ABOUT THIS DOCUMENT

This is the Defence PFAS Management Area Plan (PMAP) for RAAF Townsville.

This PMAP sets out a plan for Defence to manage the elevated risks of PFAS contamination on and emanating from RAAF Townsville, as identified in:

- the Detailed Site Investigation report (May 2018).
- the Human Health Risk Assessment report (October 2018).
- the Ecological Risk Assessment report (December 2019).
- the Seasonal Monitoring Report 1 (December 2019).
- the Seasonal Monitoring Report 2 (December 2019).

It also documents the options development and assessment process, and rationale for the proposed response actions to manage those risks.

This PMAP will be reviewed annually (or earlier where required) to take into account changes in circumstances, including:

- progress in risk management and the effectiveness of specific response actions.
- data from the Ongoing Monitoring Plan.
- changes of land use.
- changes in legislation, strategy, policy and guidelines/standards.
- outcomes of new research or development of management/remediation.
- any other new information that has the potential to impact the outcomes of the PMAP.
EXECUTIVE SUMMARY

The PFAS Management Area Plan (PMap) for RAAF Townsville (herein referred to as the “Base”) is a roadmap detailing potential management measures to address soil and water contamination and potential risks resulting from per- and polyfluoroalkyl substances (PFAS) on and proximate to the Base. This document sets out to describe potential future management actions, the efficacy of which will need to be proven through area-specific assessments of technology and management practices.

Background

Managing fuel fires is a critical capacity for all Defence bases. This includes training Defence personnel in fire-fighting techniques. PFAS was an active ingredient in legacy fire-fighting foams used at the Base from around the 1970’s. From 2004, Defence commenced phasing out its use of legacy firefighting foams containing perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) as active ingredients. Defence now uses a more environmentally safe firefighting product called Ansulite. Ansulite does not contain PFOS and PFOA as active ingredients, but only in trace amounts. Ansulite is used by Defence only in emergency situations where human life is at risk, or in controlled environments to test equipment.

PFAS is highly soluble and mobile, and able to rapidly leach through soils or disperse in waterways, travelling long distances, as well as being able to permeate some solid surfaces. It is very chemically and biologically stable, being resistant to breakdown and evaporation, as well as being environmentally persistent and bio-accumulative. PFAS has been found across and beyond the Base spread via groundwater and surface water into the community.

Lands surrounding the Base are used for low density residential, commercial/industrial, recreational activities and conservation (Townsville Town Common Conservation Park).

Management Area and Monitoring Area

The term ‘Management Area’ in this PMap refers to the area of the Base, whilst the area within which environmental sampling (surface water, sediment and groundwater) is undertaken is termed the ‘Monitoring Area’. There is a wide range of land uses and activities that have the potential for people and biota to interact with PFAS impacted water or soil within the Monitoring Area.

Environmental investigations undertaken by Defence have showed that the migration of PFAS from the Base has and is continuing to impact the environments surrounding the Base, especially following rainfall events during which surface water flows from the Base. The majority of this PFAS impacted surface water flows either into Mundy Creek or into the Louisa Creek Catchment (and subsequently the Townsville Town Common).

Identification of Source Areas & Risk

This PMap sets out a plan for Defence to manage elevated risks associated with PFAS contamination on and emanating from the Base, as identified in:

- the Detailed Site Investigation (DSI) (WSP 2018a);
- the Human-Health Risk Assessment (HHRA) (WSP 2018b);
- the Seasonal Monitoring Reports (WSP 2019a, 2019c); and
- the Ecological Risk Assessment (ERA) (WSP 2019b).

Based on the DSI report (WSP 2018a), the following source areas were prioritised for action under the PMap:

- Former Fire Training Area NQ0054;
- Fire Station NQ0055;
• Former Fire Training Area NQ0107;
• Fuel Farm 2 NQ0099; and
• 5 Aviation (5AVN).

Based on the HHRA report (WSP 2018b) the greatest contributors to exposure risk are predominantly linked to the migration of PFAS in surface water into the estuarine environment (and subsequent indirect human exposure) and direct contact with impacted soils. In particular, the following exposure pathways were identified as potentially having an elevated risk for human receptors:

• Direct contact exposure (in the absence of any controls such as personnel protective equipment (PPE), hygiene practices, etc.) to soil by sub-grade maintenance workers accessing on-Base PFAS impacted areas numerous times per year; and
• Recreational consumers of whole fish (including the offal) in excess of the Food Standards Australia and New Zealand (FSANZ) dietary advice to limit mercury exposure of three standard servings of fish per week.

On-Base management of exposure at source areas can be managed through the implementation of administrative controls at the Base. As the FSANZ mercury guidance is protective of PFAS exposure, no further actions are currently required for recreational consumers of seafood from the Monitoring Area.

Based on the ERA report (WSP 2019b), the following exposure pathways were identified as potentially having an elevated risk for ecological receptors:

• Bioaccumulation of PFAS in aquatic organisms;
• Bioaccumulation of PFAS in terrestrial organisms; and
• Bioaccumulation and trophic transfer in aquatic and terrestrial food webs.

Source Areas Contribution to Ecological Risks

Not all source areas are contributing an equivalent mass of PFAS from the Base, with some areas discharging to different catchments. The dominant flux into the Mundy Creek catchment is from Former Fire Training Area NQ0054 (Sub-Management Area 1), whilst the dominant flux to the Louisa Creek Catchment (and thus, into The Townsville Town Common) is from the Fire Station NQ0055 and Former Fire Training Area NQ0107 (Sub-Management Area 2). Whilst three sub-management areas have been identified in the PMAP, these two sub-management areas present the greatest contribution to off-Base ecological risks and so remedial actions at these areas would most likely present the greatest reduction in ongoing PFAS mass flux from the Base.

Identification and Analysis of Management Options

This PMAP documents the options development and assessment process, and the rationale for the proposed response actions to manage identified risks and prioritise source areas. In managing the risks associated with PFAS contamination on the Defence Estate, Defence currently prioritises two sets of actions:

• implementing practicable solutions to prevent or minimise the migration of PFAS beyond the Base boundary through either:
  • reducing the mass of the PFAS contamination source, and/or
  • preventing or minimising the migration of significant PFAS contamination from the source to people or other sensitive receptors, and
• working to minimise the community’s exposure to PFAS while management actions addressing source areas and/or migration pathways are underway.

Remedial options, which need to be critically assessed through the development of a Remedial Action Plan (RAP) that are likely to demonstrate the greatest efficacy at the Base are listed below. The
dominant pathway for PFAS migration from the Base is via periods of sporadic surface water flow resulting from rainfall events. Hence, remedial options that result in reducing the interaction with PFAS impacted soil and surface water are those that will result in a reduction in the mass of PFAS discharged from the Base following rainfall events.

- hydraulic control of surface water to limit runoff from source areas;
- containment of PFAS in soil via stabilisation/immobilisation techniques to reduce leachability to surface water;
- excavation and containment of PFAS impacted soil within purpose-built above-grade engineering facilities so as to isolate impacted soil from surface water; and/or
- excavation and off-Base disposal of impacted soil so that the pathway becomes incomplete.

The treatment of surface water is likely to be impracticable due to the very large quantities of water that traverse the Base during flood events. Impacted water would need to be captured and retained, which would result in heightened risk of flooding to the Base and the domestic airport (and potentially the surrounding communities), resulting in a loss of aviation capability until the water has been treated and then discharged from the Base. The scale of plant needed to treat this large volume of water would be extraordinary, with operation to treat PFAS expected to occur only during overland flow events (expected on average one week in every two years). In the intervening period, the plant would continue to operate and draw cost to the Commonwealth as it recycles clean water (most likely town water) to ensure ongoing operationality of plant components.

Ongoing Monitoring Plan

The Management Area Ongoing Monitoring Plan (OMP) will provide information on changes in PFAS contamination originating from the Base to inform risk management decisions by Defence and Queensland government agencies to protect human health and the environment.

Under the OMP, on-Base and off-Base sampling campaigns will occur twice a year, a comprehensive sampling event at the end of the wet season (April) and a targeted sampling event at the end of the dry season (October) with samples of surface water, sediment and groundwater to be collected.

Annual event-based sampling of surface water has been included in the OMP to assess surface water discharges during flushing episodes from the Base. An ‘event’ is defined as 50mm rainfall in 24 hours or a cumulative 100mm rainfall in seven days.

Information from implementation of the OMP will be shared with relevant Queensland government authorities and made publicly available including:

- monitoring data collected during the implementation of the OMP.
- decisions made in response to the data collected during implementation of the OMP.
- changes to the OMP made in response to incoming data over the implementation period.

In particular, Defence will keep the community informed regarding changes in contamination concentrations and what the changes mean in terms of risk to the community via the Defence website and ongoing community engagement (via key community briefings, community liaison).

The effectiveness of management strategies will be regularly assessed based on the results of the OMP sampling, and the program of forward works updated to achieve the most effective outcomes.

Specific reviews and updates may be triggered in the event of monitoring indicating unexpected changes in PFAS distribution or concentrations, changes to legislation or guidance documents such as the PFAS National Environment Management Plan (2018) (NEMP), or availability of new remediation technologies.
PMAP Review and Update

Ongoing implementation of the PMAP (including the OMP) will be subject to continuing annual review and update. This will ensure documentation remains current and relevant, reflects the results of the OMP (as described above) and incorporates advances in information and technology (based on ongoing technology performance assessment and review). Where changes to the PMAP and/ or OMP occur, they will be communicated and discussed with the community and other stakeholders, including relevant local, Queensland and Commonwealth government authorities.
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<th><strong>GLOSSARY</strong></th>
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</thead>
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<tr>
<td><strong>Base</strong></td>
</tr>
<tr>
<td><strong>CSM</strong></td>
</tr>
<tr>
<td><strong>DSI</strong></td>
</tr>
<tr>
<td><strong>ERA</strong></td>
</tr>
</tbody>
</table>
| **Extended implementation period** | Period when PMAP response actions are required beyond the primary implementation period. These actions include ongoing:  
  • monitoring, leachate management, and maintenance of stockpiles;  
  • monitoring of Management Area for PFAS; and  
  • assessment of developments and technologies for application to stockpiled PFAS impacted soils and materials. |
| **HEPA** | Heads of EPA, a forum of State, Territory and Commonwealth environmental regulators, and publisher of the PFAS NEMP |
| **HHRA** | Human Health Risk Assessment. |
| **Management Area** | The geographical area subject to Defence response actions as described in Section 1.1.3. |
| **Net environmental benefit (NEB)** | The net impact of a contamination response action on the environmental health of the ecosystem/s within the Management Area (or an adjoining ecosystem) that is the target of the response action. An assessment of NEB involves an assessment of risk reduction of PFAS contamination, together with:  
  1. impacts on:  
     a. ecosystem health  
     b. sensitive species  
     c. fate and transport of PFAS.  
  2. planned mitigation actions for any negative impacts. |
<p>| <strong>Off-site</strong> | Off-Base. |
| <strong>Ongoing Monitoring Plan (OMP)</strong> | The ongoing monitoring plan forming a part of this PMAP as set out in Chapter 5 and Attachment 1. |
| <strong>On-site</strong> | On-Base. |
| <strong>PFAS NEMP</strong> | PFAS National Environmental Management Framework 2018 developed cooperatively between Australian jurisdictions or as revised from time to time. |
| <strong>Primary implementation period</strong> | The period for completion of PMAP response actions characterised as primary implementation response actions. |
| <strong>Project site</strong> | A defined site for construction and maintenance works within a Base. |
| <strong>Primary source area</strong> | An original source of PFAS contamination, generally on-site, for example, a fire-fighting training ground |</p>
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project site</td>
<td>A defined site for construction and maintenance works within a Base</td>
</tr>
<tr>
<td>Public Works Committee (PWC)</td>
<td>Required to approve higher value public works (exceeding $15 million) and assess public works with a value of between $2 million and $15 million.</td>
</tr>
<tr>
<td>Remediation Action Plan (RAP)</td>
<td>Defines the purpose and objectives of the remediation, evaluates and determines the remediation options, and sets out performance measures.</td>
</tr>
<tr>
<td>Response actions</td>
<td>Actions identified as recommended or potential options to address potential risks.</td>
</tr>
<tr>
<td>Risk assessment(s)</td>
<td>The HHRA and/or ERA described in Section 1.1.1.</td>
</tr>
<tr>
<td>Secondary source area</td>
<td>An area containing elevated PFAS concentrations originally sourced from pathways from a Primary source area, and itself functioning as a source area.</td>
</tr>
<tr>
<td>Site Selection Board</td>
<td>Approve the siting of semi-permanent and permanent structures, including the location of response actions and any supporting infrastructure.</td>
</tr>
<tr>
<td>Source area</td>
<td>An area within the Management Area that is, or has the potential to be, a source of contamination</td>
</tr>
</tbody>
</table>

Unless otherwise defined in this document, terms defined in the NEMP or the ASC NEPM have those meanings. In the event of conflict, definitions used in the NEMP are to be preferred.
1 INTRODUCTION

1.1 Purpose

This PFAS Management Area Plan (PMAP) provides a roadmap for response management by Defence of potential risks arising from per- and poly-fluoroalkyl substances (PFAS) contamination associated with RAAF Townsville and surrounding areas, consistent with the intent of the PFAS National Environmental Management Plan (NEMP).

Defence’s management of the risks under the PMAP aims to avoid or minimise exposure to PFAS contamination from Defence property to human-health and ecological receptors. In doing so, Defence prioritises the following combination of measures:

1. Implementing practicable solutions to prevent or minimise the migration of PFAS beyond the Defence property boundary through:
   a. reducing the mass of the PFAS contamination source, and/or
   b. blocking or diverting the migration pathway of the contamination from the source to a receptor.
2. Limiting PFAS exposure to the community whilst management actions that address source areas and/or migration pathways are undertaken.

1.2 Application

This document will be used by Defence (including contractors) managing or carrying out the response actions set out in this PMAP.

This document may also be relevant for reference or aligning actions:

- By Defence environmental staff responsible for approving Environmental Clearance Certificates (ECCs) and any other similar approvals required for implementation of this PMAP.
- By Defence (including contractors) carrying out construction and maintenance works on the Defence estate.
- During the development and delivery phases of response actions, including by Site Selection Boards.

The Technical Working Group (TWG) established under the Queensland Interdepartmental Committee on Fluorinated Fire Fighting Foam has been consulted in the development of this document. The Queensland Department of Environment and Science (DES) coordinates the TWG.

1.3 Background

1.3.1 PFAS and its use

PFAS are a group of synthetic (i.e. ‘man-made’) compounds that include perfluorooctane sulfonate (PFOS), perfluorohexane sulfonate (PFHxS), and perfluorooctanoic acid (PFOA). PFAS have been widely used around the world since the 1950s to make products that resist heat, stains, grease and water. These include hydraulic fluid, stain resistant applications for furniture and carpets, packaged food containers, waterproof clothing, personal care products and cleaning products.

Due to its effectiveness in extinguishing liquid fuel fires, PFAS was also an ingredient in legacy aqueous film forming foam (AFFF) used extensively worldwide by both civilian and military authorities from about the 1970s. Older formulations of AFFF contained a number of PFAS now known to be persistent in the environment and in humans.
Most people living in developed nations will have some level of PFAS in their body due to their widespread use. In June 2016, the Environmental Health Standing Committee (enHealth)\(^1\), published guidance statements advising that there is currently no consistent evidence that exposure to PFOS and PFOA causes adverse human health effects\(^2\). However, since these chemicals remain in humans and the environment for many years, it is recommended that as a precaution, human exposure to PFAS be minimised.

PFAS contamination on and in the vicinity of the Defence estate arises primarily because of the historic use of AFFF for training purposes or incident control.

1.3.2 The nature of PFAS

PFAS has many qualities that combine to present particular challenges in locating, containing and remediating PFAS contamination:

- Water is the prime method of PFAS contamination transferring from a source to a receptor - a person, animal, plant, eco-system, property or a waterbody.
- PFAS is highly soluble and mobile and can rapidly leach through soils or disperse in waterways, travelling long distances. This may sometimes reduce the level of contamination of the original source material.
- Porous surfaces including concrete and other building materials are susceptible to becoming contaminated if in contact with liquids containing PFAS for example, storage tanks and fire training grounds.
- PFAS is very chemically and biologically stable and has a low vapour pressure, so it is resistant to breakdown and evaporation. However, some longer chain PFAS do break down in the environment, and are precursors to forming PFOS, PFHxS or PFOA.
- PFAS resist physical, chemical and biological degradation, and are very stable, can bioaccumulate and biomagnify. Molecules of PFAS are made up of a chain of carbon atoms flanked by fluorine atoms, with a hydrophilic group at their head. Their high solubility in water means that PFAS readily leach from soil to waters (surface and groundwater) and into the food chain, being transferred from organism to organism including plants.

1.4 Policy context

The policy context for the PMAP consists of national guidance in the form of the NEMP, Defence estate and environmental strategies, and Defence PFAS-specific strategies and guidance.

1.4.1 PFAS National Environmental Management Plan

The NEMP aims to provide governments with a consistent, practical, risk-based framework for the environmental regulation of PFAS-contaminated materials and sites. The NEMP has been developed collaboratively by the Heads of EPAs Australia and New Zealand and the Commonwealth Department of Environment and Energy (DoEE) and has been endorsed by the Commonwealth Government.

The PFAS Response Management Strategy and the requirements of the PMAP template and guidance conform to the NEMP. The PMAP template and guidance will be adjusted to conform to relevant changes in the NEMP as and when the changes are made.

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\(^1\) EnHealth is a subcommittee of the Australian Health Protection Principal Committee, and is responsible for providing agreed environmental health policy advice. Its membership includes representatives from the Health portfolios of Australian and New Zealand governments.

1.4.2 Defence estate and environmental management

The Defence Estate Strategy 2016-2036 and the Defence Environmental Strategy 2016-2036 each provide strategic direction for the management of risks associated with PFAS contamination.

Under the Defence Estate Strategy 2016-2036, sustainability is one of five strategic aims for the management of the Defence Estate. Under this strategy, the environment and its ongoing sustainable management is viewed as a critical enabler to Defence capability. For legacy contamination, including emerging contaminants such as PFAS, Defence is committed to minimising the impacts of the use of the estate on surrounding communities, proactively investigating and responding to contamination, and working with affected communities and State/Territory authorities.

The Defence Environmental Strategy 2016-2036 provides further strategic focus. Relevant strategic aims are:

- **Strategic Aim 1:** Defence will deliver a sustainable estate.
- **Strategic Aim 2:** Defence will understand and manage its environmental impacts.
- **Strategic Aim 3:** Defence will minimise future pollution risks and manage existing contamination risks.

1.4.3 PFAS Response Management Strategy

Defence’s PFAS Response Management Strategy (RMS) is a high-level strategy document that sets out the approach and principles to be applied to PFAS response management. Under the RMS sit three integrated components:

- **PFAS Management Area Plan (PMAP) template and guidance:** The template on which this PMAP is based, with embedded guidance for the comprehensive PFAS response plan for a Defence Base and its vicinity, based on the outcomes of the Detailed Site Investigations and the risk assessments.

- **PFAS Interim Response Management (IRM Guidelines):** Guidance to manage a specific risk rather than the set of risks associated with a property. These risks will generally emerge during the investigation phase. Where it is important that the risk be managed before the PMAP is in place to avoid or mitigate a significant risk to human health or the environment, the IRM guidelines provide a process for developing, assessing and recommending options, scalable from community-level actions through to Public Works Committee (PWC) referral actions.

- **PFAS Construction and Maintenance Framework:** Guidance on the management of PFAS risks when carrying out constructions and maintenance projects on the Defence estate for a site that is, or is likely to be, contaminated by PFAS.

