:2 FTS) | 0.05 | 0.05 | 0.005 | 0.005 | 0.001 | 0.001 | 0.001 | 0.001 |
| 10:2 Fluorotelomer sulfonic acid (10:2 FTS) | 0.05 | 0.05 | 0.005 | 0.005 | 0.001 | 0.001 | 0.001 | 0.001 |
| **PFAS Sums** | | | | | | | | |
| Sum of PFAS | | 0.01 | | 0.002 | | 0.0003 | | 0.0002 |
| Sum of PFHxS and PFOS | 0.01 | 0.01 | 0.002 | 0.002 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| Sum of PFAS (WA DER List) | 0.01 | 0.01 | 0.002 | 0.002 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |

*PFDoDS only available upon request, performed by ALS Sydney


# PFAS Ongoing Monitoring Plan Sampling and Analysis Quality Plan (SAQP)

RAAF Base Learmonth

Prepared for

Department of Defence

May 24

Cardno

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## Document Information

| | |
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# Table of Contents



# Tables

# Appendices

# 1 Introduction

Cardno have been engaged by the Australian Department of Defence ('Defence') to prepare a Sampling and Analysis Quality Plan (SAQP) as part of the Ongoing Monitoring Plan (OMP), the purpose of which to monitor trends in the extent and concentrations of per- and poly-fluoroalkyl substances (PFAS) impacts identified on and around RAAF Base Learmonth ("Base"), located approximately 30km south of Exmouth, Western Australia (Figure 1, Appendix A).

The OMP SAQP applies to not only RAAF Base Learmonth, but also the surrounding areas that, together with the Base, make up the "Management Area". For the purposes of this report:

- "the site" was defined as RAAF Base Learmonth (Figure 1, Appendix A).
- "the Management Area" was defined as comprising the site, plus the land east of the Base, including the salt pan, drainage channels, WAPET creek and extends to Exmouth Gulf (Figure 2, Appendix A).

The site is located on Commonwealth Land and is regulated under Commonwealth environmental legislation. The OMP outlines the rationale and scope for the monitoring of the concentrations and extent of PFAS in groundwater, surface water and sediment originating from the site. The monitoring regime consists of two main sampling events in June and November, as well a 'first flush' surface water and sediment monitoring event conducted immediately (or as close as possible) following the first heavy rainfall event of the wet season.

## 1.1 Background

## 1.2 Purpose & Objectives

The objective of the OMP SAQP is to present the specific monitoring locations, sampling methodologies and quality control / quality assurance measures for the monitoring of the concentrations and extent of PFAS in groundwater, surface water and sediment originating from the site. These findings will inform risk management decisions by Defence and the Western Australian Government to protect human health and the environment.

The specific purposes of the monitoring specified in the OMP is to:

1. Evaluate changes in the nature and extent (spatial and temporal) of PFAS impact in groundwater and surface water pathways associated with site sources of PFAS derived from legacy use of aqueous film-forming foam (AFFF);
2. Monitor the migration of PFAS in groundwater, sediment and surface water from the site;
3. Provide confirmation of the current understanding of risk; and
4. Provide supporting data for assessment of management actions, where relevant.

## 1.3 Previous Reports

The following key reports prepared in relation to the RAAF Base Learmonth PFAS Investigation have been used as a basis to develop this SAQP:

- Department of Defence, May 2019, *RAAF Base Learmonth PFAS Management Area Plan*, Revision 4.
- Department of Defence, May 2019, *RAAF Base Learmonth PFAS Ongoing Monitoring Plan*.
- GHD, December 2018, *RAAF Base Learmonth – PFAS Investigations – Preliminary and Detailed Site Investigation Report*.
- GHD, April 2019, *RAAF Base Learmonth – PFAS Investigations – Ecological Risk Assessment (ERA)*.
- Cardno, April 2020, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Base Learmonth*
- Cardno, May 2020, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*
- Cardno, December 2020, *PFAS OMP 2020 post-summer Biannual Monitoring Event RAAF Base Learmonth*.

> Cardno, February 2021, *PFAS OMP 2020 post-winter Biannual Monitoring Event RAAF Base Learmonth*
> Cardno, April 2021, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*
> Cardno, June 2021, *PFAS OMP 2020 Annual Interpretive Report – RAAF Base Learmonth*
> Cardno, August 2021, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
> Cardno, April 2022, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
> Cardno, September 2022, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*
> Cardno, October 2022, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
> Cardno, January 2023, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
> Cardno, April 2023, PFAS OMP *2021 Annual Interpretive Report – RAAF Base Learmonth*
> Cardno, September 2023, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*

## 1.4 Relevant Guidelines

This SAQP has been prepared in general accordance with the WA *Contaminated Sites Act 2003* (CS Act), applicable industry standards and guidelines relevant to an assessment of this type, and has been formulated in reference to the following:

> National Environment Protection Council (NEPC), 1999, *National Environmental Protection (Assessment of Site Contamination) Measure (as amended 2013)* (ASC NEPM).

> Heads of Environmental Protection Authority's Australia and New Zealand (HEPA), January 2020, *PFAS National Environmental Management Plan (NEMP) 2.0*.

> Australian Standard AS 4482-2005 *Guide to the investigation and sampling of sites with potentially contaminated soils, Part 1 - Non-volatile and semi-volatile compounds*.

> Standards Australia 1998. AS/NZ 5667:1998 *Water quality – sampling*.

> Australian and New Zealand Guidelines, 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*

> Department of Defence, 2021, *Defence Contamination Management Manual* (DCMM) *Annex L Data Management*.

> U.S. Environmental Protection Agency (EPA), 2000, *Guidance for the Data Quality Objectives Process (EPA QA/G-4)*.

> USEPA, 2002, *Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8).*

> Department of Water and Environmental and Regulation (DWER), 2021, *Assessment and Management of Contaminated Sites*[1].

> National Health and Medical Research Council (NHMRC), August 2019, *Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water*.

[1] It is noted that Site is located on Commonwealth Land and is regulated under the Commonwealth environmental legislation, the State based DWER guidelines are relevant for the sampling of off-Site waterways.

# 2 Site Setting

## 2.1 Site Description

For the purposes of this SAQP report, “the site” was defined as comprising RAAF Base Learmonth. A detailed description of the site is provided in GHD’s DSI Report (GHD, 2018). The site location is presented on Figure 1, Appendix A.

RAAF Base Learmonth is located approximately 30 km South of Exmouth and covers an area of 2,550 hectares (ha).

The buildings and associated infrastructure and support services include:

> Runway, taxi way and aprons
> Aircraft hangers
> Civilian Airport terminal
> Maintenance and workshop areas
> General administration
> Domestic housing
> Fuel farm (former and current)
> Sewage treatment ponds
> Base water bore-field
> There are also a number of underground storage tanks (USTs) and septic tanks across the site.

Key site identification details are presented in Table 2-1.

**Table 2-1 Site Identification Details**

| Details | Description |
|---|---|
| **Site Address** | Minilya-Exmouth Road, Learmonth, WA 6707 |
| **Land Description** | RAAF Base Learmonth |
| **Owner** | Commonwealth of Australia |
| **Planning Zone / Land use** | Public Purposes – Commonwealth Government |
| **Local Government Authority (LGA)** | Shire of Exmouth |

## 2.2 Surrounding Land Uses and Zoning

The surrounding land uses are outlined in Table 2-2.

**Table 2-2 Surrounding Land Uses**

| Direction | Land Use |
|---|---|
| **North** | Kailis Hatchery, Potshot Memorial and pastoral land |
| **West** | Cape Range National Park and pastoral land |
| **East** | Pastoral land (Exmouth Gulf Station); Exmouth Gulf further east used for commercial prawn fishing, WAPET Creek, Solar Observatory, Bureau of Meteorology. |
| **South** | Various landfills, base supply bore-field and pastoral land |

## 2.3 Environmental Setting

Key details defining the site are presented in Table 2-3.

**Table 2-3 Key Site Details**

| Setting | Description |
|---|---|
| **Climate** | The region has a hot, semi-arid climate, with a wet and dry season. The maximum temperatures range between 37.9ºC (January) and 24.2ºC (July) while minimum temperatures range between 11.4ºC (July) and 24.7ºC (February).<br>Rainfall occurs generally between January and July with monsoonal showers between January and Late April. August to December is generally dry. The highest volume of rainfall typically occurs during the month of June with a mean monthly rainfall amount of 43.5 mm. |
| **Topography** | The site is located on a coastal plain and is generally flat. The elevation on site ranges between 0 and 20 metres relative to the Australian Height Datum (m AHD).<br>To the west of site, the elevation at the coastal ranges are 220 m AHD. |
| **Acid Sulfate Soil** | A review of the Acid Sulfate Soils (ASS) risk mapping, available on the WA Atlas online database indicates the following:<br>▪ to the north of the site is classified as having a moderate to low risk of ASS occurring within the top 3m of natural soil but high to moderate risk of ASS beyond 3m of natural soil surface<br>▪ the salt pan to the east is classified as having a high to moderate risk of ASS occurring in the top 3m of natural soil. |
| **Hydrology** | The Exmouth Gulf is located approximately 600 m east of the site at its closest point. The site is also crossed west to east by three ephemeral creeks.<br>RAAF Base Learmonth contains a number of constructed drains that direct surface water towards drainage channels that discharge into WAPET Creek (Central and Southern channels) or Exmouth gulf (northern channel). It was considered likely that the water flow in these drains is limited to high rainfall event. The northern channel was noted by GHD to be inundated with seawater during high tide from the coast to the boundary of Base.<br>WAPET creek is located to the east of the site and is lined with mangroves. Water flows tidally in and out of the creek and low-lying areas around the creek are periodically inundated.<br>▪ The northern drainage channel discharges directly to the Exmouth Gulf. It is a constructed drain onsite but links to a wide natural channel offsite that cuts through the coastal dunes.<br>▪ The central drainage channel discharges into the northern reach of WAPET Creek. It is a straight constructed channel for its entire length.<br>▪ The southern drainage channel discharges into the southern reach of WAPET Creek. It is a constructed drain onsite but links to a natural channel offsite that meanders across low lying salt pan topography. |
| **Geology** | **Regional Geology**<br>The site is underlain by quaternary age alluvial, aeolian and littoral sediments superimposed on the coastal plain (Geological Survey of Western Australia 1980).<br>Further inland are Quaternary alluvium and colluvium deposits that have been derived from erosion of the Cape Ranges. The deposits include clays, silts, sands and gravels. The Cape Range forms the highlands to the west of the site and are composed of Tertiary aged Cape Range limestone units.<br>The coastal areas are fringed by Holocene aged beach and sand dunes consisting of quartz and calcarenite sands. An older Quaternary dune unit is located to the south of RAAF Base Learmonth and dune forms are visible. Intertidal flats and mangrove swamps occur immediately west of the coastal sands and are associated with estuarine creeks.<br>**Site Specific Geology**<br>The findings of intrusive investigative works at RAAF Base Learmonth, undertaken by GHD between January and June 2018, were broadly consistent with the regional geology described above.<br>▪ To the west of RAAF Base Learmonth - the geology encountered comprised of colluvium, sands and sandy clay underlain by limestone rock layer<br>▪ On RAAF Base Learmonth – generally sands and clays were observed at the surface, underlain by colluvium/alluvium, gravels and sands and then weathered limestone rock<br>Salt pan area to the east of the site – generally sands and clays were observed at the surface, underlain by alluvium/colluvium and then shallow limestone rock. Outcrops of limestone displaying fossilised coral were observed along the southern reach of WAPET Creek. |