Figure 1 below sets out a strategy and implementation map for Defence PFAS Response Management.

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Figure 1: Defence PFAS response management and implementation map

Figure 2 at the end of this chapter presents the site-management process and the roles of the PMAP and related project documentation.

1.4.4 PFAS Applied Research Strategy

The PFAS Response Management Strategy also guides the PFAS Applied Research Strategy. Its objective is that Defence is sufficiently supported by research and new technologies to efficiently and effectively manage the risks associated with PFAS contamination on or emanating from the Defence estate. This includes supporting demonstration and validating PFAS remediation technologies. The PFAS Technology Demonstration Guideline provides guidance for the processes involved in Defence investment in technology demonstration. The outcomes of this program may (as relevant) inform the review of this PMAP.

1.5 Scope

The PMAP relies on:

- the Detailed Site Investigation of May 2018 conducted by WSP Australia,
- the Human Health Risk Assessment of October 2018 conducted by WSP Australia,
- the Seasonal Monitoring Reports of December 2019 conducted by WSP Australia, and
- the Ecological Risk Assessment of December 2019 conducted by WSP Australia,

to inform risk identification and weighting for the Management Area.
The key parameters for the PMAP are set out below.

<table>
<thead>
<tr>
<th>Management Area</th>
<th>The Management Area comprises the Base where management actions, including those where institutional controls have been adopted, are identified and managed by the PMAP. The Management Area is presented in Figure 1 and is defined by the boundary of the Base.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-management Area</td>
<td>Three discrete Sub-management Areas, referred to Sub-management Area 1 to Sub-management Area 3, have been identified on-Base and are presented in Figure 1.</td>
</tr>
<tr>
<td>Monitoring Area</td>
<td>The Investigation Area in the DSI (WSP 2018) and the Seasonal Monitoring Reports (WSP 2019a, 2019c) has been maintained for monitoring purposes. This area is henceforth referred to as the Monitoring Area and is associated with the Ongoing Monitoring Plan (Appendix E).</td>
</tr>
<tr>
<td>Issue/risk identification</td>
<td>Sourced from HHRA and ERA and identified receptors with 'elevated' risk of exposure to PFAS.</td>
</tr>
<tr>
<td></td>
<td>• Recreational consumers of finfish offal sourced from waterways within the Monitoring Area at rates in excess of the Queensland Health mercury in fish advice (i.e. three servings per week);</td>
</tr>
<tr>
<td></td>
<td>• Direct contact exposure (in the absence of any controls such as personnel protective equipment (PPE), hygiene practices, etc.) to soil by sub-grade maintenance workers accessing on-Base PFAS impacted areas numerous times per year;</td>
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<tr>
<td></td>
<td>• Lower order terrestrial plants and terrestrial invertebrates;</td>
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<tr>
<td></td>
<td>• Terrestrial herbivorous mammals;</td>
</tr>
<tr>
<td></td>
<td>• Terrestrial herbivorous, invertivorous, omnivorous and predatory birds;</td>
</tr>
<tr>
<td></td>
<td>• Aquatic herbivorous and predatory mammals; and</td>
</tr>
<tr>
<td></td>
<td>• Aquatic invertivorous and omnivorous birds.</td>
</tr>
<tr>
<td>Issue/risk range</td>
<td>The PMAP addresses the range of elevated risks identified in a DSIs (WSP, 2018a; 2019a) and the risk assessments (WSP, 2018b; 2019b), but excludes occupational PFAS exposure risks within the Management Area (i.e. on-Base). Occupational exposures will be appropriately managed by the relevant contractor in accordance with applicable work, health and safety legislation.</td>
</tr>
<tr>
<td>Remediation technology status</td>
<td>The response options in this PMAP consider only proven technologies at the appropriate scale, unless otherwise identified.</td>
</tr>
</tbody>
</table>
1.6  Key response factors

When developing, and recommending appropriate response actions, the principles considered (in accordance with the Defence PFAS Response Management Strategy and the NEMP) include:

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

Defence prioritises source management in the source-pathway-receptor linkage as preferable to pathway management and pathway management as preferable to receptor management but these components may be progressed concurrently in accordance with Defence’s priorities as set out in Section 1.1.

1.7  Implementation process

Defence will undertake project management of the overall PMAP, including monitoring of implementation and progressive annual evaluation of the implementation.

This will inform any changes to, and re-alignment of, the PMAP.

Response management actions under the PMAP will be subject to Defence approval and procurement processes, including where relevant, the processes of the Parliamentary Standing Committee on Public Works Committee (PWC) processes.

Implementation timeframes will be subject to the factors set out in Section 7.2.

1.7.1  Approvals

a)  Higher value public works

Larger public works (exceeding $15 million in expenditure) require a referral to the PWC. Under very limited circumstances, exemptions from the PWC process are available:⁴

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⁴ Public Works Committee Act 1969, sections 18(8) and 18(8A)
• urgency,
• for defence purposes where that scrutiny could be contrary to the public interest, or
• for projects of a repetitive nature.

Medium works (exceeding $2 million but less than $15 million in expenditure) require a notification to the PWC. PWC assessment of a notification may result in:

• approval to proceed,
• approval to proceed, subject to specific conditions or requirements,
• Committee deliberation postponed, pending further information, or
• Committee resolution to seek a referral.

For higher value public works, a timeframe of up to 12-24 months may apply commencement of the development phase of the project to approval to commence the delivery phase. The processes may include all necessary Government and Parliamentary approvals, including PWC. This may require interim measures to be implemented to manage the risks until the response action has received approval to commence.

b) Site Selection Board

Where relevant, the Defence Site Selection Board (SSB) is required to determine the location of response actions and any supporting infrastructure (for example, containment areas or water treatment plants).

The question as to whether a regional or full review is required will be determined in accordance with Defence Estate Quality Management System (DEQMS) guidance.

1.7.2 Procurement phase

Once the PMAP is approved by Defence (and subject to the approvals in Section 1.7.1), Defence will undertake procurement actions (in order of priority) for relevant specific response actions in accordance with the Commonwealth Procurement Rules and standard Defence procurement processes. These specific response actions will be implemented and evaluated in accordance with the terms (including timeframes) of the relevant procurement agreement.

1.7.3 Implementation timelines

The outcomes of the procurement processes will inform the detailed project implementation timelines. The PMAP is divided into two implementation periods:

1. The primary implementation period applies to actions that can generally be addressed in the short to medium term (up to three years, refer Section 7.2). The implementation of the Ongoing Monitoring Plan will commence in the primary implementation period and extend through to the extended implementation period.

2. The extended implementation period commences once the primary implementation period has completed. It applies to response actions required beyond the primary implementation period on an ongoing or long-term basis. These actions include ongoing:
   a. monitoring, leachate management, and maintenance of stockpiles (noting risk at RAAF Townsville regarding inundation of the Base during flooding events),
   b. monitoring of the Management Area for PFAS,
   c. ongoing operation of remediation technologies (e.g. a water treatment plant), as required, and
   d. assessment of developments and technologies for application to stockpiled PFAS impacted soils and materials.

Response actions under this PMAP are designated as forming part of:

1. the primary implementation period,
2. the extended implementation period, or
3. both the primary and extended implementation periods (e.g. monitoring of the Management Area for PFAS).

1.7.4 A living document

The science of understanding PFAS impacts and ways of managing PFAS contamination are constantly evolving. There is still a lot that is not established about the impacts of PFAS contamination on human health and the environment. Similarly, remediation technologies, and of the required scale, are at various stages of research and development.

This PMAP has been prepared based on information available at the time of writing and relies on the findings of the DSI and the Risk Assessments and the assumption and limitations contained therein. Defence recognises that there may still be gaps in information that will be progressively addressed while impacted sites are being managed.

This document will be reviewed annually (or earlier if required). As implementation of the PMAP progresses, detailed plans supplementary to this PMAP will be prepared (as required) to address the individual management actions that have been identified in this PMAP.
Figure 2: Defence PFAS management process

INVESTIGATION | RISK ASSESSMENT | INTERIM RESPONSE ACTIONS | PMAP DEVELOPMENT | PROCUREMENT | PMAP IMPLEMENTATION
---|---|---|---|---|---
PSI | | Preliminary development | | | DSI
DSI | DSI REPORT | HHRA / HHRA / ERA Report | | | PMAP development
Preliminary development | PMAP development | Consultation / Revision | Tender Response / Evaluation | Services / supply contracts | PMAP Primary Implementation Period
HHRA / HHRA / ERA Report | PMAP Extended Implementation Period | Periodic implementation review

19 December 2019
2 PROFILE OF THE MANAGEMENT AREA AND MONITORING AREA

2.1 Description

RAAF Townsville is located in Townsville, North Queensland, located approximately 5 km west of the centre of Townsville (Figure 1a). The Management Area comprises the metes-and-bounds of the Base and is adjacent to Townsville Airport, residential and commercial suburbs of Garbutt, Rowes Bay, West End, Belgian Gardens, Pallarenda, Mount St John, Mount Louisa and Bohle (Townsville City Council (TCC) areas). The Base is also adjacent to the Townsville Town Common Conservation Park (the Town Common), a wetland listed on the Register of the National Estate.

The Base identification details are provided below.

<table>
<thead>
<tr>
<th>BASE ADDRESS</th>
<th>INGHAM ROAD, GARBURT, QUEENSLAND 4814</th>
</tr>
</thead>
</table>
| Legal identification (and area 6) | • Lot 282 on Crown Plan (CP) EP566 (3.202 hectares, ha)  
• Lot 418 on CP EP1061 (0.414 ha)  
• Lot 24 on CP EP2392 (1.349 ha)  
• Lot 23 on CP EP802462 (25.790 ha)  
• Lot 185 on Registered Plan (RP) 713911 (71.326 ha)  
• Lot 2 on RP713978 (3.286 ha)  
• Lot 249 on RP714146 (6.692 ha)  
• Lot 299 on RP716007 (2.972 ha)  
• Lot 314 on RP716876 (0.081 ha)  
• Lot 2 on RP720375 (2.023 ha)  
• Lot 3 on RP722429 (2.640 ha)  
• Lot 4 on RP722429 (2.483 ha)  
• Lot 1 on RP723988 (8.210 ha)  
• Lot 2 on RP723988 (2.135 ha)  
• Lot 3 on RP724098 (120.255 ha)  
• Lot 2 on RP746229 (7.898 ha)  
• Lot 1 on RP747057 (4.885 ha)  
• Lot 22 on RP748033 (401.856 ha)  
• Lot 1 on RP728951 (3.436 ha)  
• Lot 1 on RP802442 (0.068 ha)  
• Lot 7 on RP859800 (58.620 ha)  
• Lot 119 on RP907107 (5.427 ha)  
• Lot 100 on Survey Plan (SP) 100497 (1.700 ha) |
| Latitude | • -19.249217°S (approximate centre of Base – air traffic control tower building) |
| Longitude | • 146.767146°E (approximate centre of Base – air traffic control tower building) |
| Total Base area | • 738.327 ha |
| Management Area | • On-Base: 7.4 km² |
| Monitoring Area | • On-Base: 7.4 km²  
• Off-Base: 70.2 km² |
| Current Base name | • RAAF Townsville |

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6 Areas of Lot/Plans gained from QueenslandGlobe™
Townsville Airport comprises the commercial areas including terminals, maintenance and storage hangars, aircraft refuelling facilities, car parks and associated commercial businesses. The airport has an area of approximately 80.5 ha.

The Monitoring Area includes residential areas that have a cumulative area of approximately 2,506 ha and comprises the residential suburbs of Pallarenda, Rowes Bay, West End and Belgian Gardens. Land use is primarily residential; however, various public facilities and parklands also exist in these suburbs. The suburb of Garbutt is a mix of approximately 50% residential and 50% commercial. Garbutt State School is also located in the Monitoring Area. The suburbs of Mount Louisa, Mount St John and Bohle are zoned commercial/light industrial under the Townsville City Plan.

The Town Common is zoned “Public Utilities – Townsville City Council (Reserves)” and “Special Uses – National Parks” under the Townsville City Plan. The Monitoring Area also includes the Bohle River and Bohle River estuary, which is used extensively for recreational fishing.

2.2 Environmental setting

The following sections provide a summary of the environmental setting for the Management Area (i.e. the Base) and the Monitoring Area, which surrounds the Management Area. Further detail is provided within Section 2.3 of the DSI Report (WSP 2018a) and Seasonal Monitoring Reports (WSP 2019a, 2019c).

2.2.1 Climate

The climate of Townsville is classified as tropical; however, due to its geographical location and localised influences of topography and landform, rainfall is lower than other locations on the coast of North Queensland. The months of October to April (wet season) are hot and humid, whereas May to September (dry season) is dry with warm days and cool nights (BOM 2017).

The average annual rainfall at the Base is 1132.2 mm, with the mean minimum rainfall of 10.4 mm in September and the mean maximum rainfall of 296.6 mm in February. Rainfall varies significantly year to year, with significant rainfall that can cause localized flooding during the wet season.

In March 2018, a significant rainfall event of approximately 300 mm in three days resulted in pooled run-off water at all discharge locations and on grassed, hardstand, concreted and asphalted areas across the Base. Pooled water also covered the road to the southwest of runway 07/25. Active discharge off-Base was observed through drainage runoff into Mundy Creek and via pumping from ponded areas into the on-Base Lake Lydeamore and Three Mile Creek.

The average maximum temperature annually is 28.9°C and the average minimum temperature annually is 19.8°C. The maximum monthly mean temperature occurs in December with a mean
maximum temperature of 31.5°C. The minimum monthly mean temperature is 13.7°C and occurs in July.

Annual average wind directions are predominantly south-easterly in the morning and north-easterly in the afternoon. Wind directions are more southerly in the dry season in the morning, but there is no seasonal difference in the afternoon wind direction.

2.2.2 Topography

The Base and surrounds are generally flat and low lying associated with the Bohle River and Town Common wetlands system, and is subject to flooding. The Base and airport have an elevation between 2 mAHD and 5 mAHD, which falls slightly to the north and north-west, reaching sea level in the Town Common and on the beach at Pallarenda and Rowes Bay.

Small volcanic hills with a maximum height of 35 mAHD are present in Rowes Bay and Mount St John.

2.2.3 Surface Water

The Monitoring Area has three main surface water catchments, the Bohle River drainage sub-basin, Three Mile Creek and Mundy Creek (Figure 1). The surface water setting of the Monitoring Area is described as follows:

Base (Management Area)

Three main drainages flow into the Base, Louisa Creek, Peewee Creek and Mount St John Drain. The main inflow comes from Louisa Creek, with an upper catchment of approximately 745 ha and high peak flows with little potential for ground infiltration due to the topography, which is generally flat and urbanised. Peewee Creek drains an urban catchment of 156 ha to the south-east of the Base. It is a small water course that flows into Louisa Creek the Base to the west of Sub-Management Area 3.

Drainage of a catchment to the west enters the Base through the Mount St John Drain. The Mount St John Drain is separated from Louisa Creek by an elevated ridge line and the Mount St John water treatment plant (WTP). The primary flow path of the drain is north, away from the Base; however, in high flow event there is potential for flow to back up around the ridge line into Louisa Creek, impacting the Base.

The internal catchment of the Base catchment is approximately 700 ha, most of which drains towards the north-west into the Louisa Creek flood plain and the Bohle Estuary. The catchment is made up of mostly mix grassed and wetland areas, including Lake Lydeamore, with the remainder being buildings and hardstand. There are localised drainage issues within the south-western section of the Base due to the concentrated proportion of impervious area (Sub-Management Area 3) and minimum hydraulic capacity of the drainage network. The on-Base wetlands are generally internally draining, only discharging at times of heavy rainfall.

Four other catchments exist on the Base:

- A network of drains in the south-east corner of the Base flow off-Base to the east and then north into the Mundy Creek catchment and, in turn, Rowes Bay. The catchment consists of a mixture of hardstand, buildings and grassed areas, the largest grassed area being the former firefighting grounds (Sub-Management Area 1).

- A drainage network runs north between the ordnance loading aprons (OLAs) and Runway 01/19, which discharges from the Base through valved pipework on the Base’s northern boundary. The discharge then runs northerly through a network of wetlands past the Rowes Bay Golf Club and into Three Mile Creek. A drain runs along the Base’s eastern boundary at the northern end of the Base beyond Runway 01/19 and discharges at the Base’s north-eastern corner into the wetlands that run north past Rowes Bay Golf Club.
• A drainage network runs north between Runway 01/19 and the eastern boundary of the Base. These drains run north and south and discharge into the drain at the end of Old Common Road. This watercourse flows east into Mundy Creek and then Rowes Bay.

• The area to the north of Runway 01/19 along the eastern boundary of the Base appears to drain east into the watercourse that runs south-east to the north of the Belgian Gardens Cemetery, joining Mundy Creek before flowing into Rowes Bay.

Sections of the Base adjacent to the runways subject to inundation have pumping networks designed to prevent flooding of the runways. Surface waters are pumped from sumps into the wetlands on the western, north-western and northern sides of the Base.

**Townsville Airport (Monitoring Area)**

As Townsville Airport shares the same runway (Runway 01/19) as the Base, the drains near the runway and on the eastern border of the Base, run through Townsville Airport, into Rowes Bay and exit at Mundy Creek.

**TCC Area (Monitoring Area)**

At the northern suburb of Pallarenda, Three Mile Creek runs from the Town Common and branches out- south towards Rowes Bay and an exit towards the ocean, north of Rowes Bay Park. The watercourse is part of the Bohle drainage division. Three Mile Creek is joined by the watercourse that drains the northern part of the Base and the Rowes Bay Golf Club.

Drainage from the eastern and northern parts of Garbutt, Belgian Gardens and the northern part of West End run through a network of drains to the north, joining Mundy Creek and running into Rowes Bay.

There are canals running through the south-western section of Garbutt, which flow west into Louisa Creek, which flows north from Mt Louisa, joining Louisa Creek in the wetlands to the west of the Base.

Canals/drainage flowing from Mount Louisa end on the south side of Mount St John. Drainage and some canals also run through the outside of the industrial area, north of Mount St John. The canals on the northern section flow into Louisa Creek.

The south-western section of Garbutt and most of the suburb of West End drain to the south, entering the unnamed lake between Ingham Road and Woolcock Street, which overflows eastward into National Creek. National Creek joins Ross Creek approximately 3.7 km east of the Base, which then flows north-east, entering Cleveland Bay at the Port of Townsville.

**Town Common (Monitoring Area)**

The Town Common includes a large part of the estuarine system and drainage from the Bohle River, including Peewee Creek, Louisa Creek, and Three Mile Creek. Within the Town Common, a 1.07 ha perennial lake is located near Causeway Road and Freshwater Lagoon Road. The Town Common receives surface water runoff from the Base and from the TCC suburbs of Bohle, Mount Louisa and part of Garbutt.

### 2.2.4 Geology

The general underlying geology of the Monitoring Area is Quaternary alluvium comprising of clay, silt, sand and gravel (DME 1997). The surface geology is presented in the DSI Report (WSP 2018a), with the predominant lithology being clayey soils.

**Base (Management Area)**

The Townsville geological mapsheet (DME 1997) indicates that the Base has an underlying geology of Quaternary alluvium comprised of silt and clay of intertidal deposits, underlain by quartz sand,
minor shells of beach barrier deposits; estuarine, alluvial clay, silt and sand; which are underlain by older clay, silt, sand, gravel from flood plain alluvium on high terraces.

The underlying basement is described as Julago Volcanics, comprising rhyolitic to andesitic lava, tuff, volcanic breccia, agglomerate with some conglomerate, sandstone, siltstone, shale and coal seams (DME 1997).

SKM (2008) explained the geology in more detail and describe that the basal sediments comprise of Pleistocene, quartzose, fluviatile sands and gravels deposited by the Ross/Bohle River Systems during the most recent glacial period approximately 15,000 years before present (BP). Furthermore, in the early Holocene (~8,000 BP), deposition was dominated by shallow marine and estuarine clays, as mentioned above, and is overlain by coastal plain sediments comprising silts, clays and minor sands; sandy paleo-channels; and the development of small strand plain of shallow sand dunes and swales along the shores of Rowes Bay (SKM 2008).

Previous investigations by Maunsell (2005) has noted that the typical soil lithology is as follows:

- Sandy to clay-sand fill (0.6–1.0 m)
- Grey clay with high plasticity (1.2–1.8 m), becoming brown silty clay; and
- Coarse sand from the Holocene to Pleistocene fluvial sands and gravels.

SKM (2008) added that these lithologies grade into deeper sands and gravels linked to paleo-drainages of the Ross River and Louisa Creek systems.

The sub-surface conditions encountered on-Base during the DSI (WSP 2018a) varied between locations but generally consisted of clay and silty and/or sandy clay with some layers of silty, fine to coarse grained sand. This lithology is consistent with previous investigations (SKM, 2008; GHD, 2011).

**Townsville Airport (Monitoring Area)**

The underlying geology of the Townsville Airport is Quaternary alluvium comprising of clay, silt, sand and gravel; and flood plain alluvium on high terraces overlain by estuarine and alluvial clay, silt and sand in some areas towards the west, adjacent to the Base (DME, 1997).

**TCC Area (Monitoring Area)**

The suburbs of Town Common, Pallarenda, Rowes Bay, Belgian Gardens, West End and Garbutt have an underlying geology of quartz sand, minor shells from beach barrier deposits overlain by silt and clay from intertidal deposits (DME, 1997). In the Town Common and at Belgian Gardens the sands were underlain by silty/sandy clays, indicating the sands become thinner further from the coast, pinching out approximately 1 km from the coast at Rowes Bay/Belgian Gardens and approximately 2 km from the coast in the Town Common.

Garbutt is underlain by clay, silt, sand, gravel and flood plain alluvium (DME 1997). The lithology encountered during the DSI (WSP 2018) was consistent with DME (1997). Silty/sandy clays were found to the maximum depth of investigation (11 mbgl) at Garbutt and a two metre interval of gravel was intersected in MW216, at Belgian Gardens, which may be representative of the fluvial sand and gravel hosted aquifers that have been reported to underlie the Late Holocene sediments (SKM, 2008). The eastern part of Belgian Gardens and the northern section of West End are underlain by the Permian Castle Hill Granite, comprised of biotite leucogranite and microgranite with minor granophyre and granodiorite (DME 1997).

Mount St John has an underlying geology of Permian Julago Volcanics comprised of rhyolitic to andesitic lava, tuff, volcanic breccia, agglomerate, some conglomerate, sandstone, siltstone, shale and coal seams. It is overlain by Quaternary alluvium comprising of estuarine and alluvial clay, silt and sand; and further overlain by silt and clay from intertidal deposits (DME 1997).
Bohle has an underlying geology of Quaternary alluvium comprising of estuarine and alluvial clay, silt and sand; and further overlain by clay, silt, sand, gravel and flood plain alluvium. The northern part of Bohle is also underlain by silt and clay from intertidal deposits (DME 1997).

The sub-surface lithologies encountered during the DSI (WSP 2018) across the suburbs of Garbutt, Mount Louisa and Bohle correlate with the Late Holocene coastal plains sediments comprising silts, clays and sands as described by SKM (2008).

**Town Common (Monitoring Area)**

The Town Common has an underlying geology of Quaternary (Holocene) alluvium comprising of silt and clay from intertidal deposits underlain by quartz sand and minor shells from beach barrier deposits (DME 1997). The southern area of the Town Common is underlain by estuarine and alluvial clay, silt and sand, and a small part of the Town Common is further underlain by Quaternary colluvium comprising of boulders and cobbles with interstitial sand and clay, and talus deposits.

**2.2.5 Hydrogeology**

The findings of the DSI (WSP 2018) led to the following hydrogeological conceptualisation:

- A shallow aquifer comprised of interbedded clays, silts and sands, which form a connected, semi-confined aquifer across the Base, with a water depth of approximately 1.5 mbgl to 2.5 mbgl. It is likely this semi-confined aquifer is at least partially connected to the underlying fluvial sand and gravel-hosted aquifers, which are reported to be present at a depth of 5 mbgl to 10 mbgl (SKM 2008), but were not confidently identified in the DSI (WSP 2018). No evidence was observed to support the existence of a shallow perched aquifer in the top one to two metres at the Base, including in the review of historical groundwater investigations.

- The clay/silt/sand aquifer appears to have a depth at least that of the maximum depth of investigation, which was 11 mbgl in Garbutt and 8 mbgl on-Base. Therefore, the clay/silt/sand aquifer has a thickness of at least 5.5 m to 9.5 m. This aquifer was intersected below the coastal sands on-Base, at the Town Common, Rowes Bay and in Belgian Gardens, and is likely to underlie the sands beneath the coastal sand dunes. Similar material was intersected at Bohle, suggesting that the unit extends across the entire coastal plain between the coastal sands and the outcropping granites and volcanics of Castle Hill, Mount Louisa and Many Peaks Range.

- A shallow sand-hosted aquifer overlies the clay/silt/sand aquifer in Cleveland Bay, Rowes Bay and Pallarenda, and had a maximum depth of 6.5mbgl. The sand aquifer is likely to be several metres thicker in the centre of the sand dunes running parallel to the coast, thinning both eastwards and westwards. The eastern extent of this aquifer is not known as it extends offshore beneath Cleveland Bay. The sand aquifer extends approximately 2 km inland in the Town Common and narrows to the south, extending approximately 1 km inland at the Base and 500 m inland at Rowes Bay and Belgian Gardens.

- A deeper, semi-confined aquifer has been reported to exist beneath the Base (SKM 2008), located in sands and gravels associated with Quaternary paleo-channels at depths between 15 mbgl and 40 mbgl. This aquifer was not intersected during drilling for the DSI (WSP 2018a).

Groundwater contours derived from groundwater gauging undertaken during the DSI (WSP 2018a) and the Seasonal Monitoring (WSP 2019a, 2019c) indicate groundwater flows in a northerly direction across the Monitoring Area towards the Town Common and Rowes Bay. An elongated piezometric high extends from Garbutt south of the Base in a north-north-easterly direction through the southeast portion of the Base to Townsville Airport. Therefore, groundwater flow from the Base is partially radial, being westward from Sub-Management Area 3, north-westerly from the fire station (Sub-Management Area 2) and OLAs, north-easterly from Townsville Airport and easterly from the domestic area of the Base. Groundwater flows westerly to Peewee Creek/Louisa Creek, north-westerly to the Town Common wetlands and north-easterly and easterly to the Mundy Creek catchment and Rowes Bay. Areas of elevated water levels appear to exist in the paleo-dune system at Rowes Bay.
2.2.6 Soil

The soils underlying the majority of the Monitoring Area (the Base and Garbutt) comprises thin light grey-brown fine sandy loam or silty loam over dark grey heavy clays. The low-lying areas of the Town Common and Mundy Creek have soils comprised of fine sandy loam or loam overlying very dark greyish brown and olive heavy clays, or grey cracking clays. The coastal areas of Rowes Bay and Pallarenda have coarse sandy soils.

2.2.7 Flora and Fauna

The majority of the Monitoring Area is cleared land (airport and Base) or low-density residential and commercial/industrial land use, with little to no remnant vegetation.

The majority of the Town Common is designated a Conservation Park under the Nature Conservation Act 1992. The Town Common and the estuarine reaches of the Bohle River are part of the Bohle River Fish Habitat Area (FHA-027), which is designated ‘Management Level B’ (NPSR 2012) for its importance to recreational, traditional and commercial fisheries (NPSR 2012). No part of the Management Area is designated ‘Management Level A’. The estuarine reaches of the Town Common and Bohle River, including the on-Base wetlands to the west and south of the OLAs, are mapped as having very high and high aquatic conservation values respectively under the Queensland Aquatic Conservation Assessment (AquaBAAM) mapping (Rollason and Howell 2012). The freshwater wetlands are mapped as having high ecological significance and matters of State environmental significance (MSES) under the State Planning Policy (SPP) (DILGP 2017).

The Town Common is classified ‘Category B – Remnant vegetation’ on the Regulated Vegetation Management Map, with a section at the centre of the Town Common classified as ‘Essential Habitat Category A or B’. The lower reaches of the Bohle River are classified as ‘Category R – Reef regrowth watercourse vegetation’.

A review of previous ecological assessments (AECOM 2015) and database records demonstrates that the Town Common and Bohle River support a diverse community of commonly occurring aquatic biota and variety of aquatic habitats including freshwater wetlands and waterways, and estuarine wetlands and waterways (supporting mangroves, saltmarsh and claypans).

The wetlands in the upper reaches of Three Mile Creek between the Base and the former Rows Bay Landfill are mapped as having high aquatic conservation values under AquaBAAM mapping (DEHP 2017). The lower reaches of Three Mile Creek are also included in the Bohle River Fish Habitat Area. Portions of the Three Mile Creek and Mundy Creek wetlands are classified ‘Category B – Remnant vegetation’ on the Regulated Vegetation Management Map, with the banks of the lower reaches classified as ‘Category R – Reef regrowth watercourse vegetation’.

2.2.8 Current and Projected Land Uses

Current land use in the Monitoring Area is described in Section 2.1 and is comprised of the Base and Airport, (joint use military and civilian airfield facility), residential suburbs, commercial/industrial suburbs and environmental reserves.

The projected land uses in the Monitoring Area are not expected to change significantly in the foreseeable future according to the Townsville City Plan (TCC 2014). Additional low to medium density housing may be constructed in the currently vacant areas of Garbutt to the east of the Base, and additional commercial/light industrial development may occur on the State-owned land to the north-east of the Townsville Airport.

The current land uses immediately surrounding the Monitoring Area comprise residential suburbs to the east, commercial and light industrial suburbs to the south and south-west, Bohle River and adjacent wetlands to the west, non-wetland section of the Town Common (Many Peaks Range) to the north and the Coral Sea (Rowes Bay) to the north-west. The projected land uses for the surrounding area are not expected to change significantly according to the Townsville City Plan (TCC 2014).
2.3 Management Area complexity scale

The scale of the Management Area is rated as Medium in accordance with the table below, as the HHRA (WSP, 2018b) identified negligible / acceptable risk to off-Base human-health (i.e. the community) which forms one of the Very Large and Large complexity scale rating.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Large</strong></td>
<td>• High number of identified risks</td>
</tr>
<tr>
<td></td>
<td>• Multiple areas of contamination, both on-Base and off-Base</td>
</tr>
<tr>
<td></td>
<td>• Hydrogeological profile facilitates rapid migration of contamination</td>
</tr>
<tr>
<td></td>
<td>• Large impacted community</td>
</tr>
<tr>
<td></td>
<td>• PMAP complex</td>
</tr>
<tr>
<td></td>
<td>• Development / implementation timeframe: highly extended</td>
</tr>
<tr>
<td><strong>Large</strong></td>
<td>• Medium number of identified risks</td>
</tr>
<tr>
<td></td>
<td>• Multiple areas of contamination, both on-Base and off-Base</td>
</tr>
<tr>
<td></td>
<td>• Medium-sized impacted community</td>
</tr>
<tr>
<td></td>
<td>• PMAP moderately complex</td>
</tr>
<tr>
<td></td>
<td>• Development / implementation timeframe: extended</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>• Small-medium number of identified risks</td>
</tr>
<tr>
<td></td>
<td>• Localised areas of contamination both on-Base and off-Base</td>
</tr>
<tr>
<td></td>
<td>• PMAP simplified</td>
</tr>
<tr>
<td></td>
<td>• Development / implementation timeframe: medium</td>
</tr>
<tr>
<td><strong>Small</strong></td>
<td>• Small number of identified risks</td>
</tr>
<tr>
<td></td>
<td>• Contamination currently confined to isolated locations on-Base</td>
</tr>
<tr>
<td></td>
<td>• Potential risk of contamination to a small number of sensitive receptors</td>
</tr>
<tr>
<td></td>
<td>• Basic PMAP</td>
</tr>
<tr>
<td></td>
<td>• Development / implementation timeframe: medium</td>
</tr>
</tbody>
</table>

2.4 Extent of contamination

2.4.1 PFAS Source Areas

The use of legacy AFFF (3M Lightwater) formulations was phased out across the Defence Estate after 2004. Therefore, this primary PFAS source is no longer used at the Base. However, a secondary, ongoing PFAS source is provided by the impacted environmental media (e.g. soil, surface water and groundwater) at the Base. The AFFF Ansulite, which does not contain PFOS, PFHxS or PFOA, but does contain other PFAS compounds, continues to be used on the Base for emergency situations; however, its use is managed to minimise the risk of release into the surrounding environment.

A number of potential source areas where legacy AFFF was used and introduced into the environment were identified in the DSI (WSP 2018a). Intrusive investigations undertaken during the DSI have identified areas where elevated PFAS concentrations remain in the soil. PFAS was detected all but three soil bores drilled on-Base for the investigation. The highest concentrations were generally associated with previously identified potential source areas; however, the presence of lower concentrations in shallow soils across the Base appears to be almost ubiquitous. Up-gradient PFAS was detected in surface water samples collected from Louisa and Peewee Creeks and the Bohle River, and groundwater samples collected from monitoring wells in Garbutt and Bohle, indicating the potential presence of off-Base PFAS sources in Garbutt and Bohle. However, the relative contribution of PFAS from these background sources is considered minor when compared with the contribution from the Base.

Groundwater sampled from all monitoring wells on the Base returned elevated PFAS concentrations, indicating widespread PFAS in groundwater impact beneath the Base; however, elevated
concentrations are associated with individual source areas rather than being at a uniform concentration across the Management Area.

The detection of PFAS in all off-Base monitoring wells to the north-west, north, north-east, south-east and east of the Base suggests that groundwater ‘plumes’ have transported PFAS off-Base in these directions. However, irregularities in the results, such as the anomalously high results in MW206 and MW216, suggest that the groundwater impacts are not continuous plumes’ in the traditional hydrogeological sense i.e. a relatively homogeneous dissolved mass of chemical with steadily declining concentration away from the primary source. Elevated concentrations of PFAS in groundwater at a distance from the Base are considered more likely to be a result of surface water PFAS transport with subsequent infiltration of PFAS impacted water into the underlying aquifer.

Impacted groundwater acts as a secondary source of PFAS impact via the extraction of groundwater for the irrigation of lawns and gardens, including fruit and vegetables at residences in Garbutt, Belgian Gardens, Rowes Bay and Pallarenda.

The following activities are considered to have resulted in the most significant PFAS impact to soil, surface water, sediment and groundwater on the Base:

- **Historical fire training and equipment testing and purging at the former fire training ground (Sub-Management Area 1).**
- **Unknown activities, possibly fire response training exercises, equipment testing and sparging of fire truck tanks at Fuel Farm 2 (part of Sub-Management Area 2).**
- **Historical fire training, equipment testing and sparging of fire truck tanks and AFFF spills at the fire station (part of Sub-Management Area 2).**
- **Testing of deluge systems, including discharges and spills from hangars (e.g. Hangar 295 & Hangar 236) (Sub-Management Area 3).**

Refer to the DSI (WSP 2018a) and Seasonal Monitoring Reports (WSP 2019a, 2019c) for figures presenting the distribution of PFAS contamination associated with the Sub-Management Areas listed above.

### 2.4.2 Nature and Extent of PFAS Impacts

The results of the DSI (WSP 2018) and Seasonal Monitoring Reports (2019a, 2019c) are summarised below.

The principle PFAS present at the base is PFOS, with significant concentrations of PFHxS usually present and PFOA also present but at lower concentrations. Numerous other PFAS were detected across the Base; however, they were generally only detected where concentrations of PFOS and PFHxS were elevated and their concentrations were significantly lower than the PFOS+PFHxS concentrations.

#### Soil

Two exceedances of industrial/commercial HSLs were detected in the former fire training ground (Sub-Management Area 1). Twenty-six exceedances of residential HSLs were detected in the area, which includes the domestic portion of the Base to the south of Sub-Management Area 2.

No PFAS compounds were detected in off-Base soils in excess of soil health-based guidance values (HBGLs) or ecological screening levels. PFOS and PFHxS were detected in soil within the Town Common and Garbutt at concentrations below the nominated guidelines.

Despite the low and acceptable risks from identified soil impacts at the Base to human health and the environment, the potential exists for secondary impacts from the soil as a result of leaching and migration into groundwater and surface water.
Groundwater

PFAS was detected in groundwater from the majority of wells on the Base; however, the absence of PFAS in isolated monitoring wells suggests that there isn’t one continuous PFAS ‘plume’ beneath the Base, but a series of PFAS ‘plumes’ related to specific source areas and possibly surface water bodies. Plumes were interpreted to extend to the east and north-east from the south-eastern section of the Base, west and north-west from Sub-Management Area 3 and north from the northern end of the runway. The highest PFAS concentrations were generally reported from monitoring wells installed at the known source areas or immediately downgradient of the source areas.

The detection of PFAS in off-Base monitoring wells to the north-west, north, north-east, south-east and east of the Base suggests that groundwater ‘plumes’ have transported PFAS off-Base in these directions. However, irregularities in the results, such as the anomalous results in MW206 (Town Common) and MW216 (Belgian Gardens), suggest that the groundwater impacts are not continuous ‘plumes’ in the traditional hydrogeological sense i.e. a relatively homogeneous dissolved mass of chemical with steadily declining concentration away from the primary source. Elevated concentrations of PFAS in groundwater at a distance from the Base are considered more likely to be a result of surface water PFAS transport with subsequent infiltration of PFAS impacted water into the underlying aquifer. This mechanism is considered to still be operating in the surface water bodies of the Town Common and the Three Mile Creek and Mundy Creek catchments.

The groundwater impact to the south-east of the Base may be the result of an unidentified off-Base source.

Surface Water and Sediments

PFAS was detected in surface water and sediment on- and off-Base at concentrations exceeding the nominated guidelines. The results indicate that PFAS is being transported by surface waters from the Base into the Town Common, Louisa Creek, Three Mile Creek and Mundy Creek catchments. It is unclear whether the PFAS impacted sediments found at a distance from the Base in the DSI and DSI Addendum (WSP 2018a; 2019a, respectively) have been transported to those locations, or whether PFAS in surface water has been transported to the location and then bound to the sediments.

Results of samples collected up-gradient of the Base indicate a background source of PFAS exists in the upper catchments of Louisa and Peewee Creeks and in the middle reaches of the Bohle River during the DSI and DSI Addendum (WSP 2018a; 2019a, respectively). However, compared with the concentrations recorded in surface waters discharging from the Base, the background up-gradient input of PFAS concentrations to the Management Area is considered to be minor.

2.5 Stormwater

Immediately after the heavy rainfall event on 1 March 2018, widespread flooding occurred at the Base, resulting in pooled water at all discharge locations and on grassed, hardstand, concreted and asphalted areas across the Base. Pooled water covered the road to the southwest of Runway 07/25. Active discharge off-Base was observed through drainage runoff into Mundy Creek and via pumping from ponded areas on-Base into the Louisa Creek and Three Mile Creek catchments. Flowing water was observed in several creeks off-Base and pooled water was observed in most low-lying areas in parks, grassed areas and in the Town Common during the heavy rainfall event.