| Setting | Description |
|---|---|
| **Hydrogeology** | ▪ **Groundwater Occurrence** – The Quaternary and Tertiary geology units are hydraulically connected and form a major, unconfined aquifer.<br>Groundwater in the Quaternary units is considered to be perched and discontinuous. The superficial Quaternary layers (dunes, colluvium, alluvium) are considered to be no more than 20 m in thickness. Coastal dunes may also contain relatively fresh groundwater but of limited extent (lenses). This has not been assessed.<br>The main regional aquifer occurs predominantly within the Tulki Limestone (within permeable beds and the karst system) on the flanks of the range and the Mandu Limestone (within joints and minor permeable beds) on the crest of the range. These units extend to depths of greater than 150 m.<br>▪ **Depth to Groundwater** –depth to groundwater has been recorded ranging from approximately 0.8 m below ground level (mbgl) to approximately 8 mbgl during the OMP. The DSI (GHD, 2018) noted that depth to water increased toward the west whereby the deepest groundwater SWLs were encountered at the foothills of the Cape Range in the production bore-field. Groundwater in the low-lying area near WAPET Creek is within 1.5 m of the surface and so is likely to interact with surface salt deposits.<br>▪ **Groundwater Flow Direction** – The local groundwater flow pattern at RAAF Base Learmonth was observed to be following the regional flow regime; that is, flowing toward the east. The calculated hydraulic gradient of groundwater across the Base was low and in the order of 0.0003 to 0.0005 m/m (GHD, 2018).<br>The groundwater flow direction and hydraulic gradients greatly restricts the flow of contaminated groundwater from the site to WAPET Creek or Exmouth Gulf. Instead, groundwater from the Base tends to flow towards an area of groundwater depression with elevated salinity that lies between the site and the coast, with there being very little net flow to surface waters further to the east.<br>▪ **Salinity** – OMP observations noted groundwater was generally brackish to saline in the western wells, and becoming more saline closer to the coast.<br>The DSI (GHD, 2018) identified the water was fresher in the shallow groundwater aquifer, likely due to rain infiltration. The salinity distribution in the inferred discharge area to the east of the Base is likely to have significant influence on PFAS migration and discharge. Groundwater flow towards the east is restricted by the preferential groundwater recharge zone through the coastal dunes.<br>**Groundwater Use** – The DWER groundwater database found no registered abstraction bores were identified within a 1.0 km radius of the Base.<br>The Base is downgradient from the nearest potable water supply which is sourced from a series of wells near the base of Cape Range, 3 km to the west of the Base. |
| **Environmental Sensitive Areas** | The site is located in close proximity to the Cape Range National Park and Ningaloo Reef to the east.<br>– No Threated Ecological Communities (TECs) with national environmental significance, were identified in the EPBC Act Protected Matters Report generated on November 2, 2017.<br>– Five priority flora species and 36 threatened or priority fauna species are known or expected to be present within 10 km of RAAF Base Learmonth.<br>– The mangrove wetlands are not listed on the Ramsar Convention on Wetlands of International Importance. It does however constitute a sensitive receptor. |
| *Further information can be found in the Consolidated DSI report (GHD, 2018). Information collected as part of the OMP is consistent with that presented in the DSI.* | |

## 2.4 Conceptual Site Model

The site has been subject of previous PFAS investigations, including:

> A combined Preliminary Site Investigation and Detailed Site Investigation (GHD, 2018)

> An Ecological Risk Assessment (GHD 2019)

**Source Areas**

There are DSI monitoring areas where PFAS was detected in soil or groundwater at concentrations exceeding the adopted assessment levels. These are considered to be the most impacted areas and include (refer to Figure 2, Appendix A):

> 1A – Maintenance Area (Source Area)
> 2A and 2B– Former and current Fuel Farm (Source Area)
> 1D – Southern Drainage Channel (Pathway)
> 1E – Central Drainage Channel (Pathway)
> 2C – Northern Drainage Channel (Pathway)
> 1G – WAPET Creek northern reach (Receptor)

The results of the DSI (GHD, 2018) indicate that the two main PFAS source areas were the Fuel Farm and the Maintenance Area. PFAS were found to be present in all environmental media tested (soils, groundwater, sediments, and surface water where present) in these source areas. PFAS were also detected at lower concentrations at a number of other locations across the Base.

The potentially complete Source-Pathway-Receptor (S-P-R) linkages and associated risks for human health and ecological receptors are summarised in Table 2-4.

**Table 2-4 Conceptual Site Model S-P-R Linkages**

| Source | Pathway | Receptor | DSI/ERA (GHD, 2018) Commentary / Risk Assessment |
|---|---|---|---|
| **Human Health** | | | |
| **Soil contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Ingestion / dermal contact / inhalation | ▪ Site users and site workers | No exceedance of the health investigation levels (HILs) was recorded at the fuel farm. Only limited exceedances of the residential HIL were recorded at the maintenance area and the primary use of the site is industrial.<br>The risk to site workers and users is considered negligible as the opportunity for ingestion, inhalation or dermal contact is manageable.<br>**Negligible Risk** |
| **Groundwater contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Ingestion / dermal contact with groundwater | ▪ Site workers during excavation works | Exceedances of the HILs for both potable and non-potable use were recorded. Groundwater is not abstracted in these areas for any use. Due to groundwater flow direction and low hydraulic gradient it is unlikely groundwater from beneath the source areas is discharging to recreational areas.<br>**Negligible Risk** |
| | ▪ Bioconcentration and biomagnification in the food chain | ▪ Consumers of impacted aquatic organisms / produce | No sampling of edible produce/biota has been completed at the site. However, based on results from HEH-B the risk is considered negligible.<br>**Negligible Risk** |
| **Sediment contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Ingestion / dermal contact / inhalation | ▪ Site users and site workers | No exceedance of the HILs was recorded. The opportunity for ingestion, inhalation or dermal contact is low and manageable as sediments are confined to drains where access is limited.<br>**Low Risk**. |
| **Surface water contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Ingestion / dermal contact | ▪ Site users and site workers | No exceedance of the HILs was recorded. Water is ephemeral and not likely to be sourced for consumption. The opportunity for exposure is low and manageable.<br>**Negligible Risk** |
| **Ecological** | | | |
| **Soil contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Leaching (from soil to groundwater | ▪ Underlying aquifer | Deeper aquifer (limestone) was not directly assessed but groundwater at 20 m was impacted, so it is likely the deeper limestone will be impacted. |
| | ▪ Soil ingestion/Dermal contact<br>▪ Plant uptake | ▪ Fauna | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited.<br>**Low Risk** |
| **Groundwater contamination (PFAS)** | ▪ Lateral migration with groundwater flow | ▪ Exmouth Gulf | Groundwater may not discharge to sensitive ecosystems due to groundwater flow directions and low hydraulic gradients. |

| Source | Pathway | Receptor | DSI/ERA (GHD, 2018) Commentary / Risk Assessment |
| --- | --- | --- | --- |
| ▪ Fuel Farm<br>▪ Maintenance Area | ▪ Lateral migration followed by bioconcentration and biomagnification in the food chain | ▪ Marine ecosystem | Potential PFAS mass in groundwater is low.<br>**Low Risk**<br>Ongoing monitoring of groundwater, surface water, pore water, and sediment PFAS concentrations is recommended to confirm this level of risk. |
| **Surface water contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Dermal contact or ingestion/uptake of surface water | ▪ Flora and Fauna | Potential for uptake and accumulation in plants and animals however, water is ephemeral and therefore only periodically available for animal consumption.<br>Surface water from the site can discharge eventually into WAPET Creek via the Central Drainage Channel. However, this is likely to occur in high rain events and result in significant dilution. Sampling results indicated only very low levels of PFAS in WAPET Creek.<br>**Low Risk** |
| | ▪ bioconcentration and biomagnification in the food chain | ▪ Marine Flora and Fauna | |
| **Sediment contamination (PFAS)**<br>▪ Fuel Farm<br>▪ Maintenance Area | ▪ Dermal contact or ingestion | ▪ Fauna | Potential for uptake from soils and accumulation in predatory animals consuming soil-dwelling animals or plants. However the area is industrial, fenced off with significant hardstand and no natural, undisturbed ecosystems making exposure limited.<br>**Low Risk** |

# 3 Data Quality Objectives

Development of data quality objectives (DQOs) for the OMP SAQP is based on guidance presented in the ASC NEPM (NEPC 2013) and are consistent with *RAAF Base Learmonth PFAS Investigation PFAS Ongoing Monitoring Plan* (Defence, 2019). The DQO process comprises the following seven steps:

> Step 1: State the problem
> Step 2: Identify the decision/principal study question(s)
> Step 3: Identify the Inputs into the Decision
> Step 4: Study Boundaries
> Step 5: Decision rules
> Step 6: Tolerable limits on decision errors
> Step 7: Optimisation of the data collection process

The DQOs are detailed in Table 3-1.

**Table 3-1 Data Quality Objectives**

| Data Quality Step | Description |
|---|---|
| **State the Problem** | The DSI (GHD, 2018) identified PFAS in groundwater, surface water and sediment within the Management Area at concentrations exceeding the relevant assessment levels. The primary mechanisms by which PFAS has migrated off-Site are considered to be via surface drains, notably the Central Drainage Channel which discharges directly into WAPET Creek.<br>The ERA (GHD, 2019) identified one exposure risk associated with foraging seabirds from the consumption of impacted biota in the northern reach of WAPET Creek. Current data for the majority of sampling locations is limited to one or two sampling events. Whilst the findings of the ERA (GHD, 2019) recognised that an adverse ecological impact is unlikely, a robust dataset is required to assess trends in the nature, extent and magnitude of PFAS concentrations within sediment, surface water, seepage water and groundwater.<br>**Groundwater**<br>▪ Groundwater was found to be contaminated with PFAS, with the highest concentrations identified in the two main source areas, with relatively low concentrations elsewhere.<br>▪ PFAS concentrations varied both vertically within the groundwater profile and laterally across the site. Generally, the concentrations reduced with depth and distance from contamination source areas.<br>▪ Concentrations of PFAS in groundwater on the Base and in the vicinity of the Base exceed the guidelines for drinking water in the fuel farm, the maintenance area, MW117 (Base Landfill), STP, MW124 (Salt pan area), MW138 (Central Drainage Channel), MW172 (Former Aircraft Parking Area South), MW183 (UST at Former Powerhouse) and MW108 (UST/AST at ALER 36). In these areas the groundwater is saline and is not potable, and groundwater is not used for potable purposes.<br>▪ Traces of PFAS have been identified in potable wells to the west of RAAF Base Learmonth; however, the concentrations do not exceed the drinking water guideline.<br>▪ The groundwater flow direction and hydraulic gradients greatly restricts the flow of contaminated groundwater from the Base to WAPET Creek or Exmouth Gulf. Traces of PFAS have been detected in shallow seepage water along shorelines; this contamination is most likely to have resulted from localised infiltration of contaminated surface water rather than groundwater migrating from the Base. It was concluded that groundwater contamination present at the Base poses a low risk to the aquatic ecosystems of surface waters (WAPET Creek and the Gulf).<br>**Surface Water**<br>▪ Concentrations of PFAS in surface water exceed the recreational water guideline in drains off-site at SW171 and in the Maintenance Area (SW122).<br>▪ Groundwater may discharge to a surface water body where recreational activities occur such as swimming. However, the groundwater flow direction and hydraulic gradients greatly restrict the rate of flow and the discharge to WAPET Creek or Exmouth Gulf. Measured concentrations in surface water bodies are below relevant guideline. |

<table>
<tr><th>Data Quality Step</th><th>Description</th></tr>
<tr><td></td><td>
<ul>
<li>Waters of the WAPET Creek southern reach are regularly flushed by the tides and PFAS was not detected in samples of surface water and biota.</li>
<li>Waters of the northern reach are irregularly flushed by the tides, and PFAS was detected in samples of surface water and crabs. The concentrations of PFAS in crabs were low and do not pose a risk to humans consuming crustaceans from the northern reach of WAPET Creek.</li>
<li>Trace concentrations of PFAS were detected in water seeping from the coast line and discharging to Exmouth Gulf. PFAS were not detected in fish and crabs in the Gulf waters.</li>
</ul>
Soil and Sediment
<ul>
<li>PFAS contamination in the Maintenance Area exceeded the human health screening level protective of residential land-use however, the soil collected in residential backyards were below guidelines.</li>
<li>In several locations (the Maintenance Area, Fuel Farm, BH209 (Grid sample onsite) and BH329 (UST at Former Powerhouse) there were exceedances of the screening criterion for Interim Ecological Indirect Exposure Commercial/Industrial.</li>
<li>Contaminated soil and sediment can be mobilised and flow along surface drains offsite to WAPET Creek and Exmouth Gulf; however, such migration will be generally limited to larger rainfall events and flooding and will be subject to significant dilution</li>
</ul>
A robust dataset is required to assess trends in the nature, extent and magnitude of PFAS concentrations within sediment, surface water and groundwater to validate/improve the understanding of the CSM in relation to spatial and temporal variability of PFAS concentrations within the Management Area and associated receptors.
</td></tr>
<tr><td>Identify the decision/principal study question(s)</td><td>
This OMP is to provide further data to assess the following principal study questions:
<ul>
<li>What are the changes and trends in the nature, extent and magnitude of PFAS concentrations in the groundwater, surface water and sediment within the Management Area?</li>
<li>Has the nature, extent and magnitude of PFAS concentrations changed significantly to warrant a revision of the ERA?</li>
<li>Has the nature, extent and magnitude of PFAS concentrations changed significantly to warrant refinement of any existing management measures?</li>
<li>Has the nature, extent and magnitude of PFAS concentrations changed significantly or are they likely to change?</li>
</ul>
</td></tr>
<tr><td>Identify the Inputs into the Decision</td><td>
The following inputs are required to resolve the principal study questions outlined in Step 2:
<ul>
<li>PFAS concentrations in groundwater, surface water and sediment from previous and future monitoring events.</li>
<li>Field data (i.e. groundwater levels, physico-chemical parameters) on groundwater and surface water from previous and future monitoring events.</li>
<li>An appropriate statistical evaluation of the data (e.g. using Mann-Kendall or similar analysis) including short and long term trends, in particular for surface water and groundwater concentrations.</li>
<li>Comparison of data sets to relevant endorsed assessment levels (refer to Section 4.2.4).</li>
</ul>
</td></tr>
<tr><td>Study Boundaries</td><td>
Ongoing monitoring will be undertaken within the boundaries of the Management Area (Figure 2, Appendix A) at the groundwater, surface water and sediment monitoring locations outlined in Section 4.1.<br>
Monitoring will be undertaken every six months, with one monitoring event in November and June.<br>
An additional surface water and sediment monitoring event will take place following the first flush immediately (or as close as possible) following the first heavy rainfall event of the wet season. Section 4.2 provides further detail on the monitoring frequency.
</td></tr>
<tr><td>Develop a Decision Rule</td><td>
<ul>
<li>The analytical and field data will be used to assess changes to the nature, extent and magnitude of PFAS in surface water, sediment and groundwater and to provide supporting data for assessment of management actions, where relevant.</li>
<li>Trends in PFAS concentrations, including an assessment of temporal and spatial changes, will be assessed using an appropriate statistical analysis approach (e.g. using Mann- Kendall, GWSdat or similar analysis), with a specified level of confidence based upon the number of monitoring rounds completed.</li>
</ul>
</td></tr>
</table>

| Data Quality Step | Description |
|---|---|
| | ▪ The analytical data will be compared to the relevant assessment levels (presented in Section 4.2.4) and/or historic concentrations (i.e. maximum concentration) recorded during prior monitoring rounds [i.e. during the DSI (GHD, 2018)] to evaluate changes in the risk profile and whether revision of the OMP, ERA or implemented management measures is warranted.<br>Where exceedances of adopted assessment criteria levels (presented in Section 4.2.4) or new detections are reported, further interrogation of data will be undertaken to the extent relevant to assess the risk profile and location. A summary of the key decision rules are detailed below:<br>1. Have the analytical data collected as part of the monitoring program met the DQI (refer Table 3-2.below)? If yes, then the data can be used to answer the decision rule below and the decision statements developed in Step 2. If no, then an assessment of the need to collect additional data will be required.<br>2. Do PFAS concentrations exceed the investigation criteria? If no, then the contamination would be considered not to pose an unacceptable risk. Where results exceed the adopted investigation criteria, this may not necessarily indicate an unacceptable level of risk. Further risk assessment, and potentially additional investigations, will be required to determine the potential for unacceptable impacts.<br>3. Has PFAS been detected in any of the off-site bores previously not detected? If yes, do PFAS concentrations reported indicate an increasing trend and/or exceed historic maximum concentrations? Do results indicate a potential risk to associated receptors including associated risks that PFAS may present towards human receptors (i.e. consumers of abstracted water). Further risk assessment, and potentially additional investigations, will be required to determine the potential for unacceptable impacts.<br>4. Has PFAS been detected in onsite drainage channels and offsite surface water bodies within the management areas? If yes, do PFAS concentrations reported indicate an increasing trend or exceed historic maximum concentrations? Do results indicate a potential risk to receptors and changes to the risk profile? Further risk assessment, and potentially additional investigations, will be required to determine the potential for unacceptable impacts.<br>The Ongoing Monitoring Interpretive Report will review the results obtained against these triggers/decisions and the management response triggers and contingencies detailed in the OMP (Section 4.3). |
| **Specify Limits on Decision Error** | The potential for significant decision errors will be minimised by completing a robust QA/QC program in accordance with DWER and NEPM guideline requirements. Standard operating procedures will be closely followed in the field to ensure accurate and representative data acquisition. DQIs will be applied to assess usability of data prior to making decisions, based on precision, accuracy, representativeness, comparability and completeness. The acceptable limit on decision error is 95% compliance with the applied DQIs (see Table 3-2). If any of the DQIs are not met, further assessment will be necessary to evaluate the significance of the non- conformance and any corrective actions. |
| **Optimise the Design for Obtaining the Data** | The design of the OMP has been made in consideration of historical activities at the site, historical investigations (and findings i.e. DSI and ERA), in the context of developing responses to the principal study questions outlined in Step 2 and to meet the DQOs ensuring that a representation of the current site condition can be achieved.<br>The OMP scope is outlined in Section 6, the available data is reviewed annually and evaluated to determine if the frequency of monitoring should increase or decrease to provide better understanding of PFAS concentration fluctuations and potential risks to receptors.<br>As additional information is gathered during the course of this monitoring program, it may be beneficial for the proposed scope of works to be altered from the initial design. Changes to the proposed monitoring, if considered necessary, will be made based on risk profile reviews and updated CSM and in consultation with Defence.<br>Other factors that will optimise the design for obtaining data will include the use of laboratories that are NATA accredited for PFAS analysis and ensure laboratory LORs are suitable to meet the relevant adopted assessment levels (where possible), experienced field scientist(s), robust field and laboratory quality assurance/quality control protocols are adopted and Field and analytical data are collected in accordance with the PFAS NEMP (HEPA 2020), ASC NEPM (NEPC 2013) and the assessment of contaminated sites (DER 2014). |

An assessment of the Data Quality Indicators (DQIs) relating to both field and laboratory procedures will be undertaken with appropriate documentation provided for each environmental element or media assessed. The DQIs adopted for the DSI are summarised in Table 3-2.