The large volumes of surface water observed to be draining off the Base into the surface water bodies of the Town Common and the Three Mile Creek and Mundy Creek catchments contained relatively high concentrations of PFAS. Concentrations of PFAS increased and plateaued with time during the discharge event (WSP 2019a), indicating a potential lag between rainfall and maximum PFAS release.
2.6 Groundwater use

Groundwater extraction in the Monitoring Area is restricted to shallow bores installed in the sand-hosted aquifer at Pallarenda and Rowes Bay, and to isolated shallow bores sourcing the relatively fresh water from the top of the clay/silt/sand aquifer in Garbutt and Belgian Gardens.

A water use survey was distributed to 2,500 residents and businesses within the DSI Investigation Area to identify the presence and use of groundwater bores. As at 27 April 2018, the project team received 166 Water Use Surveys via mail, email, phone and in person. Twenty-eight respondents to the survey indicated that they had bores on their property, 22 of which were operable and 18 of which were actively in use for water supply. Residential groundwater users have been identified in the surrounding suburbs of Garbutt, Belgian Gardens, Rowes Bay and Pallarenda. Residential groundwater use is limited to the irrigation of lawns, ornamental gardens and vegetables. No extracted groundwater was identified to be used for drinking purposes, stored in tanks or used to fill swimming pools.

PFAS concentrations in residential bores in the Monitoring Area were generally below detection limits or below the Health-Based Guidance Values (HBGVs); however, three bores in Garbutt contained concentrations of PFOS+PFHxS above drinking water guidelines when sampled in August 2017 and April 2018.

2.7 Relevant legislation and government policy

The PFAS National Environmental Management Plan (NEMP) aims to provide governments in Australia with a consistent, practical, risk-based framework for the environmental regulation of PFAS-contaminated materials and sites. It is framed as an adaptive plan, able to respond to emerging research and knowledge.

The PFAS NEMP provides the guiding framework for the management of PFAS. For further information, see: http://www.epa.vic.gov.au/PFAS_NMP.

Legislation and policy instruments relevant to the development of options for PFAS management in the Management Area is set out and discussed in Appendix A.

Other key drivers and constraints impacting upon response management may include:

- Environmental Protection Act 1994 and derivative regulation and policy as it applies to land contamination and PFAS; and

2.8 Stakeholders

A range of stakeholders have been identified during the completion of the investigation. Defence will continue to engage with these groups during the implementation of response management actions identified in this documents.

Federal Government agencies are listed below:

- Department of Health (DoH)
- Department of Environment and Energy (DoEE)
- Department of Infrastructure, Regional Development and Cities (DIRDC)

Queensland Government agencies are listed below:

- Health
- Department of Environment and Science (DES)
PFAS MANAGEMENT AREA PLAN – RAAF TOWNSVILLE

- Department of Agriculture and Fisheries (DAF)
- Department of Natural Resources, Mines and Energy
- Townsville City Council (TCC)
- Great Barrier Reef Marine Park Authority (GBRMPA)
- Townsville Airport Pty Limited (TAPL)

Commonwealth and State members of Parliament:

- Federal Member of Parliament: Herbert
- State Member of Parliament: Townsville

Community:

- Impacted community (community members resident in the Monitoring Area)
- Recreational fishers within the Monitoring Area
- General public and Indigenous communities accessing recreational areas within the Monitoring Area

Efforts have been made to engage with the representatives of the Wulgurukaba people in the Monitoring Area, but no direct spokesperson had been identified.

Information has been provided to stakeholders through community walk-in sessions, factsheets, emails from the hotline, letterbox drops and face-to-face interactions. The community in the Monitoring Area are generally trusting of Defence and so the community relationship has been managed through proactive and pre-emptive engagement with the community. Thus far, community walk-in sessions that have been undertaken are as below:

- 29 November 2016 - communicating the findings of the Preliminary Sampling Program and Defence's commitment to conducting an environmental investigation.
- 06 March 2017 - announcing that the Environmental Investigation was soon to commence and detail the name of the Lead Consultant (WSP) to conduct the environmental investigation.
- 14 June 2017 - announcing that a Water Use Survey (WUS) would be undertaken within the Investigation Area.
- 29 November 2017 - updating the community on the progress of the environmental investigation.
- 09 May 2018 - communicating the findings of the DSI report (WSP, 2018a) and the progress of the investigation, which includes a HHRA, Seasonal Monitoring Report 1 and ERA reports.
- 31 October 2018 - communicating the findings of the HHRA report (WSP, 2018b) and the progress of the investigation, which includes the Seasonal Monitoring Report 1 and ERA reports.
- 04 December 2019 - communicating the findings of the ERA report (WSP, 2019b), the Seasonal Monitoring Report 1 and 2 (WSP 2019a, 2019c) and the PMAP.
THREE MILE CREEK CATCHMENT

MUNDEY CREEK CATCHMENT

LOUSA CREEK/COMMON CATCHMENT

Lake Lydeamore

JIMMYS LOOKOUT

NQ107 Former Fire Training Area

NQ0055 Fire Station

NQ0099 Fuel Farm 2

AVIATION

Sub-Management Area 1

Sub-Management Area 2

Sub-Management Area 3

Legend

- Pump Outlets
- Watercourse/Drainage
- Road
- Railway
- Drainage Catchments
- Investigation Area
- Sub-Management Area
- RAAF Base Townsville
- Wetlands
- Lake Lydeamore
- Source Area

RAAF TVL PFAS Management Area Plan - Townsville, Queensland, 4810

Figure 1b

Management Area Plan (December 2019)

Scale ratio correct when printed at A3

Coordinate system: GDA 1994 MGA Zone 55

www.wsp.com
3 PMAP METHODOLOGY AND APPROACH

3.1 Overview of approach

This PMAP conforms with the intent of the PFAS National Environmental Management Plan (NEMP) (HEPA 2018). The Technical Working Group established under the Queensland Interdepartmental Committee on Fluorinated Fire Fighting Foam has been consulted in the development of this document. The Queensland DES coordinates the TWG.

Stakeholder engagement associated with specific response actions recommended through the development of the PMAP will be addressed as relevant in the detailed implementation documents for those actions.

The PMAP methodology steps through the following stages set out in this section.

3.2 Identify risks and consequences (Chapter 4)

The list of risks to be managed in this PMAP are identified as ‘elevated’ in either the DSIs (WSP, 2018a; 2019a) and/or the risk assessments (WSP 2018b; 2019b). A source / pathways / receptor analysis based on the Conceptual Site Model (CSM) in the DSIs was used to identify the relevant source (primary and secondary), pathways and receptors for the risk. For each risk, the range of potential consequences if the risk is realised have been identified.

3.3 Prepare Ongoing Monitoring Plan (Chapter 5)

An ongoing monitoring plan (OMP) forms a mandatory part of the PMAP and is therefore provided separately and has not been subject to the options analysis. The OMP is appended to this PMAP as Attachment 1.

3.4 Develop risk management options (Section 6.1)

Management option/s were identified to address each of the risks identified in Chapter 4. The list of options has been informed by a range of information and research, both general and specific to the Management Area. Management Area-specific information including:

- HHRA (WSP; 2018b), ERA (WSP; 2019b) and DSI reports (WSP, 2018a; 2019a),
- Relevant Commonwealth and State/Territory legislation,
- Feedback from stakeholder consultation (impacted community and jurisdictional regulator),
- IRM actions undertaken or continuing in the Management Area, and
- IRM or PMAP actions undertaken or considered by Defence on other properties.

The management options include

- the ‘do-nothing’ option. It provides the ‘base case’ against which other options are assessed, and may at times be the best available option when assessed against the criteria of ‘net environmental benefit’. It does not get assessed through this process but the potential impacts are described in the Chapter 4 analysis.
- IRM actions recommended under Section 2.7 for continued implementation are included as options for further assessment.
- Additional investigations required to address uncertainties and data gaps as identified through completion of the DSI.
- Community-level options for further assessment.

Identifying information for each option includes the objective and a description of how the objective contributes to managing the identified risk.
3.5 **Detailed options analysis (Section 6.2)**

For each risk, the following analysis was undertaken:

A. **Cost / effectiveness / impact analysis**

- 1. Cost range estimate
- 2. Effectiveness rating
- 3. Implementation period / timeframe
- 4. Potential impacts
- 5. Estimated net environmental benefit (not relevant for institutional controls)

B. **Risk-based analysis**

- 6. Proportion of action to risk
- 7. Best-practice status
- 8. Verification status
- 9. Technology assessment
- 10. Risks and mitigation
- 11. Key dependencies

C. **Defence implications**

- 12. Defence capability
- 13. Project fit
- 14. Scalability

D. **Stakeholder impacts, views and consents**

- 15. Jurisdictional regulator/s
- 16. Owner / occupier consents and views
- 17. Community

E. **Comparative analysis**

Comparative analysis comparing the available options to manage an identified risk.

Details of the analysis for each of these factors are set out in Appendix C.

3.6 **Integrated options analysis (Section 6.3)**

Time and cost efficiencies and improved effectiveness may be found by looking for synergies between:

- other proposed PMAP response actions
- approved or proposed PMAP response actions in other Management Areas, and
- planned works involving infrastructure, maintenance or remediation of co-contaminants on the Defence property.

Where these synergies have been found, they are presented as an integrated package addressing the relevant sets of risks.

3.7 **Recommendations analysis (Section 7.1)**

The recommended set of PMAP response actions for each identified risk are based on the comparative analysis and the integrated analysis set out in Chapter 6.
4 IDENTIFIED RISKS AND CONSEQUENCES

4.1 Source / pathway / receptor analysis

The identification of sources of impact at RAAF Townsville and the associated pathways to receptors are described in the DSI report (WSP 2018a) and the Seasonal Monitoring Reports (WSP 2019a, 2019c). Quantification and evaluation of risks related to specific pathways are presented for human receptors in the Human Health Risk Assessment (WSP 2018b) and for ecological receptors in the Ecological Risk Assessment (WSP 2019b).

The HHRA (WSP 2018b) concluded that human-health risks to off-Base receptors were either acceptable or negligible, with the exception being ingestion of finfish offal (likely to be associated with the consumption of the whole of the organism) that could be managed by continued adoption of the mercury in fish advice from Queensland Health by recreational fishers in the waterways (i.e. three servings per week) within the Monitoring Area, that seeks to limit intake including to sensitive subpopulations. The HHRA was targeted in assessing exposure pathways that were potentially completed, based on known population behaviour. As human-health risk to off-Base receptors were either acceptable or incomplete, these have not been considered further in this PMAP.

The HHRA (WSP 2018b) identified that human-health risks to on-Base receptors were negligible and/or acceptable, with the exception of on-Base maintenance workers accessing sub-grade maintenance trenches. The exposure scenario assumed poor industrial hygiene practices and no adoption of personnel protective equipment (PPE). This unacceptable risk could be mitigated through reasonable adoption of hygiene and PPE, and given that areas of concern are listed on the CSR, management for this unacceptable human-health risk has not been considered further in this PMAP.

The ERA (WSP 2019b) identified potential unacceptable risks to species that exhibit the following attributes, with The Common and Mundy Creek being ecosystems of concern within the Monitoring Area:

- Aquatic invertebrates, amphibians and fish;
- Lower order terrestrial plants and terrestrial invertebrates;
- Terrestrial herbivorous\(^7\) mammals;
- Terrestrial herbivorous, invertivorous\(^8\), omnivorous\(^9\) and predatory birds;
- Aquatic herbivorous and predatory mammals; and
- Aquatic invertivorous and omnivorous birds.

The CSM describes the environment of The Common as a ‘sink’ for PFAS from surface water that sheds from the Base to the west in the Louisa Creek Catchment, with PFAS mass flux occurring predominately in surface water discharges during periods of high flow. This has been illustrated by the March 2018 surface water monitoring presented in the Seasonal Monitoring Reports (WSP 2019a, 2019c) and the occurrence of PFAS in biota (WSP 2018b, 2019b). With the exception of the quantum of suspended solid and water discharged from The Common during periods of high flow, The Common is a ‘sink’ as the predominant fate of PFAS in water, once entering, is for the water retained to evaporate thereby resulting in deposition of the transported PFAS into the ecosystem, which may further exacerbate risk.

Surface water in the southeast of the Base sheds into the Mundy Creek catchment, which like The Common, has PFAS mass flux occurring predominately in surface water discharges during periods of high flow. During these periods of high flow, the estuarine intertidal environment to the

\(^7\) Herbivorous - animal that consumes plants.

\(^8\) Invertivorous – animal that consumes invertebrates.

\(^9\) Omnivorous – animal that consumes both plant and animals.
south of the Rowes Bay community become inundated with overflow from Mundy Creek and during such events, the predominant fate of this water evaporation results in the addition of PFAS into the ecosystem.

A consequence of the PFAS mass flux observed during the high flow event detailed in the Seasonal Monitoring Reports (2019a, 2019c) was that an unknown quantity of the PFAS mass was discharged beyond the mouths of the waterways in the Monitoring Area and into Cleveland Bay. Whilst these punctuated releases could result in a relatively large mass of PFAS discharged, the only media that PFAS has been reported in Cleveland Bay is in marine biota below the FSANZ criteria (the source of which is likely due to animal interactions with The Common, the Bohle River and the creek mouths within the Monitoring Area) suggests that the PFAS floodwater pathway to Cleveland Bay presents a negligible or acceptable human-health and ecological risk.

In summary, surface water discharge during periods of high flow poses an unacceptable risk to the ecosystems of The Common and Mundy Creek due to ongoing PFAS mass flux into the Louisa Creek and the Mundy Creek Catchments (respectively). As the source-pathway-receptor linkages are completed and there are potentially unacceptable ecological risks (as defined in the ERA (WSP 2019b) as the potential for bioaccumulation), PMAP actions are premised on addressing these scenarios.

The source areas, migration pathways and receptor groups are described below.

<table>
<thead>
<tr>
<th>PFAS SOURCES</th>
<th>PATHWAYS RESULTING IN POTENTIALLY UNACCEPTABLE RISKS</th>
<th>RECEPTORS WHERE RISKS ARE POTENTIALLY UNACCEPTABLE</th>
</tr>
</thead>
</table>
| Source areas to Louisa Creek Catchment (i.e. The Common): | • Direct contact with PFAS impacted soil in an on-Base sub-grade maintenance trench. | Human Health 1:
| Fire Station NQ0055 | • Surface water runoff and stormwater discharges to on-Base drains, and surrounding wetlands and creeks. PFAS may also sorb onto soils and sediments within surface water drains and creeks. | • On-base sub-grade maintenance workers where no strategies are engaged to reduce exposure to PFAS impacted soil (e.g. PPE, personnel hygiene, etc.). |
| Fire Training Area NQ0107 | • The lateral migration of PFAS in surface waters off-Base. PFAS is then available for uptake via aquatic and terrestrial biota and transferred through the food web. | Ecological 2:
| Fuel Farm 2 NQ0099 | | • Aquatic invertebrates, amphibians and fish in impacted waters in source areas. |
| 5 AVN | | • Aquatic invertebrates, amphibians and fish in Louisa Creek and Mundy Creek Catchments. |
| Source areas to Mundy Creek Catchment: | | • Semi-terrestrial and terrestrial invertebrates, reptiles, amphibians, birds and mammals that consume aquatic organisms from Louisa Creek and Mundy Creek Catchments. |
| Former Fire Training Area NQ0054 | | |
| Source areas to Three Mile Creek Catchment: | | |
| Negligible and not applicable to this PMAP | | |

(1) Further detail in Human Health Risk Assessment (WSP 2018b). Other receptors and pathways did not indicate elevated intake.
(2) Further detail in Ecological Risk Assessment (WSP 2019b). Other receptors and pathways did not indicate elevated intake by direct or indirect routes.

A summary of the source-pathway-receptor pollutant linkages is presented in Appendix B.
4.2 Risk listing and consequences

Elevated risks have been identified related to statutory non-compliance with environmental values and ecological exposure, noting that human health risks off-Base were determined to be acceptable in the HHRA (WSP, 2018b) (with the exception being on-Base sub-grade maintenance workers whose risk can be managed through administrative controls). The risks were identified based on conditions described in the DSI (WSP 2018a) and Addendum DSI (WSP 2019a) reports and risks quantified in the ERA (WSP 2019b).

“Elevated” is defined as events that could lead to ecological exposure over the screening benchmarks or the no-observed-adverse-effect-level (NOAEL), breaches of legislation or regulatory notices.

The only elevated risk identified are the exposures of aquatic ecological receptors in surface waters and high order predators consuming these biota; and this is described further in the following table.

<table>
<thead>
<tr>
<th>Description &amp; Nature of Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXPOSURE OF AQUATIC ECOCLOGICAL RECEPTORS IN SURFACE WATERS, AND TO HIGHER ORDER PREDATORS CONSUMING THESE BIOTA.</strong></td>
</tr>
</tbody>
</table>

- **Description**
  - The ERA (WSP 2019b) made the following conclusions:
    - Surface water PFOS concentrations measured in waters discharging into and within the Louisa Creek, Mundy Creek and Three Mile Creek Catchments were above the screening level for assessment of adverse effects due to direct contact exposure by aquatic species and bioaccumulation within aquatic ecosystems (HEPA 2018).
    - There is the potential for direct toxicity effects to lower order terrestrial/semi-terrestrial and aquatic species. Further evaluation of potential risks to higher order species via a quantitative food web modelled concluded potential unacceptable risks via the potential for exposure to bioaccumulate PFOS through the food web:
      - Lower order terrestrial plants and terrestrial invertebrates;
      - Terrestrial herbivorous mammals;
      - Terrestrial herbivorous, invertivorous, omnivorous and predatory birds;
      - Aquatic herbivorous and predatory mammals; and
      - Aquatic invertivorous and omnivorous birds.

- **Pathway(s)**
  - Uptake into food web (ecological) from surface water impacts.

- **Receptor(s)**
  - Bioaccumulation into higher order ecological receptors including:
    - Aquatic invertebrates, amphibians and fish in impacted waters in source areas.
    - Aquatic invertebrates, amphibians and fish in Louisa Creek and Mundy Creek Catchments.
    - Semi-terrestrial and terrestrial invertebrates, reptiles, amphibians, birds and mammals that consume aquatic organisms from Louisa Creek and Mundy Creek Catchments.
### EXPOSURE OF AQUATIC ECOLOGICAL RECEPTORS IN SURFACE WATERS, AND TO HIGHER ORDER PREDATORS CONSUMING THESE BIOTA.