**Table 3-2 Data Quality Indicators**

<table>
<tr><th>Data Quality Indicator</th><th>Detail</th></tr>
<tr><td>QA Documentation</td><td>Provision of appropriate work plans, DQI and DQO defined for the site and all QA/QC aspects documented.</td></tr>
<tr><td>Bias</td><td>A measure of the potential distortion in an analysis which can result in errors in one direction (e.g. one laboratory consistently higher results or consistent poor spiked matrix recovery).<br>Bias will be assessed with reference to the analysis of spiked matrix samples (NEPC 1999b).</td></tr>
<tr><td>Representativeness</td><td>A qualitative measure of the confidence that data is representative of each medium present on the site. Use of appropriate and documented sampling methods, sampling handling, preservation and transport and holding times.</td></tr>
<tr><td>Precision:</td><td>A quantitative measure of data variability or reproducibility, measured by the calculation of %RPD values for duplicate samples (i.e. measure of agreement).<br>Precision in DQI is considered an important assessment in an environmental study (USEPA, 2002, Guidance on Environmental Data Verification and Data Validation). It can be measured as follows:<br>▪ Percentage of the mean of the measurement such as Relative Percent Difference (i.e. %RPD). The %RPD will be calculated for the field and secondary duplicate (i.e. inter and intra-laboratory analysis); and<br>▪ Use of similar analytical method and instrument (e.g. for inter-laboratory assessment).<br>The %RPD will be considered as acceptable if the values are:
<table>
<tr><th>Magnitude of result</th><th>Acceptable RPD range</th></tr>
<tr><td><10 x limit of reporting (LOR)</td><td>No limits</td></tr>
<tr><td>10 – 20 x LOR</td><td>0% - 50%</td></tr>
<tr><td>>20 x LOR</td><td>0% - 20%</td></tr>
</table>
▪ Should there be a result that is greater than acceptable RPD range, then a “review should be conducted of the cause (e.g. instrument calibration, appropriateness of method used)” (NEPC, 2013).<br>For the purpose of this OMP SAQP, field and secondary duplicates should be collected at a rate of 1 in 10 samples (HEPA 2020 and GHD, 2018).</td></tr>
<tr><td>Accuracy</td><td>A quantitative measure of the closeness of data to a ‘true value’, measured by the analysis of spike, blank and laboratory control samples (LCS). The LCS consists of a standard reference material or a matrix of known concentration.<br>For the purpose of assessing accuracy, it is required that at least one LCS for each process batch be analysed (NEPC, 2013).</td></tr>
<tr><td>Comparability</td><td>A qualitative measure of the confidence that data may be considered to be equivalent for each sampling and analytical event. By use of standard procedures, comparable methods, qualified personnel and review of sample integrity.</td></tr>
<tr><td>Completeness</td><td>A measure of the amount of usable data (expressed as a percentage - %) from a data collection activity, based on completeness of test program, overall QA/QC completeness and validity of data set.</td></tr>
</table>

# 4 Sampling Locations, Rationale and Methodology

## 4.1 Monitoring Locations and Sampling Schedule

### 4.1.1 Monitoring Frequency

All monitoring locations will be sampled every six months. The main sampling events will be undertaken in November and June to record the concentration and extent of PFAS and determine any seasonal fluctuations or trends. This monitoring frequency aligns with the climate of the Management Area, which features the highest volume of rainfall typically between January and July and lower rainfall between September and December.

An additional monitoring event for surface water and sediment will be conducted immediately (or as close as possible) following the first heavy rainfall event of the wet season. This would serve to assess the potential increase in PFAS surface water concentrations following ‘first flush’ rainfall and subsequent timeframe for attenuation to ‘long-term average’ concentrations.

### 4.1.2 Groundwater and Seepage water Monitoring Locations

The groundwater monitoring locations as part of the OMP monitoring are presented in Table 4-1, along with the rationale for the selection, and are shown on Figure 3, Appendix A. For the multilevel monitoring wells, only the shallowest-non-dry screened intervals will be sampled.

Groundwater sampling, particularly those near WAPET Creek and Exmouth Gulf, must consider tidal periods to ensure spurious elevation data is not used to assess groundwater flow. Given the remoteness of the site, one-off opportunistic sampling is not considered feasible. Seepage water sampling will occur at low, outgoing tides which is considered the optimal condition for groundwater discharge.

Seepage water sample locations were chosen to assess the inferred groundwater discharge zone along the coast and are shown on Figure 3. They include locations near the mouth of WAPET Creek, the Northern Drainage Channel, a low point in the dunes near the southern reach and other locations along the coast.

**Table 4-1 Groundwater and Seepage water Monitoring Locations**

| Area | Monitoring Well / Bore ID | Rationale |
|---|---|---|
| Source Areas | **Source 1 – Maintenance Area -** MW018, MW021, MW112, MW113, MW114, MW115, MW162, MW163, MW164, MW165, MW166, MW167, MW168, MW211, MW233.<br>**Source 2 – Fuel Farm** – MW105, 0960_MW148D, MW148S, MW151, MW159, MW238. | Confirmation of overall PFAS impact identified in the DSI (GHD, 2018). Assessment of overall changes in PFAS concentration in the source areas to provide temporal data on depletion of the source zone. |
| Pathway | MW102, MW103, MW104, MW122, MW124, MW126, MW127, MW134, MW135, MW138, MW139, MW140, MW143, MW144, MW145, MW146, MW147, MW170, MW172, MW175, MW180, MW181. | Confirmation of overall PFAS impact identified in the DSI (GHD, 2018). Assessment of changes in PFAS concentration and distribution in the main migration pathways. This will also allow for early detection of significant changes in migration so contingencies can be put in place. |
| Receptor | MW137, MW141, MW176, MW177, MW178, MW179. | Confirmation of overall PFAS impact identified in the DSI (GHD, 2018). Assessment of changes in PFAS concentration and distribution in the main aquatic receptors. |
| Seepage | OTH103, OTH106, OTH107, OTH129, OTH132, OTH134. | To assess the inferred groundwater discharge zone along the coast. |

Construction details for the groundwater wells monitored as part of the OMP are provided in Table 4-2.

### Table 4-2 OMP Groundwater Monitoring Wells Construction Details

| Well ID | Date drilled | Easting[1] | Northing[1] | RL TOC (mAHD) | Depth (mbgl) | Screen interval (mbgl) |
|---|---|---|---|---|---|---|
| MW018 | 2006 | 199251.86 | 7537465.65 | 6.403 | 8.5 | 5.5-8.5 |
| MW021 | 2006 | 199143.14 | 7537433.45 | 6.745 | 8.6 | 5.6-8.6 |
| MW102 | 2018 | 200487.728 | 7538870.392 | 4.6266 | 8.5 | 2.5-8.5 |
| MW103 | 2018 | 199762.727 | 7540965.102 | 2.2785 | 5.8 | 1.0-5.8 |
| MW104 | 2018 | 199946.08 | 7540599.855 | 2.7256 | 6.5 | 1.0-6.5 |
| MW105 | 2018 | 199491.679 | 7540303.158 | 3.7272 | 8.0 | 2.0-8.0 |
| MW112 | 2018 | 199473.4723 | 7537651.252 | 5.1191 | 8.0 | 3.0-8.0 |
| MW113 | 2018 | 199156.14 | 7537686.096 | 7.3165 | 10.0 | 4.0-10.0 |
| MW114 | 2018 | 199037.9871 | 7537512.217 | 7.7467 | 10.0 | 4.0-10.0 |
| MW115 | 2018 | 199604.327 | 7537522.607 | 4.9133 | 8.0 | 3.0-8.0 |
| MW122 | 2018 | 200580.746 | 7537635.452 | 3.9702 | 7.7 | 1.7-7.7 |
| MW124 | 2018 | 200525.625 | 7539636.566 | 2.9183 | 6.0 | 1.0-6.0 |
| MW126 | 2018 | 200301.728 | 7536952.205 | 4.5088 | 8.0 | 2.0-8.0 |
| MW127 | 2018 | 200158.599 | 7536314.042 | 5.6238 | 8.5 | 2.5-8.5 |
| MW134 | 2018 | 200439.185 | 7540598.585 | 2.5155 | 5.7 | 1.0-5.7 |
| MW135 | 2018 | 200867.402 | 7540438.161 | 2.7781 | 3.0 | 2.5-3.0 |
| | | | | 2.7828 | 5.0 | 4.5-5.0 |
| | | | | 2.7858 | 7.0 | 6.5-7.0 |
| | | | | 2.7884 | 9.5 | 9.0-9.5 |
| MW137 | 2018 | 201611.362 | 7539047.314 | 2.1687 | 1.3 | 0.8-1.3 |
| | | | | 2.1691 | 3.0 | 2.5-3.0 |
| | | | | 2.2017 | 5.0 | 4.5-5.0 |
| | | | | 2.2034 | 7.0 | 6.5-7.0 |
| MW138 | 2018 | 200820.406 | 7538649.357 | 3.3074 | 3.5 | 3.0-3.5 |
| | | | | 3.3166 | 5.5 | 5.0-5.5 |
| | | | | 3.3205 | 7.5 | 7.0-7.5 |
| | | | | 3.3224 | 9.5 | 9.0-9.5 |
| MW139 | 2018 | 201088.954 | 7536832.655 | 4.1386 | 7.0 | 2.0-7.0 |
| MW140 | 2018 | 202004.879 | 7537028.632 | 2.4916 | 2.0 | 1.5-2.0 |
| | | | | 2.5035 | 4.0 | 3.5-4.0 |
| | | | | 2.5081 | 6.5 | 6.0-6.5 |
| | | | | 2.5345 | 9.0 | 8.5-9.0 |
| MW141 | 2018 | 202555.223 | 7537320.681 | 2.7999 | 2.0 | 1.5-2.0 |
| | | | | 2.8073 | 3.5 | 3.0-3.5 |
| | | | | 2.8141 | 5.5 | 5.0-5.5 |
| | | | | 2.8224 | 7.5 | 7.0-7.5 |
| MW143 | 2018 | 200819.408 | 7539420.558 | 2.8174 | 3.5 | 3.0-3.5 |
| | | | | 2.8204 | 5.5 | 5.0-5.5 |
| | | | | 2.8221 | 7.5 | 7.0-7.5 |

| Well ID | Date drilled | Easting[1] | Northing[1] | RL TOC (mAHD) | Depth (mbgl) | Screen interval (mbgl) |
|---|---|---|---|---|---|---|
| | | | | 2.8273 | 9.5 | 9.0-9.5 |
| MW144 | 2018 | 200691.327 | 7540195.613 | 3.0481 | 3.5 | 3.0-3.5 |
| | | | | 3.052 | 5.5 | 5.0-5.5 |
| | | | | 3.0545 | 7.5 | 7.0-7.5 |
| | | | | 3.0573 | 9.5 | 9.0-9.5 |
| MW145 | 2018 | 201084.426 | 7538337.599 | 3.1416 | 3.5 | 3.0-3.5 |
| | | | | 3.1481 | 5.5 | 5.0-5.5 |
| | | | | 3.1506 | 7.5 | 7.0-7.5 |
| | | | | 3.1519 | 9.5 | 9.0-9.5 |
| MW146 | 2018 | 201126.901 | 7537691.759 | 2.7937 | 3.5 | 3.0-3.5 |
| | | | | 2.8009 | 5.5 | 5.0-5.5 |
| | | | | 2.802 | 7.5 | 7.0-7.5 |
| | | | | 2.8184 | 9.5 | 9.0-9.5 |
| MW147 | 2018 | 201259.369 | 7537322.231 | 2.9123 | 3.5 | 3.0-3.5 |
| | | | | 2.9152 | 5.5 | 5.0-5.5 |
| | | | | 2.9183 | 7.5 | 7.0-7.5 |
| | | | | 2.9209 | 9.5 | 9.0-9.5 |
| MW148D | 2018 | 199536.808 | 7540521.489 | 3.5778 | 20.0 | 14.0-20.0 |
| MW148S | 2018 | 199537.603 | 7540521.649 | 3.6851 | 8.0 | 2.0-8.0 |
| MW151 | 2018 | 199442.761 | 7540459.319 | 4.0631 | 8.0 | 2.0-8.0 |
| MW159 | 2018 | 199164.27 | 7540373.912 | 4.1895 | 9.0 | 3.0-9.0 |
| MW162 | 2018 | 199230.504 | 7537650.674 | 6.856 | 20.0 | 17.0-20.0 |
| MW163 | 2018 | 199232.4874 | 7537569.5756 | 6.7808 | 20.0 | 17.0-20.0 |
| MW164 | 2018 | 199251.946 | 7537546.874 | 6.7893 | 20.0 | 17.0-20.0 |
| MW165 | 2018 | 199312.5481 | 7537531.6778 | 6.1043 | 9.0 | 3.0-9.0 |
| MW166 | 2018 | 199363.212 | 7537610.565 | 5.7441 | 8.5 | 2.5-8.5 |
| MW167 | 2018 | 199368.445 | 7537673.832 | 6.2094 | 8.5 | 2.5-8.5 |
| MW168 | 2018 | 199390.678 | 7537754.41 | 6.1713 | 8.5 | 2.5-8.5 |
| MW170 | 2018 | 199828.672 | 7536509.856 | 5.639 | 8.5 | 2.5-8.5 |
| MW172 | 2018 | 199755.067 | 7536989.143 | 5.6193 | 8.5 | 2.5-8.5 |
| MW175 | 2018 | 201458.887 | 7540121.278 | 4.7916 | 4.5 | 4.0-4.5 |
| | | | | 4.7982 | 6.0 | 5.5-6.0 |
| | | | | 4.7995 | 7.5 | 7.0-7.5 |
| | | | | 4.8316 | 9.5 | 9.0-9.5 |
| MW176 | 2018 | 201711.745 | 7539606.488 | 2.1274 | 2.0 | 1.5-2.0 |
| | | | | 2.1279 | 4.0 | 3.5-4.0 |
| | | | | 2.1594 | 6.5 | 6.0-6.5 |
| | | | | 2.1712 | 9.0 | 8.5-9.0 |
| MW177 | 2018 | 202130.765 | 7539004.262 | 2.2299 | 2.0 | 1.5-2.0 |
| | | | | 2.2517 | 4.0 | 3.5-4.0 |

| Well ID | Date drilled | Easting[1] | Northing[1] | RL TOC (mAHD) | Depth (mbgl) | Screen interval (mbgl) |
|---|---|---|---|---|---|---|
| | | | | 2.2531 | 6.5 | 6.0-6.5 |
| | | | | 2.2718 | 9.0 | 8.5-9.0 |
| MW178 | 2018 | 201387.629 | 7539566.48 | 2.1612 | 2.5 | 2.0-2.5 |
| | | | | 2.1614 | 4.5 | 4.0-4.5 |
| | | | | 2.1726 | 7.5 | 7.0-7.5 |
| | | | | 2.1762 | 9.5 | 9.0-9.5 |
| MW179 | 2018 | 201939.471 | 7538448.239 | 2.222 | 1.5 | 1.0-1.5 |
| | | | | 2.2371 | 3.7 | 3.2-3.7 |
| | | | | 2.2653 | 6.4 | 5.9-6.4 |
| | | | | 2.2689 | 9 | 8.5-9.0 |
| MW180 | 2018 | 201567.932 | 7537913.284 | 1.9179 | 1.5 | 1.0-1.5 |
| | | | | 1.9226 | 4 | 3.5-4.0 |
| | | | | 1.9368 | 6.5 | 6.0-6.5 |
| | | | | 1.9458 | 9 | 8.5-9.0 |
| MW181 | 2018 | 201688.497 | 7537372.233 | 2.2333 | 2 | 1.5-2.0 |
| | | | | 2.2773 | 4 | 3.5-4.0 |
| | | | | 2.2789 | 6 | 5.5-6.0 |
| | | | | 2.3122 | 7.5 | 7.0-7.5 |
| MW211* | | 199199.771 | 7537549.138 | 6.3409 | | |
| MW233 | 2015 | 199198.57 | 7537590.67 | 6.262 | 7 | 4-7 |
| MW238 | 2006 | 199446.65 | 7540509.92 | 3.98 | 6 | 3.0 – 6.0 |

**Note:** * No bore log available

### 4.1.3 Surface water and Sediment Monitoring Locations

The surface water locations as part of the OMP monitoring are presented in Table 4-3 along with the rationale for the selection, and are highlighted on Figure 4, Appendix A. The location shown on Figure 4 are for guidance and actual locations will depend on conditions at the time of sampling. Priority will be given to areas where surface water has pooled and to low lying areas where sediment can accumulate.

**Table 4-3 OMP Surface water and Sediment Monitoring Locations**

| Area | Surface water Sampling Location ID | Sediment Sampling Location ID | Rationale |
|---|---|---|---|
| Drainage channels (source and pathway) | **Bi-annual and first flush events:**<br>SW108, SW113, SW114, SW121 SW122, SW123, SW124, SW125, SW157, SW166, SW168, SW170, SW174, SW176, SW189, SW190, SW192, SW193, SW198, SW199, SW200, SW219, SW227, SW231, SW234, SW235, SW243, SW265, SW277, SW278, SW279, SW288, SW291, SW292, SW293, SW298 | **Bi-annual and first flush events:**<br>SD199, SD200, SD219, SS108, SS113, SS114, SS121, SS122, SS123, SS124, SS125, SS157, SS166, SS168, SS170, SS174, SS176, SS189, SS190, SS192, SS193, SS227, SS231, SS234, SS235, SS243, SS265, SS277, SS278, SS279, SS288, SS291, SS292, SS293, SS298 | The monitoring will assess the PFAS extent and changes in the Central Drainage Channel leading to WAPET Creek. It will also confirm the low risk posed by sediment and surface water in other drainage channels.<br>Monitoring of these locations will provide an indication of any change in the nature or magnitude of PFAS in surface waters and sediments, and will help in determining changes attributable to seasonal fluctuations.<br>Priority will be given to areas where surface water has pooled and to low lying areas where sediment can accumulate. This includes surface water pooling on Base at the flood gate release point, which if present during wet season monitoring will be sampled. |
| WAPET CREEK (Receptor) | **Bi-annual and first flush events:**<br>SW001, SW205, SW207, SW208, SW209, SW210, SW211, SW300, SW301, SW302, SW303, SW304, SW305 | **Bi-annual and first flush events:**<br>SD205, SD207, SD208, SD209, SD210, SD211, SD300, SD301, SD302, SD303, SD304, SD305, SS301 | WAPET Creek is the most important receptor with respect to identified risk. Monitoring of these locations will provide an indication of any change in the nature or magnitude of PFAS in surface waters and sediments, and will help in determining changes attributable to seasonal fluctuations |

## 4.2 Sampling Methodology

### 4.2.1 Groundwater and Seepage water Sampling Methodology

Groundwater monitoring will be undertaken by no purge HydraSleeve® method for the single-level wells, while the multilevel wells will be sampled with a peristaltic pump and seepage water sampling will be conducted using the methodology that is consistent with the 2018 DSI, as detailed in Table 4-4.

**Table 4-4 Groundwater and Seepage water Monitoring – Sampling Method**

| Activity | Details |
|---|---|
| Well Gauging | Standing Water Level (SWL) will be gauged using an interface probe. All wells will be measured against a specified mark at the top of the well casing. |
| Groundwater Field Parameters | For the single level wells, the field parameters will be recorded via a water quality meter from HydraSleeves® or hand-bailed water.<br>For the multilevel wells, the field parameters will be recorded with a flow cell during purging.<br>The following field parameters will be recorded:<br>▪ pH.<br>▪ electrical conductivity (EC).<br>▪ oxidation reduction potential (ORP).<br>▪ Dissolved oxygen (DO).<br>▪ Temperature.<br>Once field parameters have stabilised (as indicated by at least three consecutive measurements falling within +/- 10% of each other), stabilised parameters' measurement will be recorded on field data records.<br>All field instruments (e.g. water quality meter) will be calibrated by the equipment supplier and daily readings of reference solutions (bump tests) completed to optimise the accuracy of the measurements taken. |
| Peristaltic pumping (multilevel well sample collection) | The shallowest (non-dry) wells will be sampled at each location using Teflon-free dedicated and disposable high-density polyethylene (HDPE) tubing coupled to a peristaltic pump system. The groundwater will be purged at a low flow rate of 0.2L/min.<br>Near-continuous monitoring of SWL and field parameters will be undertaken during purging and post sample collection to ensure limited drawdown effects. The groundwater will be sampled when the field parameters have stabilised, or before drawdown reaches a maximum of 30 cm. |
| Deployment and Retrieval of HydraSleeves® (single level well sample collection) | HydraSleeves® will be deployed with top weight sample collection to begin at the lowest point (where practicable). HydraSleeves® should not sit at the base of a monitoring well where sediment may be present.<br>HydraSleeves® sampling devices deployed with bottom weights will be left in wells for a minimum of 4 hours to allow restabilisation of the well following the slight disturbance caused by sampler deployment.<br>HydraSleeves® sampling devices with top and bottom weights will be left in wells for a minimum of 24 hours to allow restabilisation of the well and for the top weight to compress.<br>Samples will be collected via continuous pull method at a rate allowing the water to pass through the check value into the sample sleeve.<br>Samples will be discharged immediately (minimise changes in chemistry) via discharge tube.<br>Following sampling, new HydraSleeves® will be deployed in preparation for the next OMP monitoring event using the same string for consistency (same depth of sampling i.e. within screen depth). |
| Alternative sampling methodology (hand bailing) | Disposable HDPE hand bailers, attached to a polypropylene string, will be used in the event that the water column isn't sufficient to fill the HydraSleeve®. Purging of the well (i.e. removal of 3x well volume) will be undertaken prior to sampling to ensure that a sample representative of the aquifer is taken. Field |