<table>
<thead>
<tr>
<th>Source(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Source(s)</td>
<td>PFAS in surface water discharging from the Base into the Louisa Creek and Mundy Creek Catchments.</td>
</tr>
<tr>
<td>Secondary Source(s)</td>
<td>PFAS in sediments in the Louisa Creek and Mundy Creek Catchments, which may act as an ongoing source of PFAS to surface water.</td>
</tr>
<tr>
<td>Contributing Source(s)</td>
<td>Overland surface water flow from impacted soil areas (such as former fire training area) into on-site drainage lines that discharge to the Louisa Creek and Mundy Creek Catchments. Other off-Base PFAS sources (not associated with the Base) due to potential mobility and migratory nature of aquatic species and higher order predators.</td>
</tr>
</tbody>
</table>

#### Consequence

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Impacts</td>
<td>Harm to ecological receptors has not as yet been demonstrated and potential endpoints (e.g. reduction in species diversity) is an unknown.</td>
</tr>
<tr>
<td>Potential Impacts</td>
<td>Aquatic ecological receptors have PFAS concentrations above trigger levels for ecological health. Adverse effects to ecological health from higher order bioaccumulation within food web.</td>
</tr>
<tr>
<td>Temporal Impacts</td>
<td>Ongoing contribution of PFAS from the primary and secondary source in the discharge of surface water from Base drainage lines to the Louisa Creek and Mundy Creek Catchments.</td>
</tr>
</tbody>
</table>

#### Extent

<table>
<thead>
<tr>
<th>Location and Extent</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Base surface water features, drainage channels and the Louisa Creek (The Common) and Mundy Creek Catchments as per Figure 1.</td>
<td>PFAS may be discharged beyond these waterways into Cleveland Bay during high flow events (e.g. flooding), although the resultant impact from this could be negligible and/or short-lived (noting that other than in biota (WSP 2018b, 2019b), PFAS has not been detected in Cleveland Bay).</td>
</tr>
</tbody>
</table>

#### Existing Management Measures

<table>
<thead>
<tr>
<th>Defence</th>
<th>Discontinue use of legacy AFFF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholders</td>
<td>No management measures enacted.</td>
</tr>
<tr>
<td>Potential Additional Controls</td>
<td>Source Management and/or isolation or reduction of soil-water interactions through surface water management to reduce PFAS flux to surface water.</td>
</tr>
<tr>
<td></td>
<td>Ongoing monitoring of ecosystem health, with a view to future ecological risk revision once ecosystem health is identified to be improving from contributing source management actions.</td>
</tr>
</tbody>
</table>
5 ONGOING MONITORING PLAN

5.1 Overview

The Ongoing Monitoring Plan (OMP) monitors changes to the contamination plume and surface water contamination characteristics in the Monitoring Area. Changes may result from the specific or cumulative impact of remediation or containment actions, existing transportation trends, changes to hydrogeology, or weather events.

The OMP is set out in Appendix E. An OMP forms a standard component of all PMAPs.

5.1.1 Objective and purpose

The objective of the OMP is to provide information on changes in PFAS contamination originating from a Defence Base to inform risk management decisions by Defence and State/Territory agencies to protect human health and the environment.

Data on changes in the distribution, concentration, transport (pathways and flow rates) and transformation of the contaminants and assessment against appropriate guideline values provides:

- an evidence base for targeted and effective risk management of PFAS contamination to protect human health and environmental receptors currently impacted by PFAS.
- an early warning that additional management of PFAS contamination may be warranted in areas not currently affected by PFAS.

5.1.2 Impacted decisions

Changes detected through the implementation of the OMP may inform a number of risk-management decisions including:

- additional investigations,
- re-assessment of one or more remediation or containment actions,
- additional remediation or containment actions,
- changing risk management actions at receptor level (e.g. provision or cessation of alternate drinking water supplies where bore water is the primary source of drinking water),
- changes to State/Territory advice on types of exposure-minimisation behaviours (e.g. consumption of home produce or seafood),
- changes to State/Territory advice on boundaries of a designated management area and the management zones within, and
- changes or refinements to the monitoring network, frequency and parameters.

5.1.3 Related documentation

One or more specific remediation action plans (RAPs) may be developed for the Sub-Management Area. The RAP(s) will contain specific on-going monitoring actions to assess and validate the impact of that remediation plan.

5.2 OMP communications

The following will be shared with relevant State/Territory authorities and made publicly available:

- OMP,
- monitoring data collected during the implementation of the OMP,
- decisions made in response to the data collected during implementation of the OMP, and
- changes to the OMP in response to incoming data over the implementation period.
5.3 **OMP summary**

The OMP will include the following monitoring:

- On-Base and off-Base groundwater monitoring wells; and
- On-Base and off-Base stormwater drainage network and surface water features.

The OMP also sets out uncertainties in investigations, monitoring and management that may require consideration of contingency measures and/or reassessment of risk with changes in conditions (higher concentrations of surface water, migration of groundwater), further investigations establishing a greater extent of groundwater than identified, or implementation of management measures.

The primary implementation period of the OMP will be three years during implementation of potential management options. After this time the extended implementation period of the OMP will be reviewed to assess the extent of the monitoring network and frequency required, based on the specific characteristics of the Monitoring Area, the behaviour of the plume measured against specific data trends, and the revision of risk that may occur based on the assessment of results obtained from the monitoring.

5.4 **OMP review**

The OMP will be reviewed annually in conjunction with the annual review of the PMAP, or the frequency of the review program may be tailored to site specific characteristics and the existing trend data available. The review frequency may be revised during the implementation period as more data becomes available.
6 OPTIONS IDENTIFICATION AND ANALYSIS

6.1 Options identification and analysis

This section summarises the analysis of the management options identified as available to address the range of risks identified in the DSI (WSP 2018a), the Seasonal Monitoring Reports (WSP 2019a, 2019c) and the HHRA (WSP 2018b) and ERA (WSP 2019b).

Details of the assessment are presented in Appendix D.

In developing the options for Sub Management Areas 1 - 3-specific information that has been considered includes:

- The outcome of the HHRA and ERA and each Sub-Management Area’s contribution of PFAS into the broader Monitoring Area.
- Relevant Commonwealth and State/Territory legislation;
- Feedback from stakeholder consultation (impacted community and jurisdictional regulator);
- IRM actions undertaken or continuing in the Management Area; and
- IRM or PMAP actions undertaken or considered by Defence on other properties.

The management options include:

- the ‘do-nothing’ option. It provides the ‘base case’ against which other options are assessed, and may at times be the best available option when assessed against the criteria of ‘net environmental benefit’. It does not get assessed through this process but the potential impacts are described in Section 4.
- IRM actions recommended under Section 2.7 for continued implementation are included as options for further assessment.
- Additional investigations required to address uncertainties and data gaps as identified through completion of the DSI (WSP 2018a) and Seasonal Monitoring Reports (WSP 2019a, 2019c). Furthermore, surface water flux modelling was commissioned to quantify the mass of PFAS discharge from the Base in surface water run-off and stormwater discharge events (WSP 2019c) so that there is a foundation from which the effect of mitigation strategies / interventions can be predicted.
- Community-level options for further assessment.

The range of potential remedial options considered have been based on plausible and proven technologies described in NEMP (HEPA 2018) and ITRC (2018). A summary of the techniques described in these documents is provided in Appendix D1.

Initial screening was undertaken for plausible options related to each type of risk, to identify options for detailed assessment. The screening level options assessment is provided in Appendix D. The following table lists the options identified for further analysis.

The ratings applied to each option are based on the criteria in Table 6.1 below.
### Table 6.1 Ranking definitions for remedial options

<table>
<thead>
<tr>
<th>Rating</th>
<th>Cost</th>
<th>Likelihood of success &amp; risk</th>
<th>Defence implications</th>
<th>Stakeholder impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>Prohibitive cost to achieve required clean-up target.</td>
<td>Method not verified or uncertain outcome. Potential to generate harmful secondary risks.</td>
<td>Prevention of critical Base operations.</td>
<td>Anticipate widespread community rejection or inconsistent with regulator requirements.</td>
</tr>
<tr>
<td>☣</td>
<td>Low cost to achieve method specific target.</td>
<td>Well established technique with a high likelihood of achieving objective.</td>
<td>Minor or no disruption of important Base activities.</td>
<td>Anticipate widespread acceptance by community and approval by regulator.</td>
</tr>
</tbody>
</table>

Designate an indicative timeframe for implementation:

**Primary implementation period**

Where an action extends across both the primary and extended implementation period, both should be designated. Different procurement actions may apply.

- **Short term**: 1-12 months from the date of the PMAP
- **Medium term**: 1-3 years

**Extended implementation period**

- **Long term**: beyond 3 years.
### Table 6.2 Remedial options assessment

<table>
<thead>
<tr>
<th>RISK</th>
<th>OPTION ID</th>
<th>OPTION TYPE</th>
<th>REMEDIAL OPTION</th>
<th>METHOD DESCRIPTION</th>
<th>RATING</th>
<th>SET-UP PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration of PFAS in surface water and stormwater from the Base</td>
<td>- -</td>
<td>- -</td>
<td>Base Case - Do Nothing.</td>
<td>No remediation undertaken. Continue monitor surface water discharges and environmental burden (sediment, surface water, groundwater orphan plumes, and possibly bioaccumulation in aquatic and semi-terrestrial biota).</td>
<td>L H L H</td>
<td>- -</td>
</tr>
<tr>
<td>Option 1</td>
<td>Pathway Interception</td>
<td></td>
<td>Hydraulic control of surface water to limit runoff from source areas.</td>
<td>Control / direct surface water transport at the Base to limit interaction with PFAS source areas through surface capping and / or altering base drainage and improvements to drainage features, culverts, etc. Hydraulic alterations at the Base will need to allow the airfield to remain operational during rainfall events.</td>
<td>M M M L</td>
<td>S</td>
</tr>
<tr>
<td>Option 2</td>
<td>Source Management</td>
<td></td>
<td>Containment of PFAS in soil via stabilisation/immobilisation techniques.</td>
<td>Addition of a binding agent to soil to immobilise PFAS. Applications can be made either in situ or ex situ, using conventional plant and equipment. Treatability trials with on-going monitoring required to demonstrate effectiveness and durability of the immobilisation process.</td>
<td>M M M L</td>
<td>M</td>
</tr>
</tbody>
</table>

---

10 S = Short term (1-12 months from the date of the PMAP); M = Medium term (1-3 years); and L = Long term (beyond 3 years).
<table>
<thead>
<tr>
<th>RISK</th>
<th>OPTION ID</th>
<th>OPTION TYPE</th>
<th>REMEDIAL OPTION</th>
<th>METHOD DESCRIPTION</th>
<th>RATINGS</th>
<th>SET-UP PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migration of PFAS in surface water and stormwater from the Base</td>
<td>Option 3</td>
<td>Source Management</td>
<td>Excavation and containment of PFAS impacted soil within purpose-built above-grade engineering facility.</td>
<td>PFAS impacted soils/sediments from source area are excavated and placed within an above-grade containment cell(s) with appropriate basal liner and cover system to prevent infiltration and PFAS leaching to underlying aquifer. Contamination cells are subject to long term management, including flood risk mitigation.</td>
<td>M L M L M</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>Option 4</td>
<td>Source Management</td>
<td>Excavation and off-Base disposal of impacted soils.</td>
<td>PFAS impacted soils are identified and excavated from source areas to control PFAS coming into solution when contacting soil. The soil is transported in accordance with Queensland waste transport regulations to a licenced facility for long-term containment or destruction.</td>
<td>M L M L</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Option 5</td>
<td>Source Management</td>
<td><em>Ex situ</em> treatment of PFAS impacted groundwater.</td>
<td>Extraction of contaminated groundwater via a network of extraction wells to reduce the mass at source areas.</td>
<td>H M L M</td>
<td>M</td>
</tr>
<tr>
<td>RISK</td>
<td>OPTION ID</td>
<td>OPTION TYPE</td>
<td>REMEDIAL OPTION</td>
<td>METHOD DESCRIPTION</td>
<td>RATING</td>
<td>$</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------</td>
<td>---</td>
</tr>
<tr>
<td>Migration of PFAS in surface water and stormwater from the Base</td>
<td>Option 6</td>
<td>Pathway Interception</td>
<td>Ex situ treatment of surface water to treat surface water through a WTP(s).</td>
<td><em>Ex situ</em> treatment of surface water through a WTP is technically feasible as the technology is employed to treat surface water and groundwater at other Bases. Hydraulic alterations at the Base would be needed to allow redirection and retention of surface water such that PFAS impacted surface water could be processed through the WTP prior to discharge off-Base. This could result in adverse effects such as increasing the risk of flooding at the Base and for the adjacent communities off-Base due to the retention of water. Without retaining water for treatment, the remedial efficacy of the intervention is greatly reduced. The remedial approach would also likely result in considerable cost to the Commonwealth. The scale of plant needed would be very large and at best could be expected to operate for one week in every two years. In the intervening period, it would continue to operate and draw cost to the Commonwealth whilst in care and maintenance.</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>
Note that due to the very large quantities of water during flood events and the negligible surface water flow in dry periods, \textit{ex situ} treatment of surface water through a water treatment plant is impractical (refer Appendix D). To treat surface water, the Base (which is 4m above sea level) would need to become a “holder” of water during flood and this alone would result in the Base and the domestic airport losing all capability until the water is treated to the required level and then discharged from the Base to allow the runway to reopen. The scale of plant needed to treat this large volume of water would be extraordinary, with operation expected to only during overland flow events (expected on average one week in every two years). In the intervening period, the plant would continue to operate and draw cost to the Commonwealth as it recycles clean water (most likely town water) to ensure ongoing operationality of plant components.

The detailed identification and analysis of an option or set of options for each risk is set out in Appendix E, using the criteria set out in Appendix D.

\subsection*{6.2 Comparative analysis}

Comparative analysis was conducted for each of the identified plausible options using a 17-point review. Description of each approach or technology against the 17 aspects is presented in Appendix E covering a range of application scenarios. These descriptions were then applied to show simplified analysis of each approach or technology related to each Sub-Management Area.

- **Sub-Management Area 1:** Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Mundy Creek Catchment. Remedial Option 1 is expected to provide the highest efficacy at this location, perhaps with targeted implementation of Remedial Option 3 or 4 for hotspots.

- **Sub-Management Area 2:** Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Louisa Creek Catchment. Remedial Option 1 is expected to provide the highest efficacy at this location, perhaps with targeted implementation of Remedial Option 3 or 4 for hotspots.

- **Sub-Management Area 3:** Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Louisa Creek Catchment. Remedial Option 1 for the drainage channel is expected to provide the highest efficacy at this location. The efficacy of other Remedial Options is likely to have limited value at this location.

The efficacy of the remedial options listed above would need to be assessed within the frameworks of a targeted RAP to be developed for the Sub-Management Area, noting that other remedial approaches may become actionable through technological advances (e.g. mobile thermal treatment). The RAP(s) will contain specific on-going monitoring actions to assess and validate the impact of that remediation plan.

Co-contaminants were not noted in the key source zones or points of exposure, at concentrations that would materially impact treatability by any approach nominated.

\subsection*{6.3 Integrated options analysis outcomes}

Implementation of response measures in the form of engineering source control should be undertaken where opportune to do so through integration with the redevelopment works, and with the areas directly involved with or affected by the redevelopment works. It is important to note that the implementation of risk management options will not eliminate PFAS mass flux in surface water from the Base, but rather will serve to reduce the mass of PFAS discharged following periods of high rainfall.
7 CONCLUSION

7.1 Recommended PMAP response actions

Based on the comparative analysis and the integrated analysis, the recommended actions for each Sub-Management Area are set out below.

- **Sub-Management Area 1**: Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Mundy Creek Catchment.
  - Remedial Option 1 (*Hydraulic control of surface water to limit runoff from source areas*) is expected to provide the highest efficacy at this location.
  - Remedial Option 3 (*Excavation and containment of PFAS impacted soil within purpose-built above-grade engineering facility*) or Remedial Option 4 (*Excavation and off-Base disposal of impacted soils*) potentially for targeted implementation of hotspots.

- **Sub-Management Area 2**: Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Louisa Creek Catchment.
  - Remedial Option 1 (*Hydraulic control of surface water to limit runoff from source areas*) is expected to provide the highest efficacy at this location.
  - Remedial Option 3 (*Excavation and containment of PFAS impacted soil within purpose-built above-grade engineering facility*) or Remedial Option 4 (*Excavation and off-Base disposal of impacted soils*) potentially for targeted implementation of hotspots.

- **Sub-Management Area 3**: Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Louisa Creek Catchment.
  - Remedial Option 1 (*Hydraulic control of surface water to limit runoff from source areas*) is expected to provide the highest efficacy at this location.
  - The efficacy of other Remedial Options is likely to have limited value at this location.

The efficacy of the remedial options listed above would need to be assessed within the frameworks of a targeted Remedial Action Plan (RAP) to be developed for the Sub-Management Area, noting that other remedial approaches may become actionable through technological advances (e.g. mobile thermal treatment). The RAP(s) will contain specific on-going monitoring actions to assess and validate the impact of that remediation plan.

To support the preparation of the RAP, the following actions should be considered to increase certainty that the remedial option with the highest efficacy is recommended for each of the Sub-Management Areas:

- Targeted grid-based soil characterisation to increase certainty regarding the mass of PFAS impacted soil in Sub-Management Area, which could be utilised to develop an excavation model (if excavation is a recommended remedial option).
- Analysis of soil samples consistent with ERA60 (refer Section A2.1.2) from the Sub-Management Area to allow an assessment of landfill disposal options and whether these conditions could be met through the addition of a stabilisation / immobilisation agent.
- Installation of lysimeters targeting a range of soil concentrations to assess surface water infiltration to the aquifer in the Sub-Management Area.
- Surveying of the ground surface of the Sub-Management Areas to allow the construction of the excavation model and allow calculation of stream flows (i.e. transects across drainage channels) so that surface flux estimates can be predicted during surface water discharge events.
• Event-based surface water discharge sampling to allow calculation of surface water flux from the Sub-Management Areas, which should include:
  • laboratory analysis of water and suspended solids;
  • observation of surface water depth along surveyed transects; and
  • measurement of stream flowrate at points of surface water depth observation.

Whilst not all actions listed above may be appropriate for every Sub-Management Area, consistent with NEPM each of the proposed actions to be advanced will need to be supported by a SAQP that defines the activity and the data quality objectives for the task.

7.2 PMAP implementation

7.2.1 Response timeframes

Estimated timeframes are indicative only at this stage.

7.2.2 PMAP implementation

The timeframes for implementation of this PMAP will be informed by a risk based approach that provides value for money in the use of public resources. Key factors include:

<table>
<thead>
<tr>
<th>Priority for PFAS migration and human health</th>
<th>Priority accorded under the Defence PFAS Response Management Strategy to implementing practicable solutions to prevent or minimise the migration of PFAS beyond the Defence property boundary; and measures to protect the community from exposure while management actions addressing source areas and/or migration pathways are underway.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority for higher risks</td>
<td>Priority given to relatively higher risks within one or more Sub-Management Areas.</td>
</tr>
<tr>
<td>Response actions underway</td>
<td>Response actions already underway, having commenced during the site investigations phase to manage a risk identified as requiring early intervention.</td>
</tr>
<tr>
<td>Co-dependent actions</td>
<td>Whether the implementation of one response action is dependent on the implementation of another response action.</td>
</tr>
<tr>
<td>Use of public resources</td>
<td>Defence’s obligations under the Commonwealth Procurement Rules (issued under the Public Governance, Performance and Accountability Act 2013) to achieve value for money in procurement; and to use public money in an efficient, effective, economical and ethical manner. Cost-effectiveness may be facilitated through:</td>
</tr>
<tr>
<td>• grouping the implementation of similar response actions within one or more Management Areas</td>
<td></td>
</tr>
<tr>
<td>• aligning Defence infrastructure and maintenance plans with a recommended response action.</td>
<td></td>
</tr>
<tr>
<td>Public Works Committee</td>
<td>Timeframes for approvals and notification processes under the Public Works Committee Act 1969 for medium and larger public works.</td>
</tr>
</tbody>
</table>

Priority of response actions may change over the life of the PMAP based on a range of variables including:

• the outcomes of earlier PMAP response actions
• the development of relevant legislation, policy, guidelines and whole-of-government positioning
• changes in land use surrounding the site
• feedback received from stakeholders
• the availability of new relevant science and technology
• changes in timeframes for approvals (e.g. PWC) and procurement processes.

7.3 Review and update

This PMAP (including the OMP) has been developed based on existing knowledge, current government policy settings, and available scientific methodologies and technology. PFAS management is a field that is rapidly evolving.

Defence will review and update (where necessary) the PMAP at intervals of 12 months to ensure that the document is current and its recommendations are valid.

Performance measures for individual response actions under this PMAP will be contained in the relevant approval or procurement documentation.