| Activity | Details |
|---|---|
| | parameters will be regularly recorded during the bailer purge to confirm field parameter stability is achieved. |
| Seepage Water Sampling | Sampling will be carried out within a two-hour period; one hour each side of the low tide. Sampling protocol will involve a shallow excavation in the beach sand; just above where inundation by wave action is occurring. In-situ water parameters will be measured from water seeping into the excavation using a calibrated water quality meter. Water seeping into the excavation will be purged prior to measuring water quality parameters (using a dedicated syringe or jug). Once more water seeps in to the excavation, sampling containers will be lowered into the exposed seepage water and filled. |
| Field Records | Field records will include the following information:<br>▪ Sampling time and date.<br>▪ Weather conditions.<br>▪ Sample Collection method. Where a HydraSleeve® is used for sample collection, the target interval depth will be recorded.<br>▪ Stabilised field parameters (three readings required when a bailer is used).<br>▪ Sampling equipment decontamination procedures where non-disposable sampling equipment is utilised.<br>▪ Calibration and daily bump test records.<br>All sample documentation including field notebooks, reporting records, COC and equipment calibration certificates and procedures will be retained within project files. |
| Decontamination procedure | Dedicated HydraSleeves® and single use nitrile gloves will be used at each groundwater bore thus removing the need for decontamination.<br>All re-usable sampling equipment will be thoroughly washed using PFAS-free detergent then double rinsed with clean water before the sample collection. |
| Sample identification, preservation transport and holding times | Each sample container will be pre-labelled by the laboratory with a unique barcode for identification.<br>Samples will be collected directly in appropriately preserved laboratory supplied bottles (Teflon-free) and packed in chilled containers for delivery to the laboratory under Chain of Custody (CoC) documentation.<br>Sample containers, preservation procedures, sample storage requirements and holding times will be undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998). |
| Laboratory Testing | ▪ Full PFAS analytical suite (see Appendix B).<br>▪ Major anions and cations (include calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity and ionic balance) |
| Laboratory Testing – Quality Control | ▪ Groundwater QC samples will be collected at the following frequencies as detailed in the OMP (Defence, 2019):<br>▪ Field duplicate (intra-laboratory) samples at 1 per 10 water samples or 1 per batch if the batch is less than 10 samples.<br>▪ Field triplicate (inter-laboratory) samples at 1 per 10 water samples should be sent to a secondary laboratory.<br>▪ Rinsate blank sample at 1 per day [collected off re-used sampling equipment (e.g. interface probe)].<br>▪ Field blank samples at 1 per day. |
| Laboratory Accreditation and Limits of Reporting | All groundwater analysis will be undertaken by laboratories accredited by the NATA.<br>▪ Primary analysis will be undertaken by ALS Global Laboratories (Perth)<br>▪ Secondary analysis will be undertaken by Eurofins ARL (Perth).<br>Laboratory LORs will be suitable to meet the relevant adopted assessment levels (0.01 µg/L). |

### 4.2.2 Surface Water Sampling Methodology

The methodology for the surface water monitoring is detailed in Table 4-5.

**Table 4-5 Surface Water Monitoring**

| Item | Details |
|---|---|
| Field parameters | Surface water physiochemical parameters (i.e. pH, electrical conductivity (EC), oxidation reduction potential (ORP), dissolved oxygen (DO), and temperature) will be recorded at the time of sampling using a pre-calibrated water quality meter.<br>Field observations such as odours or sheen presence must also be recorded on field sampling sheets. |
| Sampling Method | Surface water samples will be collected directly into sample containers using a 'Grab' (manual) sample method via a long-handled sampling device.<br>Where depth permits, the sample container should be positioned at least 10 cm below the surface water level and above the sediment bed and oriented with the capped opening facing downwards to avoid the collection of surface films. Samples will be decanted into the laboratory supplied sample containers.<br>Samples will be collected in accordance with Australian/New Zealand Standards (AS/NZS 5667.1:1998) '*Water quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples'*. |
| Sample Collection | Water samples will be placed directly into appropriately labelled, laboratory supplied sample bottles and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation. |
| Decontamination | All re-usable sampling equipment will be thoroughly washed using PFAS-free detergent, then double rinsed with clean water before the sample collection. Single-use nitrile gloves will be worn during sampling. |
| Sample identification, preservation, transport and holding times. | Each sample container will be pre-labelled by the laboratory with a unique barcode for identification.<br>Samples will be contained in appropriately preserved laboratory supplied bottles (Teflon-free) and packed in chilled containers for delivery to the laboratory under Chain of Custody (CoC) documentation.<br>Sample containers, preservation procedures, sample storage requirements and holding times will be undertaken in accordance with those recommended by Standards Australia (AS/NZS 5667.1:1998). |
| Field Records | Field records will include the following information:<br>▪ Sampling time and date.<br>▪ Weather conditions.<br>▪ Sample Collection method.<br>▪ Sampling equipment decontamination procedures where non-disposable sampling equipment is utilised.<br>▪ Calibration and daily bump test records.<br>All sample documentation including field notebooks, reporting records, COC and equipment calibration certificates and procedures will be retained within project files. |
| Laboratory Testing | Surface water samples will be analysed for the following:<br>▪ Full PFAS analytical suite (see Appendix B).<br>▪ Major anions and cations (include calcium, magnesium, sodium, potassium, chloride sulfate, alkalinity and ionic balance). |
| Laboratory Testing – Quality Control | Surface water QC samples will be collected at the following frequencies as detailed in the SAQP:<br>▪ Field duplicate (intra-laboratory) samples at 1 per 10 water samples or 1 per batch if the batch is less than 10 samples.<br>▪ Field triplicate (inter-laboratory) samples at 1 per 10 water samples should be sent to a secondary laboratory.<br>▪ Rinsate blank sample at 1 per day [collected off re-used sampling equipment (e.g. interface probe)]. |
| Laboratory Accreditation and Limits of Reporting | All surface water analysis will be undertaken by laboratories accredited by the NATA.<br>▪ Primary analysis will be undertaken by ALS Global Laboratories (Perth) |

| Item | Details |
|---|---|
| | ▪ Secondary analysis will be undertaken by Eurofins ARL (Perth).<br>Laboratory LORs will be suitable to meet the relevant adopted assessment levels (0.01 µg/L). |

### 4.2.3 Sediment Sampling Methodology

The methodology for sediment sampling is detailed in Table 4-6.

**Table 4-6 Sediment Investigation Methodology**

| Item | Details |
|---|---|
| Sample Collection | Sediment samples will be collected at the sediment/water interface (0-0.1 mbgl) using hand tools (e.g. trowel, hand auger, PVC pipe etc.) with samples placed directly into appropriately labelled, laboratory supplied sample containers and packed in chilled containers for delivery to the laboratory under Chain of Custody documentation.<br>At each sampling location, the sediment sample will be visually assessed and observations (including physical description) recorded on field data sheets. |
| Field Records | Field records will include the following information:<br>▪ Sampling time and date.<br>▪ Sample description and condition.<br>▪ Weather conditions.<br>▪ Sample Collection method.<br>▪ Sampling equipment decontamination procedures where non-disposable sampling equipment is utilised.<br>All sample documentation including field notebooks, reporting records, COC and equipment calibration certificates and procedures will be retained within project files. |
| Decontamination | All re-usable sampling equipment will be thoroughly washed using PFAS-free detergent, then double rinsed with clean water before the sample collection. Single-use nitrile gloves will be worn during sampling. |
| Laboratory Testing | Sediment samples will be analysed for the following:<br>▪ Full PFAS analytical suite (see Appendix B). |
| Laboratory Testing – Quality Control | Sediment QC samples will be collected at the following frequencies as detailed in the SAQP:<br>▪ Field duplicate (intra-laboratory) samples greater than 1 per 10 sediment samples or 1 per batch if the batch is less than 10 samples.<br>▪ Field triplicate (inter-laboratory) samples greater than 1 per 10 sediment samples should be sent to a secondary laboratory. |
| Laboratory Accreditation and Limits of Reporting | All sediment analysis will be undertaken by laboratories accredited by the NATA.<br>▪ Primary analysis will be undertaken by ALS Global Laboratories (Perth)<br>▪ Secondary analysis will be undertaken by Eurofins ARL (Perth). |

### 4.2.4 Waste Management

All liquid wastes generated from the OMP activities will be temporarily stored on-site (in an agreed location as approved by Base Support) within either a wastewater drum or wastewater container and disposed off-site to a licensed facility. Disposal of the liquid waste is anticipated to occur once the drum(s) or container(s) are full, or as required and will be organised by Cardno.

Any solid waste generated during the sampling event will be disposed of either off-site or in appropriate bins on-site, as approved by Base Support.

### 4.2.5 Data Management

All data collected as part of the OMP will be managed in accordance with the DCMM Annex L (Defence, 2021). This includes:

> The location codes, project ID, and sample naming conventions presented in the DCMM Annex L will be followed.

> Laboratory and field data will be uploaded onto the Defence Environmental Data Management Software (EDMS (ESdat)).

> Laboratory data will be reviewed, approved and QA/QC data reconciled in ESdat.

#### 4.2.6 Fieldwork data collection and documentation

The data collection in the field will be completed using the following mobile applications:

**ESRI FieldMap** will have the OMP monitoring locations' GPS coordinates, location codes, type of media sampled and any access specific information.

**ESRI Survey123** will be used for the recording of field data at each sampling location. Data collected in the application will be regularly synchronised and saved to the cloud.

**ALS Compass** application will be used to scan the sampling containers' barcodes, generate and submit CoCs for ALS (primary laboratory).

# 5 Assessment Criteria

## 5.1 Groundwater, seepage water and Surface Water

The assessment levels adopted for groundwater, seepage water and surface water in this OMP SAQP are based upon the Heads of Environmental Protection Authorities (HEPA) Australia and New Zealand (2020) *PFAS National Environmental Management Plan 2.0* (NEMP; HEPA 2020) and finding of previous site assessment i.e. Detailed Site Investigation (DSI) (GHD, 2018). The adopted assessment criteria for groundwater and surface water are detailed in Table 5-1.

**Table 5-1 Criteria for Groundwater, Seepage Water and Surface Water**

| Receptor | Adopted Assessment Criteria |
|---|---|
| **Ecological** | **99% species protection level for Fresh Water and interim Marine Water:**<br>▪ PFOS – 0.00023* µg/L<br>▪ PFOA – 19 µg/L |
| **Human Health** | **Recreational Use:**<br>▪ PFOS + PFHxS – 2.0 µg/L<br>▪ PFOA – 10 µg/L |

*The criterion of 0.00023 µg/L is lower than the laboratory level of reporting (LOR) and is somewhat impractical. However, the PFAS NEMP 2020 allows for the adoption of the laboratory LOR as a screening level rather than a quantified measurement.

## 5.2 Sediment

It is noted that there are currently no Australian regulatory endorsed assessment levels for risk posed to ecology or human health by PFAS in sediment.

# 6 Deviations from the OMP

## 6.1 OMP SAQP History

The changes made to the OMP SAQP since the Rev1 are documented in Table 6-1.

Table 6-1 OMP SAQP History

| SAQP Version | Date | Report Section | Changes | Justification |
|---|---|---|---|---|
| Rev 2 | 21/11/2019 | - | Formatting and figures updates, minor changes. | Defence review |
| Rev 3 | 18/06/2020 | 7 | Update of assessment criteria and reference to HEPA (2020). | New guideline (HEPA, 2020) |
| Rev 4 | 10/03/2021 | 6.3 | Table 'Wells construction details' added.<br>Well ID update as per DCARM update (MWA0294 renamed MW211).<br>MW063A (lost) replaced by MW233 | DCARM update<br>Defence review |
| | | 6 | Methodology tables updates | |
| Rev 5 | 14/06/2021 | 6 | Groundwater Methodology table updates | Defence review |
| Rev 6 | 16/06/2022 | 6 | Lost monitoring well MW016 replaced by adjacent suitable monitoring well MW238 | MW016 was found filled with soil due to no gatic lid covering the well. MW238 is also positioned down-gradient of the Fuel Farm (source area 2) and historical data is available as this location was sampled as part of the DSI. |
| Rev 7 | 02/11/2022 | - | Methodologies & guidelines updates | Defence review, revised guideline documents |
| Rev 8 | 23/02/2023 | - | Minor formatting updates | Defence review |
| Rev 9 | 01/06/2023 | - | Minor updates | SAQP update |
| Rev 10 | 23/10/2023 | | Formatting updates | Defence review |
| Rev 11 | 13/05/2024 | 2 | Typo corrected | SAQP review |

## 6.2 Deviations from the OMP

Since the start of the implementation of the OMP, changes have been made to the monitoring network and sampling methodology. Details, justification and impact are presented in Table 6-2.

Table 6-2 Deviation from the OMP

| SAQP Version | Deviation | Justification | Impact |
|---|---|---|---|
| Rev 3 | Update of assessment criteria and reference to HEPA (2020). | Guideline update | No impact, criteria values did not change. |
| Rev 4 | Well ID update as per DCARM update (MWA0294 renamed MW211).<br>MW063A (lost) replaced by MW233 | Compliance with DCARM<br>OMP location replacement | No impact on OMP |
| Rev 6 | Lost monitoring well MW016 replaced by adjacent suitable monitoring well MW238 | OMP location replacement | No impact on OMP |

# 7 References


### General References

1. Australian Standard AS 4482-2005 *Guide to the investigation and sampling of sites with potentially contaminated soils, Part 1 – Non-volatile and semi-volatile compounds*.
2. *Contaminated Sites Act 2003*, Western Australia.
3. Department of Defence, 2021, *Defence Contamination Management Manual* (DCMM) *Annex L Data Management*.
4. Department of Defence, May 2021, *PFAS OMP Factual Report Guidance*, Version 0.2.
5. Department of Defence, October 2022, *PFAS OMP Annual Interpretive Report Guidance*, Version 0.4.
6. Department of the Environment and Energy (2017) in the *National Greenhouse and Energy Reporting Scheme Measurement Technical Guidelines for the Estimation of Emissions by Facilities in Australia*.
7. Department of Water and Environmental Regulation (DWER), 2021, *Assessment and Management of Contaminated Sites*.
8. Environmental Protection Agency (United States EPA), November 2002, Reference: EPA/240/R-02/004, *Guidance on Environmental Data Verification and Data Validation.*
9. The Heads of EPAs Australia and New Zealand (HEPA; 2020) *PFAS National Environmental Management Plan (NEMP) 2.0*, January 2020.
10. National Environment Protection Council (NEPC), 1999, *National Environmental Protection (Assessment of Site Contamination) Measure* (as amended), registered May 2013.
11. National Health and Medical Research Council (NHMRC) (2011 – updated 2022) *National Water Quality Management Strategy Australian Drinking Water Guidelines 6*, September 2022.
12. NHMRC, August 2019, *Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water*.
13. Standards Australia/Standards New Zealand (1998) AS5667.1:1998 *Water Quality – Sampling, Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*.
14. U.S. Environmental Protection Agency (EPA), 2000, *Guidance for the Data Quality Objectives Process* (EPA QA/G-4).
15. USEPA, 2002, *Guidance on Environmental Data Verification and Data Validation* (EPA QA/G-8).

### Site Specific References

16. Cardno, April 2020, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Base Learmonth.*
17. Cardno, May 2020, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth.*
18. Cardno, December 2020, *PFAS OMP 2020 post-summer Biannual Monitoring Event RAAF Base Learmonth*.
19. Cardno, February 2021, *PFAS OMP 2020 post-winter Biannual Monitoring Event RAAF Base Learmonth*.
20. Cardno, April 2021, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*.
21. Cardno, June 2021, *PFAS OMP, 2020 Annual Interpretive Report – RAAF Base Learmonth*.
22. Cardno, August 2021, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
23. Cardno, April 2022, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
24. Cardno, September 2022, *PFAS OMP First Flush Sampling Event Factual Report RAAF Learmonth*
25. Cardno, October 2022, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
26. Cardno, January 2023, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
27. Cardno, April 2023, *PFAS OMP 2021 Annual Interpretive Report – RAAF Base Learmonth*
28. Cardno, September 2023, *PFAS OMP Biannual Monitoring Event Factual Report RAAF Learmonth*
29. Department of Defence, May 2019, *RAAF Base Learmonth PFAS Management Area Plan*.
30. Department of Defence, May 2019, *RAAF Base Learmonth PFAS Ongoing Monitoring Plan*.
31. GHD, December 2018, *RAAF Base Learmonth – PFAS Investigations – Preliminary and Detailed Site Investigation Report*.
32. GHD, April 2019, *RAAF Base Learmonth – PFAS Investigations – Ecological Risk Assessment (ERA)*.

APPENDIX

# A

## Figures


FIGURE 1

1:60,000 Scale at A3

Metres

0 1,500 3,000

# Site Location

SAMPLING AND ANALYSIS QUALITY PLAN
RAAF BASE LEARMONTH
DEPARTMENT OF DEFENCE

Cardno

Map Produced by Cardno WA
Date: 2023-02-23 | Project: DEF19009
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Map: DEF19009_WA_0960-GS-001_RegionalLocation 02.mxd
Aerial Imagery Supplied by Google Earth

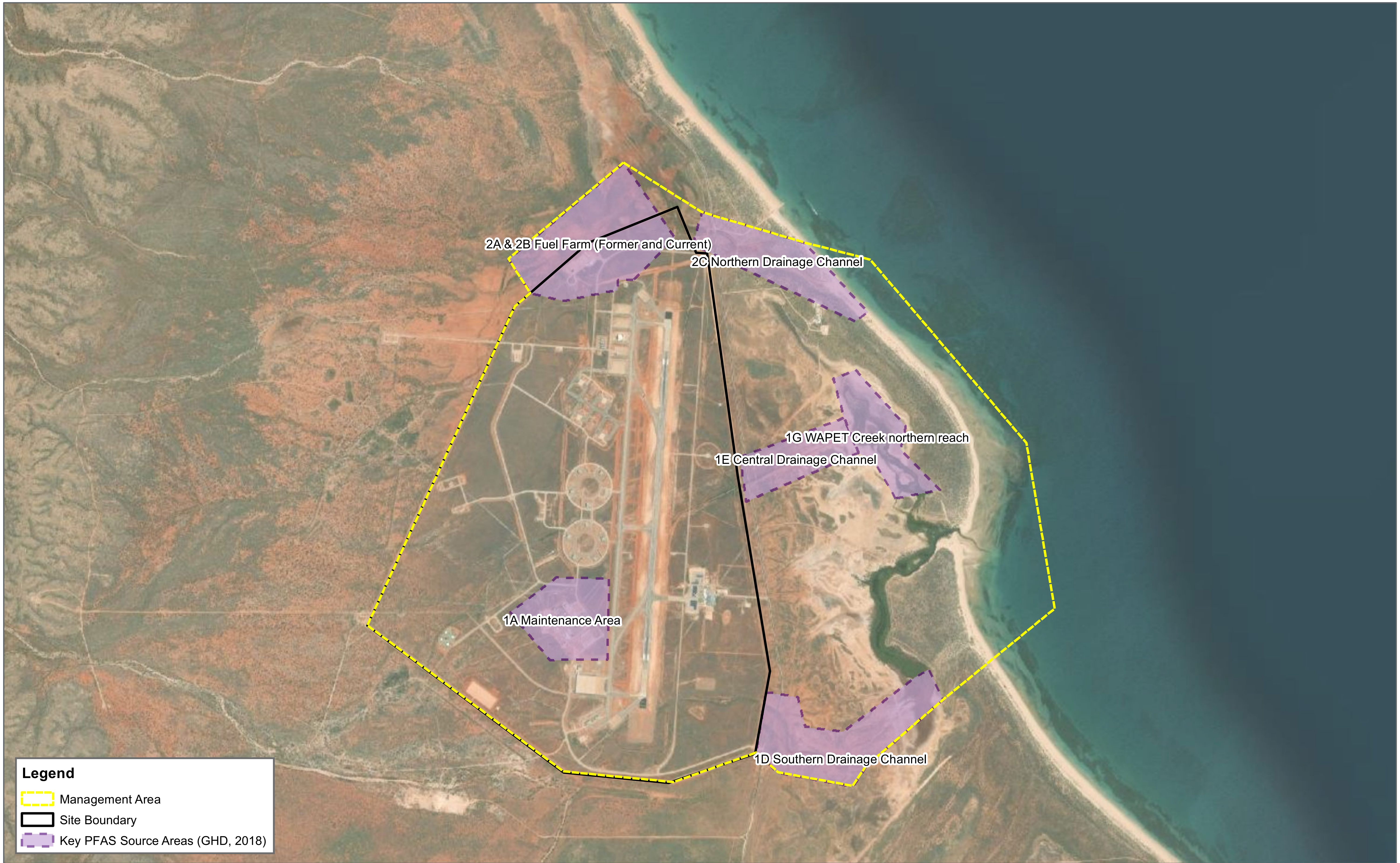


FIGURE 2

1:31,000 Scale at A3

Metres

0 1,000 2,000

# Management Areas

SAMPLING AND ANALYSIS QUALITY PLAN
RAAF BASE LEARMONTH
DEPARTMENT OF DEFENCE

N

Cardno

Map Produced by Cardno WA
Date: 2023-02-23 | Project: DEF19009
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Map: DEF19009_WA_0960-GS-002_ManagementAreas 02.mxd
Aerial Imagery Supplied by Google Earth