An earlier review/update may be triggered where circumstances demand it. Examples of circumstances that may trigger a review/update include:

• a performance evaluation of specific PMAP response actions that recommends changes or advises that its objectives are not being met.
• updated information obtained from PMAP response actions involving further investigations or data from the Ongoing Monitoring Plan.
• feedback and information received as a result of the on-going community and/or stakeholder consultation.
• any significant changes of land use which may occur in the area within the Management Area or adjoining land.
• changes in legislation, policy and guidelines/standards that could have a direct bearing on the project.
• changes to Defence’s strategic approach to managing PFAS contamination.
• on-going research and development of management/remediation technologies to address PFAS impacted soil and groundwater.
• changes to water supply options available to land owners and residents in the area surrounding the site (in the event of bore water use for potable domestic purposes).
• progress in risk management and remediation activities that may require realignment or further calibration.
• new scientific findings that update the knowledge or assumptions underlying the PMAP or specific PMAP response actions.
• any other new information that has the potential to positively or negatively impact the objectives of the PMAP.

Any proposed changes to this PMAP will be communicated and discussed with the community and key stakeholders including Federal and State/Territory government agencies and the local Council.
APPENDIX A: Regulatory and policy analysis

Appendix A supplements section 2.6 (Relevant legislation and government policy).

This Appendix identifies relevant legislation, policy and standards applicable to the development and prioritisation of management options for the Management Area. It further identifies key drivers and constraints affecting that development and/or prioritisation.

A1 Commonwealth legislation, policy and standards

A1.1 Outline

The following Commonwealth legislation and policy is relevant to the risk management of the Management Area:

Commonwealth legislation


Commonwealth policy, standards and guidance

Defence policy, standards and guidance

- Defence Environmental Policy,
- Defence Estate Strategy 2016-2036,
- Defence Environmental Strategy 2016-2036,
- Defence Construction and Maintenance Framework 2019,
- Defence PFAS Response Management Strategy 2018,
- Defence Interim Response Management Guidelines 2018, and
- Defence PMAP Template and Guidance 2018.

Commonwealth whole-of-government policy, standards and guidance

- Intergovernmental Agreement on a National Framework for Responding to PFAS Contamination 20 February 2018,
- PFAS National Environmental Management Plan 2018 (NEMP), HEPA January 2018,
- Australian and New Zealand Governments (ANZG) 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, August 2018, and
- Final Health Based Guidance Values (HBGV) for PFAS for use in site investigations in Australia, FSANZ February 2017.

A1.2 Key drivers and constraints impacting on development/prioritisation of options

Currently there is limited Commonwealth legislation on the designation of waste disposal criteria. Whilst the PFAS NEMP indicates potential criteria to be adopted at the State level for a State based receiving site, there is no approved landfill disposal site in North Queensland that is licensed to receive PFAS impacted solids from the Sub-Management Areas as monocell disposal following reduction of leachability (to meet acceptance limits as per ERA60) would be required, if achievable.

The PFAS NEMP document outlines the preferred framework for PFAS management including containment, remediation, treatment and disposal. The document acknowledges that each site is unique and any management response must consider site-specific conditions in determining the best
approach to the management of PFAS. Overall the document presents the hierarchy of options for site clean-up, which is consistent with the policy intent of the Queensland waste management requirements (refer below), being any clean-up of land will reflect the order of preference set out in the waste hierarchy (i.e. treatment and reuse on-site is preferred to treatment and reuse off-site, while long-term containment off-site is least preferred).

A2 State/Territory Legislation and Policy

A2.1 Outline

Defence responsibilities are under the EPBC Act. It is noted that Defence land is not subject to State regulation, however Defence endeavours, wherever possible, to abide by the ‘spirit and intent’ of that legislation. As the base is located in Queensland compliance with the ‘spirit and intent’ of Queensland legislation is acknowledged.

The following State legislation is relevant for the purposes of this PMAP:

- State of Queensland Environmental Protection Regulation 2008.
- Environmental Protection and Other Legislation Amendment Act 2014.
- Environmental Protection (Water) Policy 2009.

A2.1.1 Environmental Protection Act (Queensland) 1994

The primary environmental legislative instruments in Queensland are contained within the Environmental Protection Act 1994 (Qld) (EP Act) and subsidiary regulations.

The EP Act and its subordinate legislation provide a series of tools to ensure the objective of protecting Queensland’s environment is met. These tools range from providing for a licensing system for environmentally relevant activities (called an environmental authority) through to response tools such as environmental protection orders.

Under the EP Act, environmental protection policies have been developed to cover specific aspects of the environment. Approved policies include:

- air
- environmental nuisance
- waste
- water

Relevant State Legislation and Policy in the context of this PMAP are generally discussed below.

A2.1.1.1 EP Act - Contaminated Land Aspects

The EP Act as currently enforced by DES is unlikely to result in properties within the Management Area being listed on the EMR due to the occurrence of underlying PFAS impacted groundwater. This is because of an incongruence between low density residential land use and an EMR listing (as one of the standards against which land is to be removed from the EMR is suitability for “unrestricted land use”, which in practice is low density residential11, and so land used for that purpose should not by

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11 Consideration of risk to environmental receptors, including compliance with Environmental Values, is also a consideration for removal of land from the EMR
extension be listed). However, this approach to listing of land on the EMR is a policy position of DES and Defence are not recommending a change to this policy position by DES.

Chapter 7, Part 8 of the EP Act details matters relating to the investigation and management of contaminated land. In Queensland, activities that have been identified as likely to cause land contamination are referred to as notifiable activities and are defined in Schedule 3 of the EP Act. Land parcels used for notifiable activities are reported to the government and recorded on the EMR, a centralised register of potential or actual contaminated land parcels. Inclusion of a land parcel on the EMR does not necessarily mean that the land is contaminated.

Where contamination is intersected, disturbed or remediated (partially or in full) and a statutory outcome is being sought in accordance with the EP Act, investigation works and management plans/processes would need to be overseen by a suitably qualified person (SQP) and relevant Contaminated Land Investigation Document (CLID) would require approval by an environmental auditor (as per Section 389 of the EP Act).

The key elements applicable from the EP Act and the Queensland Guidelines include:

- Environmental Management Register (EMR): The EP Act enables the DES to list a lot on the EMR if either a notifiable activity has been or is being conducted, or the lot is contaminated land. Entry on the EMR does not mean the lot presents a risk to human-health or the environment, nor that it must be cleaned up or that the current land use must cease.

- Disposal Permit: Section 739 maintains in force the previous Section 424 (and Section 425) of the EP Act, pending the ability of the DES to administer via regulation in the future as “Regulated Waste” (refer Section A.2.1.2). At present, a Disposal Permit must be obtained for soil that is contaminated and originates at a site listed on the EMR prior to removal of that soil from the subject site. If the chosen remediation option includes the removal of contaminated soil from the subject site to a DES-licensed landfill, then appropriate sampling and analysis results must be forwarded to the DES, together with supporting documentation and the appropriate application form, to obtain a Disposal Permit. In the case where the subject site is not listed on the EMR, the DES may exercise its discretion to issue an ‘approval letter’ or similar document to acknowledge that the appropriate contaminated soil management approach is being taken in the soil removal. The Base has Lots listed on the EMR and not on the EMR (refer Section 2.1) and so either process could be applied where applicable.

- CLID reports and supporting contaminated land information is to be developed in accordance QLD Department of Environment and Science (DES) 2018, Queensland Auditor Handbook for Contaminated Land Module 6.

A2.1.2 Environmental Protection Regulation 2008

The Environmental Protection Regulations (EPR) prescribe the detail for the processes contained in the EP Act. The EPR provides definitions of terms noted in the EP Act for example Part 1 item 65 “What is a Regulated Waste?” It also contains a list of ‘prescribed Environmentally Relevant Activities’ (ERA) which are regulated under the EP Act and prescribes the fees to be paid, such as application fees and annual fees for these ERAs.

Under the Environmental Protection Regulation 2008 waste handlers must submit waste tracking information when transporting regulated waste or waste residues. A complete list of trackable regulated wastes can be found in Schedule 2E of the Environmental Protection Regulation 2008. PFAS containing waste materials are classified as a Regulated in QLD.

Waste tracking ensures that waste is transported and managed in a way that helps prevent illegal waste management activities, which may cause environmental harm.
A2.1.3 Environmental Protection (Water) Policy

The Environmental Protection (Water) Policy 2009 (EPP (Water)) achieves the object of the EP Act to protect Queensland’s waters while supporting ecologically sustainable development and provides for the development of Environmental Values (EV) and Water Quality Objectives (WQOs). Queensland waters include water in rivers, streams, wetlands, lakes, groundwater aquifers, estuaries and coastal areas.

EVs and WQOs are being progressively determined for areas of Queensland. EVs define the uses of the water by aquatic ecosystems and for human uses (e.g. drinking water, irrigation, aquaculture, recreation). WQOs define objectives for the physical, chemical and biological characteristics of the water (e.g. nitrogen content, dissolved oxygen, turbidity, toxicants, fish).


Waste Regulation is currently under review in Queensland.

A2.1.5 Planning Act 2016 & Planning Regulation 2017

The Planning Regulation 2017 came into effect on 3 July 2017 as a subordinate legislation to the Planning Act 2016 and it identifies circumstances where development is prohibited.

As per Part 4, Division 1, Section 6 entitled Prohibited development - material change of use on contaminated land the following applies:

1. A material change of use of premises is prohibited development if—
   a. all or part of the premises are on—
      i. the contaminated land register; or
      ii. the environmental management register; and
   b. the premises are not being used for a sensitive land use; and
   c. the material change of use involves—
      i. a sensitive land use; or
      ii. a commercial use involving an accessible underground facility, including, for example, a basement car park, workshop or office; and
   d. neither the contaminated land register nor the environmental management register state that the premises are suitable for the proposed use in accordance with a site suitability statement for the premises.

2. In this section— site suitability statement, for premises, means a site suitability statement included in a site investigation report, or validation report, for the premises under the Environmental Protection Act.

A.2.2 Key institutional drivers and constraints impacting on development/prioritisation of options

There are currently no constraints from the State that could impact on the development or prioritisation of remedial options under the PMAP. Limitations are driven by the associated technical and practical issues of remedial actions.
A3 Planning Instruments or environmental permitting/licence controls

A3.1 Waste Disposal

In relation to the identification and evaluation of remediation options for this project, the key elements considered from the Waste Reduction and Recycling Act 2011 are:

- The waste management hierarchy of reduce, reuse, recycle also applies to contaminated land management, the preferential management options from most to least preferable being:
  - Treatment of contaminated soil on-site, followed by on-site reuse
  - Management of contaminated soil on-site with appropriate mitigation measures to protect human health and the environment
  - Off-site treatment
  - Off-site disposal.
- The setting of Waste Acceptance Criteria specific to individual landfill sites and differentiation between contaminated soil and regulated wastes. This includes soils with PFAS which can only be disposed at ERA(60(1a)) regulated waste disposal.
- The requirement for a Disposal Permit in relation to disposal of contaminated soil prior to acceptance of the contaminated soil by the landfill facility.

A3.2 Environmental Management of Firefighting Foam – Operational Policy

DES developed the Operational Policy for the Environmental Management of Firefighting Foam which was released in July 2016. The Policy requires firefighting foam end users to implement best-practice management practices for foam handling, use and disposal in compliance with The EP Act. Defence are meeting the objectives of this policy, however the policy does not apply to Defence as the use of firefighting foam does not occur beyond the Defence estate.

The above requirements would be applicable to developments within the Management Area noting that any property sited on State land would need to comply with the above, the EP Act and subordinate regulation.
APPENDIX B Source – pathway – receptor analysis

Appendix B supplements section 4.1 (Source - pathway - receptor analysis).

Potential pathways for the migration of PFAS associated with application and use at the Base include:

- Vertical migration of PFAS through soil to the groundwater.
- Mobilisation of PFAS in soil to surface water and stormwater during precipitation and flood events.
- Infiltration of PFAS in surface water to groundwater.

Receptors where complete pathways are present include:

- Consumers of recreationally caught seafood within the Monitoring Area, where the chronic weekly intake is in excess of Queensland guidance for mercury in seafood (i.e. three servings per week).
- Aquatic ecological receptors including flora and fauna in three catchments within the Monitoring Area.
- Terrestrial and semi-terrestrial ecological receptors including flora and fauna within the Monitoring Area.

The source-pathway-receptor analysis has been presented in three parts as described in the DSI (WSP 2018a) and the Seasonal Monitoring Reports (WSP 2019a, 2019c), representing the three primary receiving surface water catchments:

- Louisa Creek/Town Common/Bohle River;
- Three Mile Creek; and
- Mundy Creek.

Summary of the linkages between identified sources, exposure pathways and sensitive receptors for the three catchments as described in the DSI (WSP 2018a) and Seasonal Monitoring Reports (WSP 2019a, 2019c) are in a graphical representation below, noting that there are subsets to these described in the HHRA (2018b) and ERA (2019b).
Three Mile Creek Catchment

Runway 01/19

Base Boundary

Wetlands

Rowes Bay Golf Club

Three Mile Creek

Pallarenda

Rowes Bay

Lake Holocene Coastal Plains Sediments

KEY

- Inferred Groundwater Flow
- Groundwater Impact and Migration
- Subsurface Migration
- Surface Water Runoff / Migration
- Groundwater Table

SOURCES

1 Former FTA

PATHWAYS

1 Surface water runoff
2 Surface water infiltration
3 Groundwater migration
4 Biomagnification
5 Sediment migration

POTENTIALLY COMPLETED PATHWAYS

1 Human direct contact (surface water)
2 Human ingestion of aquatic organisms
3 Aquatic ecosystems - direct contact (surface water and sediment)
4 Terrestrial and aquatic predators
5 Human ingestion/ inhalation of groundwater
6 Human ingestion of stock or produce grown with groundwater
Louisa Creek / Common Catchment

Pee Wee Creek  Lake Lyndemore  Onsite wetlands  Common wetlands  Louisa Creek  Bohle River  Halifax Bay

Sub-Management Area 3 (5 AVN)
Sub-Management Area 2 (Fuel Farm)
Sub-Management Area 2 (Fire Station)
Pad Braham

KEY
- Inferred Groundwater Flow
- Groundwater Impact and Migration
- Surface Water Runoff / Migration
- Subsurface Migration
- Groundwater Table

SOURCES
1. Potential unidentified off-Base source
2. Ingham Road sports field
3. Sub-Management Area 3 (5 AVN)
4. Runway 13/31
5. Sub-Management Area 2 (Fuel Farm)
6. Sub-Management Area 2 (Fire Station)
7. Pad Braham

PATHWAYS
1. Surface water runoff
2. Surface water infiltration
3. Groundwater migration
4. Biomagnification
5. Sediment migration

POTENTIALLY COMPLETED PATHWAYS
1. Human direct contact (Surface water)
2. Human ingestion of aquatic organisms
3. Aquatic ecosystems direct contact (Surface water and sediment)
4. Terrestrial and aquatic predators
Mundy Creek Catchment

**KEY**
- Inferred Groundwater Flow
- Groundwater Impact and Migration
- Subsurface Migration
- Surface Water Runoff / Migration
- Groundwater Table

**SOURCES**
1. Sub-Management Area 1 (Former FTA)
2. Former cadet training ground
3. Potential former fire training ground
4. Potential unidentified off-Base source

**PATHWAYS**
1. Surface water runoff
2. Surface water infiltration
3. Groundwater migration
4. Biomagnification
5. Sediment migration
6. Wind erosion - aerial transport of dust particles

**POTENTIALLY COMPLETED PATHWAYS**
1. Human direct contact (surface water)
2. Human ingestion of aquatic organisms
3. Aquatic ecosystems - direct contact (wind/sediment)
4. Terrestrial and aquatic predators
5. Human inhalation and direct contact (soil/dust)
6. Human ingestion/inhalation of groundwater aerosols
7. Human ingestion/ inhalation of groundwater
8. Human ingestion of stock or produce grown with groundwater
## APPENDIX C Options analysis criteria

Appendix C supplements Section 3.5 (Detailed options analysis methodology).

This Appendix sets out the criteria for the detailed options analysis.

### Cost / effectiveness / impact analysis

| 1 | Cost range estimate | Estimate a cost range for implementation of the option, accompanied by an explanation of the basis of that estimate. The cost ranges below have overlapping values: this is to avoid a scenario where a borderline cost may distort the analysis. Where a cost estimate falls into an overlapping range, but effectiveness of the option in 1.2 is assessed as ‘high’, use the lower cost range to adjust the margin of error in favour of the ‘effectiveness’ criterion.
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>PWC approval required above $15 million.(^{12})</td>
<td>&gt; $13,000,000</td>
</tr>
<tr>
<td>Category 2</td>
<td>Medium works notification to PWC required above $2 million</td>
<td>&gt; $1,500,000 &lt; $15,000,000</td>
</tr>
<tr>
<td>Category 3</td>
<td>Project actions</td>
<td>&gt; $450,000 &lt; $2,000,000</td>
</tr>
<tr>
<td>Category 4</td>
<td>Community level actions(^{13})</td>
<td>&lt; $500,000</td>
</tr>
</tbody>
</table>

Cost ranges should include direct, indirect, recurrent costs and the costs of mitigating any secondary risks identified in 2.5 below.

Where there will be a need for ongoing operations, management, maintenance and monitoring beyond the Primary Implementation Period, a separate risk should be identified and a separate options analysis applied.

| 2 | Effectiveness rating | Assign an effectiveness rating in accordance with the following criteria:
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>The option is projected to meet all its objectives or meet a ‘best available’ standard</td>
<td></td>
</tr>
<tr>
<td>High with supplementary option</td>
<td>The option, together with a supplementary option, is projected to meet all its objectives or meet a ‘best available’ standard</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>The option is projected to make significant progress towards meeting its objectives.</td>
<td></td>
</tr>
<tr>
<td>Medium with supplementary option</td>
<td>The option, together with a supplementary option, is projected to make significant progress towards meeting its objectives</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>The option cannot reliably be projected to make significant progress towards meeting its objectives or may only do so in a timeframe that is</td>
<td></td>
</tr>
</tbody>
</table>

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\(^{13}\) Accommodates a range of community level response actions such as arranging alternative grazing for impacted agricultural businesses or providing fencing. The value of community-level actions may also exceed $500,000.
not aligned with effective management of the identified risk.

| 3 | Implementation period / timeframe | Designate an indicative timeframe for implementation: 
Primary implementation period  
- Short term: 1-12 months from the date of the PMAP  
- Medium term: 1-3 years  
Extended implementation period  
- Long term: beyond 3 years.  
Where an action extends across both the primary and extended implementation period, both should be designated. Different procurement actions may apply. |

| 4 | Potential impacts | List any potential environmental and socio-economic impacts (positive and negative).  
Negative impacts should be further analysed and addressed in section 10 below. |

| 5 | Estimated net environmental benefit | Whether the impacted environment as a whole would experience a net benefit. Rate as negative / marginal / moderate / significant.  
For an institutional or administrative control, this item may be deleted or rated as N/A.  
This factor does not require a detailed analysis. Rather, it requires an informed estimate. For example, the draining of an important wetland to remove the PFAS would be likely to result in negative net environmental benefit for biota and be unacceptable to environmental regulators and the community. |

**Risk-based analysis**

| 6 | Proportion of action to risk | Assess the scale (timing/implementation logistics/impact on Defence capability) and cost of the action in comparison to the likelihood and scale of the risk. |

| 7 | Best-practice status | Consider whether there is a recognised ‘best-practice’ standard available for the category of the proposed solution and whether the solution meets a relevant standard. |

| 8 | Verification status | Where an action involves a remediation technology, provide information on the verification status. |

| 9 | Technology assessment | Where an option involves a remediation technology:  
- infrastructure and energy requirements  
- ability to construct and operating technology  
- reliability of technology  
- ability to monitor effectiveness  
- ability to obtain any necessary approvals  
- availability of services and materials |
<p>| | | |</p>
<table>
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</tr>
</thead>
</table>
| 10 | Risks and mitigation | List primary, secondary\(^{14}\) and residual\(^{15}\) risks of implementation and associated mitigation options, such as:  
- potential environmental impacts, including PFAS transference, cross-contamination, and remobilisation; and presence of contaminants other than PFAS  
- the availability of treatment/storage management options to manage waste streams  
- impact on existing infrastructure (including bores)  
- potential social and economic impacts (e.g. land use or employment.)  
Specify whether mitigation options form a part the same option or whether they are developed separately (provide option identification number). |
| 11 | Key Dependencies | List any key dependencies, including the implementation of any other options, and any external factors. |

**Defence implications**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Defence capability</td>
<td>The extent to which an aspect of Defence capability will be impacted by the process or outcome of implementation of the option and the availability and cost of alternatives (consultations with Defence)</td>
</tr>
<tr>
<td>13</td>
<td>Project fit</td>
<td>Whether the project outcomes complement the outcomes of response management actions for the same or other sites (consultations with Defence)</td>
</tr>
<tr>
<td>14</td>
<td>Scalability</td>
<td>Whether the outcomes of the project can be scaled up or down to address similar needs in the same or other Bases.</td>
</tr>
</tbody>
</table>

**Stakeholder impacts, views and consents**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Jurisdictional regulator/s</td>
<td>List jurisdictional authorisations required to implement the option. Note the views of any relevant jurisdictional regulator</td>
</tr>
<tr>
<td>16</td>
<td>Owner / occupier consents and views</td>
<td>List any owner / occupier consents required to implement the option. Note the views of any relevant landowner or occupier.</td>
</tr>
<tr>
<td>17</td>
<td>Community</td>
<td>Defence’s understanding of the views of the impacted community.</td>
</tr>
</tbody>
</table>

---

\(^{14}\) Secondary risks are risks that emerge from implementation of a risk management response  
\(^{15}\) Residual risks comprise that component of the identified risk that is not addressed by the option.
APPENDIX D Options listing and analysis

Appendix D supplements section 6.1 (Options identification and analysis).