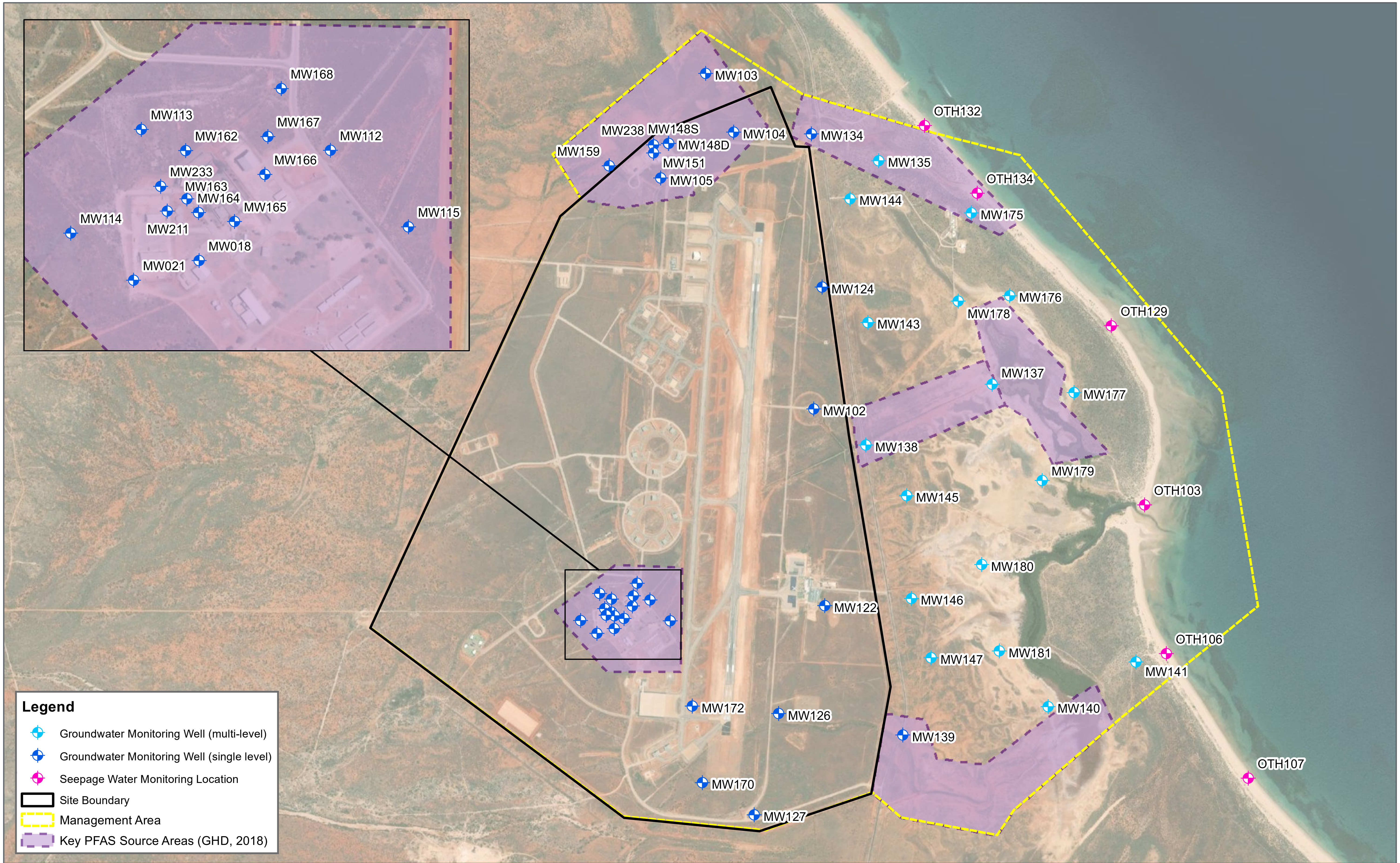


FIGURE 3

1:24,000 Scale at A3

Metres

0 1,000 2,000

## Groundwater and Seepage Water Monitoring Locations

SAMPLING AND ANALYSIS QUALITY PLAN
RAAF BASE LEARMONTH
DEPARTMENT OF DEFENCE

N

Cardno

Map Produced by Cardno WA
Date: 2023-02-23 | Project: DEF19009
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Map: DEF19009_WA_0960-GS-003_GroundwaterMonitoringLocations 02.mxd
Aerial Imagery Supplied by Google Earth

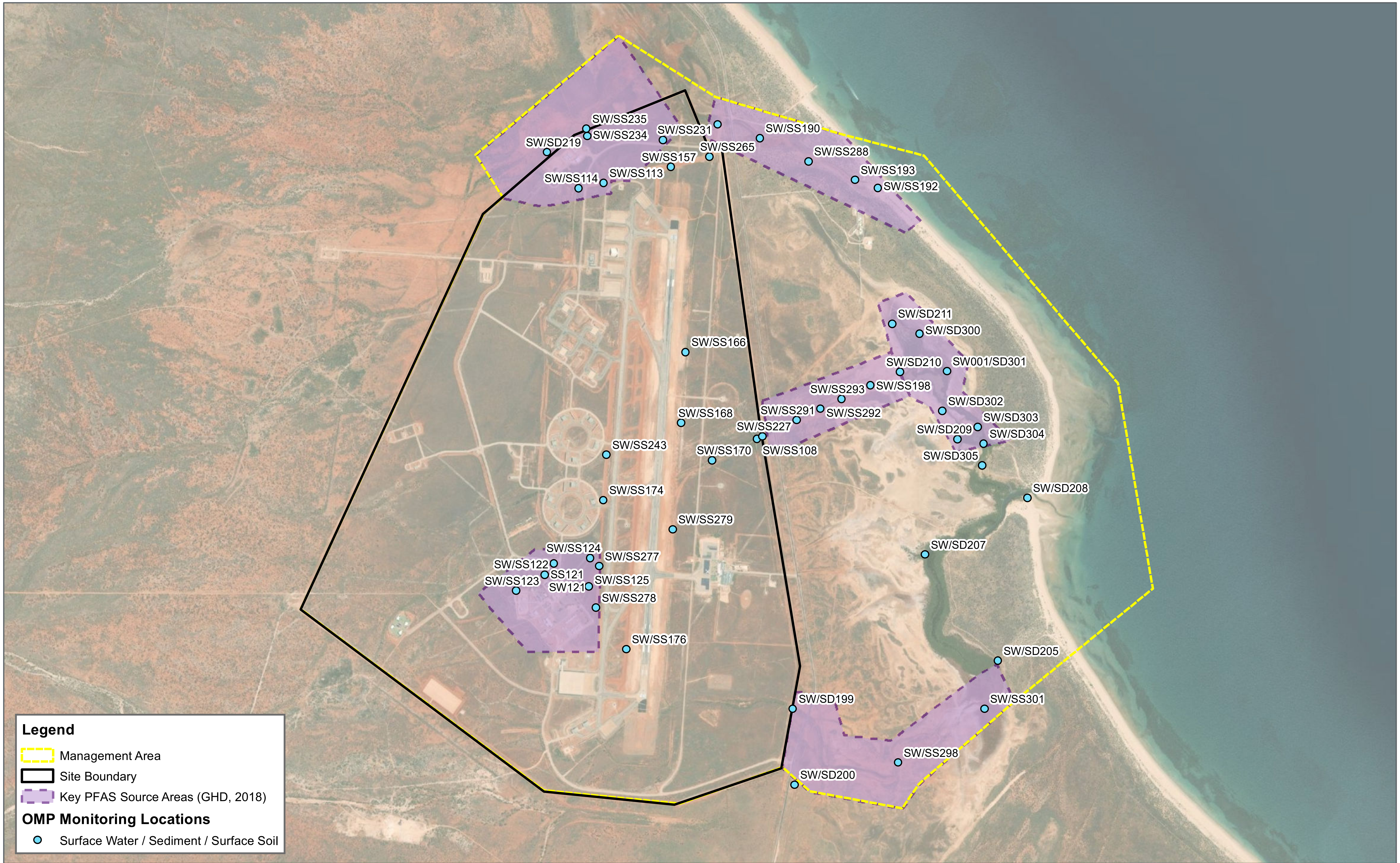


FIGURE 4

1:25,000 Scale at A3

Metres

0 1,000 2,000

# Surface water and sediment monitoring locations

SAMPLING AND ANALYSIS QUALITY PLAN
RAAF BASE LEARMONTH
DEPARTMENT OF DEFENCE

Cardno

Map Produced by Cardno WA
Date: 2023-02-23 | Project: DEF19009
Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere
Map: DEF19009_WA_0960-GS-004_SurfaceWater&SedimentMonitoringLocations 02.mxd

APPENDIX

# B

## Full PFAS Analytical Suite

### Full PFAS Analytical Suite

| Group | Analyte | CAS No. |
|---|---|---|
| Perfluoroalkane Sulfonic Acids | Perfluorobutane sulfonic acid (PFBS) | 375-73-5 |
| | Perfluoropentane sulfonic acid (PFPeS) | 2706-91-4 |
| | Perfluorohexane sulfonic acid (PFHxS) | 355-46-4 |
| | Perfluoroheptane sulfonic acid (PFHpS) | 375-92-8 |
| | Perfluorooctane sulfonic acid (PFOS) | 1763-23-1 |
| | Perfluorodecane sulfonic acid (PFDS) | 335-77-3 |
| Perfluoroalkane Carboxylic Acids | Perfluorobutanoic acid (PFBA) | 375-22-4 |
| | Perfluoropentanoic acid (PFPeA) | 2706-90-3 |
| | Perfluorohexanoic acid (PFHxA) | 307-24-4 |
| | Perfluoroheptanoic acid (PFHpA) | 375-85-9 |
| | Perfluorooctanoic acid (PFOA) | 335-67-1 |
| | Perfluorononanoic acid (PFNA) | 375-95-1 |
| | Perfluorodecanoic acid (PFDA) | 335-76-2 |
| | Perfluoroundecanoic acid (PFUnDA) | 2058-94-8 |
| | Perfluorododecanoic acid (PFDoDA) | 307-55-1 |
| | Perfluorotridecanoic acid (PFTrDA) | 72629-94-8 |
| | Perfluorotetradecanoic acid (PFTeDA) | 376-06-7 |
| Perfluoroalkyl Sulfonamides | Perfluorooctane sulphonamide (FOSA) | 754-91-6 |
| | N-Methyl perfluorooctane sulfonamide (MeFOSA) | 31506-32-8 |
| | N-Ethyl perfluorooctane sulfonamide (EtFOSA) | 4151-50-2 |
| | N-Methyl perfluorooctane sulfonamidoethanol (MeFOSE) | 2448-09-7 |
| | N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE) | 1691-99-2 |
| | N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA) | 2355-31-9 |
| | N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA) | 2991-50-6 |
| (n:2) Fluorotelomer Sulfonic Acids | 4:2 Fluorotelomer sulfonic acid (4:2 FTS) | 757124-72-4 |
| | 6:2 Fluorotelomer sulfonic acid (6:2 FTS) | 27619-97-2 |
| | 8:2 Fluorotelomer sulfonic acid (8:2 FTS) | 39108-34-4 |
| | 10:2 Fluorotelomer sulfonic acid (10:2 FTS) | 120226-60-0 |