This Appendix provides the analysis of the management options identified as available to address the range of risks identified in the DSI (WSP 2018a), the Seasonal Monitoring Reports (WSP 2019a, 2019c) and the HHRA (WSP 2018b) and ERA (WSP 2019b).

Risk management includes the application of remediation technology and methodologies; pathway management; as well as institutional and administrative controls and advisories.

Part D1 sets out the range of remediation technology and methodologies with an initial screening for applicability to the remediation of PFAS contamination within the Management Area.

Part D2 sets out the remediation options for consideration within each of the Sub-Management Area and includes the detailed options analysis for the identified risks.

Part D3 provides the detailed a comparative analysis of the options for each identified risk.
## D1 PFAS remediation options screening

### D1.1 Solids (Soil/Sediment)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TECHNICAL APPLICABILITY</th>
<th>LIFECYCLE COSTS</th>
<th>RELATIVE COST</th>
<th>TIMEFRAME</th>
<th>SOCIAL AND ENVIRONMENTAL VALUES</th>
<th>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</th>
<th>FURTHER CONSIDERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-Situ Treatment – solids</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bioremediation</strong>&lt;br&gt;The activity of naturally occurring microbes is stimulated by circulating water-based amendment solutions in-situ through contaminated soils to enhance biological degradation of organic contaminants. Amendments may be used to enhance contaminant desorption from the soils. Most applicable to saturated media.</td>
<td>Not applicable to PFAS.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td><strong>Chemical Oxidation or Reduction</strong>&lt;br&gt;Oxidation/reduction chemically converts the hazardous contaminants to non-hazardous or less toxic compounds that are more stable, and/or inert. Oxidising/reducing agents most commonly used are Fentons reagent, permanganate, hydrogen peroxide and other proprietary formulations. Chemical commonly delivered by vertical well pressure injection. Delivery issues with contact of reagent with affected media. Most applicable to saturated media.</td>
<td>Not applicable to PFAS derived from AFFF, hence not relevant.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td><strong>Soil Flushing</strong>&lt;br&gt;Water or amendments (base, surfactant or chelating agent) are added to increase hydraulic gradients and 'flush' contaminants via advective pore flushing, desorption and diffusion gradients from impacted materials. Hydraulic control is required to capture the fluids and treat ex situ. Relevant PFAS are soluble and have low soil partitioning coefficients, and are potentially amenable to this approach. However, low level concentrations are expected to be persistent due to desorption and matrix diffusion.</td>
<td>Full scale in situ application has not been identified in Australia.</td>
<td>Hydraulic control would be required but would be difficult to achieve – there is a risk of increasing hazards via groundwater migration exposure pathways where shallow groundwater is present.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td><strong>Soil Vapour Extraction</strong>&lt;br&gt;Soil vapour is extracted and treated, thereby reducing volatile contaminant mass in unsaturated media. Can be combined with air sparging.</td>
<td>Not applicable to relevant PFAS – non- or low volatility.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
</tbody>
</table>

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### Adsorption - In-situ Stabilisation/Immobilisation

Contaminants are physically bound or enclosed within a stabilised mass (solidification), or surface reactions are induced between the stabilising agent and contaminants to reduce their mobility (stabilisation).

Potential additives (stabilisation/binding) include activated carbon, RemBind or MatCARE. Cement solidification not applicable due to PFAS leachability under alkaline conditions.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TECHNICAL APPLICABILITY</th>
<th>LIFECYCLE COSTS</th>
<th>RELATIVE COST</th>
<th>TIMEFRAME</th>
<th>SOCIAL AND ENVIRONMENTAL VALUES</th>
<th>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</th>
<th>FURTHER CONSIDERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adsorption - In-situ Stabilisation/Immobilisation</td>
<td>The longevity of full scale in situ application has not been identified in Australia. Solidification is not applicable to PFAS.</td>
<td>Chemical injection and soil mixing is commonly conducted in-situ in Australia (last 10 years). Full scale in situ application has not been identified in Australia. Can require up to 25% v/v amendment addition to achieve stabilisation.</td>
<td>Moderate to high (largely due to high amendment costs and large area of application)</td>
<td>+ 12 months. Validation of pre-treated material (e.g. stabilisation) may take 6 months.</td>
<td>Affects asset access</td>
<td>Affects asset access</td>
<td>No</td>
</tr>
</tbody>
</table>

### Ex-Situ Treatment – solids

**Excavation and Off-site Disposal/Destruction**

Commonly available soil treatment approach for categorised materials. Materials are excavated and transported to an appropriate facility for disposal and/or destruction.

On-Base pre-treatment may be required to dewater and/or dry the materials prior to transport from the Base. Reduction in leachability through the additional of additives would also be required for some material prior to disposal.

Excavation and dewatering/drying of materials is technically feasible, as is the mixing of additives to meet landfill license conditions.

There is not a suitable landfill in Townsville (i.e. monocell construction) and so carting soil to Southeast Queensland is the only practical option.

Interstate facilities or facilities outside of the Townsville area would need to be identified if the fate is destruction.

High (Largely due to disposal costs and transport) + 12 months. Validation of pre-treated material (e.g. stabilisation) for landfill disposal may take 6 months. Off-site disposal/destruction is considered the least desirable approach to managing contaminated soils on the PFAS NEMP waste hierarchy. Intra-state transport to an off-site facility would be very energy intensive and increase the risk for vehicular accidents.

Off-site disposal/destruction is considered the least desirable approach to managing contaminated soils on the PFAS NEMP waste hierarchy. Intra-state transport to an off-site facility would be very energy intensive and increase the risk for vehicular accidents.

Significantly disruptive to operations.

### Bioremediation

Materials are excavated and treated via biodegradation at an on-site or off-site facility. Dewatering of excavated materials may be required prior to treatment.

The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance biological degradation of organic contaminants. Nutrients, oxygen and other amendments may be used to enhance biodegradation / contaminant desorption from the soils via either open land-farming or in engineered ‘bio-piles’.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TECHNICAL APPLICABILITY</th>
<th>LIFECYCLE COSTS</th>
<th>RELATIVE COST</th>
<th>TIMEFRAME</th>
<th>SOCIAL AND ENVIRONMENTAL VALUES</th>
<th>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</th>
<th>FURTHER CONSIDERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioremediation</td>
<td>Not applicable for PFAS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>TECHNICAL DESCRIPTION</td>
<td>TECHNICAL APPLICABILITY</td>
<td>LIFECYCLE COSTS</td>
<td>RELATIVE COST</td>
<td>TIMEFRAME</td>
<td>SOCIAL AND ENVIRONMENTAL VALUES</td>
<td>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</td>
<td>FURTHER CONSIDERATION</td>
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<td>-----------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Adsorption - Solidification/ Stabilisation/ Immobilisation</td>
<td>Applicable</td>
<td>Applicable.</td>
<td>Moderate</td>
<td>12+ months.</td>
<td>Treatment and reuse of contaminated soil is considered high on the PFAS NEMP and DES' waste hierarchy.</td>
<td>Significant disruption to operations.</td>
<td>Yes, but only as part of an overall management alternative that could be coupled with off-site disposal, on-site retention (noting the shallowness of groundwater and hydrology limitations of maintaining Base operations during flooding) or as part of in-situ management options (noting the flux to surface water from soil is the primary concern).</td>
</tr>
<tr>
<td>Chemical Oxidation or Reduction</td>
<td>Not applicable to PFAS derived from AFFF, hence not relevant.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Soil Washing / Chemical Extraction</td>
<td>Full scale application has not been identified in Australia, with pilot studies underway. Likely to have limited capability for clay rich soils.</td>
<td>Treatment of multiple waste streams (water, sludge concentrate) required. Geotechnical suitability of treated material (i.e. graded materials) for site retention needs consideration.</td>
<td>Moderate to high (potentially due to waste stream management and processing time)</td>
<td>12+ months with material handling on-site</td>
<td>Treatment and reuse of contaminated soil is considered high on the PFAS NEMP and DES waste hierarchy.</td>
<td>Significant disruption to operations.</td>
<td>No</td>
</tr>
<tr>
<td>Low-temperature Thermal Desorption (on- or off-site)</td>
<td>Not field proven for PFAS.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>DESCRIPTION</td>
<td>TECHNICAL APPLICABILITY</td>
<td>LIFECYCLE COSTS</td>
<td>RELATIVE COST</td>
<td>TIMEFRAME</td>
<td>SOCIAL AND ENVIRONMENTAL VALUES</td>
<td>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</td>
<td>FURTHER CONSIDERATION</td>
</tr>
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<td>-------------</td>
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<td>----------------------</td>
</tr>
<tr>
<td>High-Temperature Thermal Desorption (on- or off-site)</td>
<td>Not field proven for PFAS.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Materials are excavated and treated at an on-site or off-site facility. Dewatering of excavated materials may be required prior to treatment. Wastes are heated to volatilise water and organic contaminants. A carrier gas or vacuum system transports volatilised water and organics to the gas treatment system for scrubbing/polishing.</td>
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<td></td>
</tr>
<tr>
<td>Pyrolysis and oxidative thermal destruction (on or off-site)</td>
<td>Applicable</td>
<td>Only feasible for PFAS at high temperatures. Off gas treatment required. Most feasible if transported to an existing off-site facility. Treatment of off gas and PFAS destruction by-products is required. These may include hydrofluorine and sulfuric acids. Incomplete combustion products may include carbon monoxide, carbonyl difluoride, sulfur</td>
<td>Very high (due to treatment costs)</td>
<td>4 to 5 years.</td>
<td>High energy use and consideration for potential destruction by-products and incomplete combustion products is required.</td>
<td>Significant disruption to operations</td>
<td>No</td>
</tr>
<tr>
<td>Materials are excavated and treated at an on-site or off-site facility. Dewatering of excavated materials may be required prior to treatment. High temperatures are used to volatilise water and PFAS, then combust, in the instance of oxidative thermal destruction in the presence of oxygen, organic constituents in hazardous wastes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other – solids</td>
<td>Applicable</td>
<td>In situ management is acceptable where conducted in an environmental audit and risks are demonstrated to be low and acceptable.</td>
<td>Applicable</td>
<td>Low</td>
<td>Depends on project staging and auditor.</td>
<td>In-situ management of soil is considered to be high on the PFAS NEMP’s waste hierarchy and avoids transport of materials off-site so is therefore considered more sustainable than placement in an off-site facility. Manages issue while technologies are developing. Ability to review treatment practicability in future with known location of wastes.</td>
<td>Yes. This approach is likely to present the greatest efficacy as the goal is isolation of PFAS impacted soil from surface water. This approach could form the foundation of an overall management approach that could be supplemented by alternative remedial approaches.</td>
</tr>
<tr>
<td>In-situ management</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Impacted materials managed via reduction in contaminant mobility by reducing infiltration to the extent practicable, and reducing soil-water interactions with impacted material. This would be achieved via a low permeability cover and sub-drainage as a contingency to control seepage (if any) and reduce contact with surface water (e.g. through controlling surface hydrology) as mass flux in surface water discharges from the Base is the dominant pathway for PFAS migration from the Base.</td>
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</tbody>
</table>
### On-Base containment in an engineered facility

On-site containment is acceptable and involves excavation and placement in an engineered repository or containment cell that would be lined and capped.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TECHNICAL APPLICABILITY</th>
<th>LIFECYCLE COSTS</th>
<th>RELATIVE COST</th>
<th>TIMEFRAME</th>
<th>SOCIAL AND ENVIRONMENTAL VALUES</th>
<th>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</th>
<th>FURTHER CONSIDERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site containment is acceptable where conducted in an environmental audit and risks are demonstrated to be low and acceptable. Requires suitable location for the facility.</td>
<td>Applicable</td>
<td>Applicable</td>
<td>Low</td>
<td>Depends on project staging and auditor.</td>
<td>On-site containment is lower on the waste hierarchy as the process involves construction of an engineered facility. This avoids transport of materials offsite so is considered more sustainable than placement in an off-site facility.</td>
<td>Depending upon source area, low to significant disruption to operations</td>
<td>Yes during flooding, but only as part of an overall management alternative. The shallowness of groundwater and hydrology limitations of maintaining Base operations would make siting a facility difficult on-Base.</td>
</tr>
</tbody>
</table>
## D1.2 Waters (Surface water and groundwater)

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>TECHNICAL APPLICABILITY</th>
<th>LIFECYCLE COSTS</th>
<th>COST EFFECTIVENESS (RELATIVE COST)</th>
<th>TIMEFRAME</th>
<th>SOCIAL AND ENVIRONMENTAL VALUES</th>
<th>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</th>
<th>FURTHER CONSIDERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-Situ Treatment – water</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioremediation As described above for in situ biodegradation of soil/sediments.</td>
<td>Not applicable to PFAS.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Chemical Injection (ISCO) Chemicals are injected into the aquifer at pre-determined dosage rate. May include oxidation/reduction to chemically convert the hazardous contaminants to non-hazardous or less toxic compounds that are more stable, and/or inert.</td>
<td>Emerging technology (laboratory scale only). However, no proven PFAS destruction technology currently available.</td>
<td>Chemical injection (oxidant) is commonly conducted in-situ in Australia (last 10 years). Significant chemical volumes would be required.</td>
<td>High (largely due to chemical costs and application)</td>
<td>12 to 24 months</td>
<td>In-situ treatment is considered high on DES' waste hierarchy.</td>
<td>Some disruption to operations</td>
<td>No</td>
</tr>
<tr>
<td>Chemical Injection (Sorption) Chemicals are injected into the aquifer at pre-determined dosage rate. Options may include novel additives such as slurried activated carbon.</td>
<td>Emerging technology. As with soil adsorption, the longevity of this option is the primary concern.</td>
<td>Significant chemical volumes would be required, with the potential need for reapplication.</td>
<td>High (largely due to chemical costs and application)</td>
<td>12 to 24 months</td>
<td>In-situ treatment is considered high on DES' waste hierarchy.</td>
<td>Some disruption to operations</td>
<td>No</td>
</tr>
<tr>
<td><strong>Air Sparging</strong> Air is injected into the subsurface to add oxygen and volatilise contaminants. Soil vapour is extracted and treated, thereby reducing volatile contaminant mass.</td>
<td>Not applicable to PFAS – non- or low volatility.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td><strong>Thermal Treatment</strong> As described above for in situ thermal treatment of soil/sediments.</td>
<td>Not applicable to PFAS.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Monitored Natural Attenuation A variety of physical, chemical, or biological processes that, under favourable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. This typically is only applicable if the primary source has been controlled, and risks are demonstrated to be, or can be controlled to be, low and acceptable.</td>
<td>Not applicable to PFAS – there is limited natural attenuation in the environment.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td><strong>Permeable Reactive Barriers</strong> A permeable reactive barrier (PRB) is installed across the flow path of the groundwater contaminant plume, allowing the plume to passively pass through the wall, but the reactive media either sorbs, degrades or transforms contaminants. Common reactive media include zero valent iron, natural zeolites and organic substrates. PRBs can either be configured as a continuous wall to intersect the plume, or as a funnel-and-gate system with low permeability walls that direct groundwater flow through reactive media in a ‘gate’.</td>
<td>Potentially applicable as a standalone or component of an overall strategy. However, no full scale application for PFAS identified in Australia or globally. Expected to be applicable in short term for some hydrogeological settings.</td>
<td>Reactive media can require replacement (depending on sorptive capacity and concentrations being treated) and disposal/treatment. Moderate to High (Depends on size, reactive media to be used, replacement of media)</td>
<td>Long term operation</td>
<td>-</td>
<td>In-situ treatment is considered high on the PFAS NEMP and DES' waste hierarchy.</td>
<td>Depending on source area, low to significant disruption to operations.</td>
<td>No</td>
</tr>
<tr>
<td>DESCRIPTION</td>
<td>TECHNICAL APPLICABILITY</td>
<td>LIFECYCLE COSTS</td>
<td>COST EFFECTIVENESS (RELATIVE COST)</td>
<td>TIMEFRAME</td>
<td>SOCIAL AND ENVIRONMENTAL VALUES</td>
<td>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</td>
<td>FURTHER CONSIDERATION</td>
</tr>
<tr>
<td>------------------------------</td>
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</tr>
<tr>
<td>Ex-Situ Treatment – water</td>
<td></td>
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</tr>
<tr>
<td>Groundwater extraction</td>
<td>Not applicable as a stand-alone option – is not likely to be practicable to address secondary sources (e.g. PFAS sorbed to soils). Desorption and back diffusion of contaminants from the formation can limit the ability to reach low-level management goals and cause extended treatment timeframes.</td>
<td>Requires water treatment (See below). Applicable as a component of an overall management strategy. Moderate capital cost, but high lifecycle cost due to long duration</td>
<td>1+ years, long term operation</td>
<td>Low to some disruption to operations.</td>
<td>Considered low on hierarchy when used in isolation but can be a component of overall site strategy</td>
<td>Yes, but has limited efficacy at the Base given the low permeability of the aquifer and would only form part of an overall management alternative. Trenches would be preferable to extraction wells given the shallow depth and higher surface area established (allowing greater recovery). The greatest mass flux from the Base is from soil to surface water and this strategy does not address that pathway.</td>
<td></td>
</tr>
<tr>
<td>DESCRIPTION</td>
<td>TECHNICAL APPLICABILITY</td>
<td>LIFECYCLE COSTS</td>
<td>COST EFFECTIVENESS (RELATIVE COST)</td>
<td>TIMEFRAME</td>
<td>SOCIAL AND ENVIRONMENTAL VALUES</td>
<td>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</td>
<td>FURTHER CONSIDERATION</td>
</tr>
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</tr>
<tr>
<td>Excavation and/or dewatering</td>
<td>Applicable</td>
<td>Requires water treatment (See below). Applicable as a component of an overall management strategy.</td>
<td>Low to moderate</td>
<td>6 to 12 months.</td>
<td>Disposal considered energy intensive and low on DES’ waste hierarchy.</td>
<td>Significant disruption (excavation) and increased risk of subsidence if dewatering alone.</td>
<td>Yes, but only as part of an overall management alternative. The greatest value would be for hotspots and the &lt;0.5m depth as this is where surface water interactions are resulting in mass flux from the Base. The disposal fate of soil would be problematic as the Base is subject to inundation and groundwater is shallow so on-Base containment is difficult, and there is unlikely to be a suitable receiving landfill proximate to the Base in North Queensland.</td>
</tr>
<tr>
<td>Extracted groundwater treatment</td>
<td>Applicable Treatment technologies are commercially available and have been used for PFAS water treatment in Australia (in particular ion exchange resin and GAC, and to a lesser extent ultrafiltration and ion exchange). Applicable A pilot trial and treatment train approach may be required depending on water quality and co-contaminants. A method to manage waste media is required (see above for soil/sediment options for disposal, on site containment or in situ management)</td>
<td>Moderate</td>
<td>See for above options</td>
<td>See for above options</td>
<td>Little disruption to operations</td>
<td>Yes, but has limited efficacy at the Base given the low permeability of the aquifer and would only form part of an overall management alternative. The greatest mass flux from the Base is in surface water and this strategy does not address that pathway.</td>
<td></td>
</tr>
<tr>
<td>DESCRIPTION</td>
<td>TECHNICAL APPLICABILITY</td>
<td>LIFECYCLE COSTS</td>
<td>COST EFFECTIVENESS (RELATIVE COST)</td>
<td>TIMEFRAME</td>
<td>SOCIAL AND ENVIRONMENTAL VALUES</td>
<td>IMPACT – DEFENCE CAPABILITY / SERVICE DELIVERY</td>
<td>FURTHER CONSIDERATION</td>
</tr>
<tr>
<td>---------------------------</td>
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<td>---------------------------------</td>
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<td>----------------------</td>
</tr>
<tr>
<td>Surface water treatment</td>
<td>Not applicable at this Base.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Other – water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydraulic containment</td>
<td>Applicable</td>
<td>Applicable</td>
<td>Low to moderate</td>
<td>Ongoing</td>
<td>Considered energy intensive and low on DES' waste hierarchy, but system can be optimised to reduce O&amp;M costs.</td>
<td>Little disruption to operations, but combined with a low permeability cover system would result in significant disruption to operations.</td>
<td>Yes, but only as part of an overall management alternative. Would have limited efficacy as groundwater flow is negligible. The greatest mass flux from the Base is in surface water and this strategy does not address that pathway.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires water treatment (See above). Would only be feasible if combined with a strategy to reduce infiltration to the perched aquifer (e.g. a low permeability cover).</td>
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</tbody>
</table>

Ex situ treatment of surface water discharges is technically feasible, however the volume of water that sheds from the Base during high flow events would make this scenario unfeasible at this Base. The scale of the water treatment plant, which would operate ad hoc, and the inability to dam and channel the overland flow towards extraction points makes this option unviable at this Base.

Sub-surface hydraulic barriers consist of a series of vertically installed walls, or excavated trenches near the perimeter of shallow water impacts, to:
- Affect hydraulic gradients or direct flow within the shallow system so that flow occurs laterally to drains/sumps/wells for extraction; and/or
- Reduce and retard lateral shallow groundwater flow.

If no measures are implemented to reduce infiltration, will require ongoing water extraction and treatment, and does not reduce management requirements. If combined with a low permeability cover to reduce infiltration to the shallow aquifer, there would be limited ongoing treatment of water required.
### D2 Options listing and detailed options analysis

#### D2.1 Hydraulic control for surface water / soil interactions at the Sub-Management Area

<table>
<thead>
<tr>
<th>No #</th>
<th>Remedial Option 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Title (functional)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Objective</strong></td>
</tr>
<tr>
<td></td>
<td><strong>How this objective contributes to managing the identified risk</strong></td>
</tr>
<tr>
<td></td>
<td><strong>The extent to which this option is expected to meet the objective</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Whether the option addresses</strong> source, pathway, receptor, and/or extended implementation period requirements</td>
</tr>
<tr>
<td></td>
<td><strong>Supplementary / complementary options</strong></td>
</tr>
</tbody>
</table>

#### Cost / effectiveness / impact analysis

<table>
<thead>
<tr>
<th>1</th>
<th>Cost range estimate</th>
<th>Estimate a cost range for implementation of the option is <strong>Category 2</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost range estimate</td>
<td><strong>Category 2</strong> Medium works notification to PWC required above $2 million</td>
</tr>
</tbody>
</table>

> $1,500,000 < $15,000,000

The cost estimate is based on the very large areas in both Sub-Management Area 1 and Sub-Management Area 2.
### Effectiveness rating

The effectiveness rating is **Medium**.

**Medium**  
The option is projected to make significant progress towards meeting its objectives.

This option will mitigate PFAS migration in surface water from the Base, however may not allow for surface water concentrations to comply with Environmental Values of the receiving environment.

### Implementation period / timeframe

**Primary implementation period**
- Medium term: 1-3 years from the date of the PMAP.

**Post-implementation period**
- Long term: beyond 3 years.

The cap and drainage culverts will need to be periodically inspected given the solution is an engineered control.

### Potential impacts

**Positive** environmental and socio-economic impacts are the reduction of PFAS migrating from the Base in surface water.

**Negative** environmental and socio-economic impacts could result if the ‘loss’ in catchment capacity at the Base is not balanced and consideration is not given to the impact on a change in hydrology to the Base and to receiving areas off-Base.

### Estimated net environmental benefit

The net environmental benefit is **moderate** given that some residual PFAS will continue to be remobilised at low level contaminated areas of the Base where there is no intervention.

### Risk-based analysis

**Proportion of action to risk**
The option is considered **Proportionate** given that the hierarchy of control (i.e. isolation) and the high concentrations of PFAS reported in Sub-Management Area 1 and Sub-Management Area 2.

**Best-practice status**
The option is best-practice for isolating a surface water pathway, but does not remedy the source area and so warrants ongoing management.

**Verification status**
Verification of the option can be proven through direct measurements of the cap (e.g. permeability) and supported by an environmental monitoring program of surface water (including discharge event-based monitoring) based on the Ongoing Monitoring Plan.
### Technology assessment

<table>
<thead>
<tr>
<th>Infrastructure and energy requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>• No energy is required to support the technology.</td>
</tr>
<tr>
<td>• No infrastructure is required to support the technology.</td>
</tr>
</tbody>
</table>

**Ability to construct and operating technology**

| Technology is readily constructible. |

**Reliability of technology**

| The technology is simple and reliable. |

**Ability to monitor effectiveness**

| Efficacy can be assessed directly at installation and inferred by implementation of provisions in the Ongoing Monitoring Plan. |

**Ability to obtain any necessary approvals**

| No difficulty is likely in obtaining requisite approvals to construct. |

**Availability of services and materials**

| Technology can be purchased ‘off the shelf’ and contractors with expertise in implementation of the technology are present within the Australian marketplace. |

### Risks and mitigation

| Primary risks are considered **Low** and **Manageable**. |
| Secondary risks pertain to the effect on hydrology at the Base outside the Sub-Management Areas, while residual risks relate to ongoing management of the Sub-Management Areas as the option does not reduce mass, only flux. |

### Key Dependencies

| Administrative controls will be required to define the extent of the cap and to ensure competence of the cap is maintained, especially during intrusive activities and/or Base redevelopments. |
| Depending on the thickness of the cap and change to drainage at the Sub-Management Areas, this may cause the ‘displacement’ of water during high flow events and so alteration to the hydrology at the Base will need to be considered so that the Base maintains operationality and does not impact on receiving areas. |

### Defence implications

| Defence capability |
| Defence capability is unlikely to be impacted given that capping activities can be managed to limit impact on Defence operations. |

| Project fit |
| The option is low technology that has been utilised in other contaminated land settings. |

| Scalability |
| The option is readily and easily scalable. |
Stakeholder impacts, views and consents

<table>
<thead>
<tr>
<th></th>
<th>Jurisdictional regulator/s</th>
<th>Activities are on-Base so there is no regulation required to advance the technology. Proximity to the airfield could trigger DIRDC consent with respect to impact on the domestic and international airport.</th>
</tr>
</thead>
</table>
| 15| Owner / occupier consents and views | RAAF Townsville Department of Infrastructure, Regional Development and Cities (DIRDC) Townsville Airport Pty Limited (TAPL)  
Sub-Management Areas are proximate to the airfield and so a Method of Working Plan (MoWP) is likely to be required to facilitate the option. |
| 16| Community | No community impacts identified as activities are on-Base.  
Isolation of a component of mass flux to the surface water pathway is anticipated to be received positively by the community. |

D2.2 Adsorption - Solidification/ Stabilisation/ Immobilisation of soil at the Sub-Management Area

<table>
<thead>
<tr>
<th>No #</th>
<th>Remedial Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title (functional)</td>
<td>Sorption of PFAS in soil though immobilisation or stabilisation techniques.</td>
</tr>
<tr>
<td>Description</td>
<td>Addition of a binding agent to soil to reduce the mobility of PFAS.</td>
</tr>
<tr>
<td>Objective</td>
<td>Immobilisation of PFAS in the lithology to allow a reduction in the mass of PFAS in surface water from primary source areas, resulting in subsequent reduction in mass flux and down-gradient concentrations along drainage pathways from the Base.</td>
</tr>
<tr>
<td>How this objective contributes to managing the identified risk</td>
<td>Sub-Management Area 1 and Sub-Management Area 2 account for most mass and flux in surface water discharges to Mundy Creek and to the Town Common, respectively. Reduction in remobilisation of PFAS from these areas will have a measurable reduction in PFAS migrating from the Base.</td>
</tr>
<tr>
<td>The extent to which this option is expected to meet the objective</td>
<td>Reduction of greater than 50% PFAS concentration and mass flux in surface water is considered plausible.</td>
</tr>
<tr>
<td>Whether the option addresses − source, − pathway − receptor, and/or − extended implementation period requirements</td>
<td>Option is an engineered control to isolate the pathway, but does not address the source and so would require ongoing management to maintain efficacy.</td>
</tr>
<tr>
<td>Supplementary / complementary options</td>
<td>Option does not address the on-Base exposure risk in the HHRA (WSP 2019b) associated with subgrade maintenance workers, however reasonable adoption of hygiene and PPE would assist in closing out this exposure pathway risk.</td>
</tr>
</tbody>
</table>
### Cost / effectiveness / impact analysis

<table>
<thead>
<tr>
<th></th>
<th>Cost range estimate</th>
<th>Estimate a cost range for implementation of the option is <strong>Category 2</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td><strong>Category 2</strong> Medium works notification to PWC required above $2 million &gt; $1,500,000 &lt; $15,000,000</td>
</tr>
</tbody>
</table>

The cost estimate is based on the very large areas in both Sub-Management Area 1 and Sub-Management Area 2.

<table>
<thead>
<tr>
<th></th>
<th>Effectiveness rating</th>
<th>The effectiveness rating is <strong>Medium</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td><strong>Medium</strong> The option is projected to make significant progress towards meeting its objectives.</td>
</tr>
</tbody>
</table>

This option will mitigate PFAS mobilisation migration in to surface water from the Base, however the intervention is likely to not be sufficient to may not allow for surface water concentrations to comply with Environmental Values of the receiving environment.

<table>
<thead>
<tr>
<th></th>
<th>Implementation period / timeframe</th>
<th>Primary implementation period</th>
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<tbody>
<tr>
<td>3</td>
<td></td>
<td><strong>Medium term</strong>: 1-3 years from the date of the PMAP.</td>
</tr>
</tbody>
</table>

**Post-implementation period**

- **Long term**: beyond 3 years.

The efficacy of the additive will need to be assessed over time and may 'breakdown' warranting future activities.

<table>
<thead>
<tr>
<th></th>
<th>Potential impacts</th>
<th>Positive environmental and socio-economic impacts are the reduction of PFAS migrating from the Base in surface water. Negative environmental and socio-economic impacts are expected to be negligible.</th>
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<tbody>
<tr>
<td>4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Estimated net environmental benefit</th>
<th>The net environmental benefit is <strong>moderate</strong> given that some residual PFAS will continue to be remobilised at low level contaminated areas of the Base where there is no intervention.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
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</tbody>
</table>

### Risk-based analysis

<table>
<thead>
<tr>
<th></th>
<th>Proportion of action to risk</th>
<th>The option is considered <strong>Proportionate</strong> given that the hierarchy of control (i.e. isolation) and the high concentrations of PFAS reported in Sub-Management Area 1 and Sub-Management Area 2.</th>
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<tbody>
<tr>
<td>6</td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Best-practice status</th>
<th>The option is good-practice for managing the pathway, however there is risk that as a standalone option, the efficacy of applying the additive in a clayey setting presents technical difficulties.</th>
</tr>
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<tbody>
<tr>
<td>7</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Verification status</th>
<th>Bench-top trials have demonstrated that addition of additives can reduce the leachability of PFAS from soil. Long-term efficacy of the approach has yet to be reliably demonstrated and field scale trials in clayey soils (including in non-PFAS settings) is of concern.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td></td>
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</tbody>
</table>
### Technology assessment

<table>
<thead>
<tr>
<th></th>
<th>Infrastructure and energy requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• No energy is required to support the technology.</td>
</tr>
<tr>
<td></td>
<td>• A treatment pad to support mixing is required to support the technology.</td>
</tr>
</tbody>
</table>

#### Ability to construct and operating technology

|   | Technology is readily constructible. |

#### Reliability of technology

|   | The technology is simple, however long-term efficacy has not been demonstrated reliably. |

#### Ability to monitor effectiveness

|   | Efficacy can be assessed directly by measuring leachability pre- and post-treatment, and inferred by implementation of provisions in the Ongoing Monitoring Plan. |

#### Ability to obtain any necessary approvals

|   | No difficulty is likely in obtaining requisite approvals to construct. |

#### Availability of services and materials

|   | Technology can be purchased ‘off the shelf’ and contractors with expertise in implementation of the technology are present within the Australian marketplace. |

### Risks and mitigation

Primary risks are considered **Medium** and **Manageable**, however the long-term efficacy of the option is likely to be unknown. Approaches such as weathering trails would assist in assessing this risk.

Secondary risks pertain to the effect on future use options of the Sub-Management Areas at the Base as constructability on the lithology may be adversely affected by the additive. Residual risks are relate to ongoing management of the Sub-Management Areas as the option does not reduce mass, only flux.

### Key Dependencies

Administrative controls will be required to define the extent of the treatment area.

### Defence implications

Defence capability is unlikely to be significantly impacted given that excavation can be managed to limit impact on Defence operations. There is risk that the addition of the agent may impact on constructability in is the geotechnical properties of the lithology are adversely affected.

The option is low technology that has been utilised in other contaminated land settings, however distribution of the ‘agent’ at the correct ratio at the field scale will be problematic given the clayey lithology at the Base.

The option is readily and easily scalable.
### Stakeholder impacts, views and consents

<table>
<thead>
<tr>
<th></th>
<th>Jurisdictional regulator/s</th>
<th>Activities are on-Base so there is no regulation required to advance the technology. Proximity to the airfield could trigger DIRDC consent with respect to impact on the domestic and international airport.</th>
</tr>
</thead>
</table>
| 15 | Owner / occupier consents and views | RAAF Townsville  
Department of Infrastructure, Regional Development and Cities (DIRDC)  
Townsville Airport Pty Limited (TAPL)  
Sub-Management Area 1 and Sub-Management Area 2 are proximate to the airfield and so a Method of Working Plan (MoWP) is likely to be required to facilitate the option. |
| 16 | Community | No community impacts identified as activities are on-Base.  
Isolation of a component of mass flux to the surface water pathway is anticipated to be received positively by the community. |

### D2.3 On-Base containment of soil in an above-grade engineered facility

<table>
<thead>
<tr>
<th>No #</th>
<th>Remedial Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title (functional)</td>
<td>Excavation and long-term storage in engineered above-grade facility to prevent leaching, contact and migration.</td>
</tr>
</tbody>
</table>
| Description | The containment cells will need to be above-grade given the shallow depth to groundwater at the Base. A basal lining system, surface capping system and leachate control will need to be included as part of the cell construction.  
The location of the cell would need to be selected to ensure it is away from areas of the Base that are inundated, or constructed in such a way that the contamination is above the flood level. |
| Objective | Isolation of PFAS impacted soil in contamination cells to prevent the release of contamination to the environment.  
The approach allows for other soil treatment technologies to ‘mature’ such that field scale implementation can be advanced at the Base with reduced risk. |
<p>| How this objective contributes to managing the identified risk | Sub-Management Areas account for most mass and flux in surface water discharges to Mundy Creek and to the Town Common, respectively. Isolation of PFAS from the Sub-Management Areas will have a measurable reduction in PFAS migrating from the Base. |
| The extent to which this option is expected to meet the objective | Reduction of greater than 50% PFAS concentration and mass flux in surface water is considered plausible, although this will be based on the volume of soil exhumed. |</p>
<table>
<thead>
<tr>
<th><strong>Whether the option addresses</strong></th>
<th><strong>Option is an engineered control to isolate the pathway, but does not address the mass of PFAS at the Base and requires ongoing management of the facility to maintain efficacy.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supplementary / complementary options</strong></td>
<td><strong>Option may require additional controls, such as hydrology, depending on the siting.</strong></td>
</tr>
</tbody>
</table>

**Cost / effectiveness / impact analysis**

<table>
<thead>
<tr>
<th><strong>1 Cost range estimate</strong></th>
<th><strong>Estimate a cost range for implementation of the option is <strong>Category 2</strong>.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category 2</strong></td>
<td><strong>Medium works notification to PWC required above $2 million</strong></td>
</tr>
<tr>
<td><strong>$2 million</strong></td>
<td><strong>&gt; $1,500,000 &lt; $15,000,000</strong></td>
</tr>
<tr>
<td><strong>The cost estimate is based on the very large areas in both Sub-Management Area 1 and Sub-Management Area 2.</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>2 Effectiveness rating</strong></th>
<th><strong>The effectiveness rating is <strong>High</strong>.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td><strong>The option is projected to meet all its objectives or meet a ‘best available’ standard</strong></td>
</tr>
<tr>
<td><strong>This option will mitigate reduce PFAS mobilisation migration in to surface water from the Base through isolation of the pathway, however the intervention does not destroy the PFAS.</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>3 Implementation period / timeframe</strong></th>
<th><strong>Primary implementation period</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium term:</strong> 1-3 years from the date of the PMAP.</td>
<td><strong>Post-implementation period</strong></td>
</tr>
<tr>
<td><strong>Long term:</strong> beyond 3 years.</td>
<td><strong>The facility will need to be maintained, with leachate from the basal liner requiring collection and treatment.</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>4 Potential impacts</strong></th>
<th><strong>Positive environmental and socio-economic impacts are the reduction of PFAS migrating from the Base in surface water.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Negative environmental and socio-economic impacts are expected to be the constraint on future development at the sited location.</strong></td>
<td></td>
</tr>
</tbody>
</table>

| **5 Estimated net environmental benefit** | **The net environmental benefit is **moderate** given that some residual PFAS will continue to be remobilised at low level contaminated areas of the Base where there is no intervention.** |

**Risk-based analysis**

<table>
<thead>
<tr>
<th><strong>6 Proportion of action to risk</strong></th>
<th><strong>The option is considered <strong>Proportionate</strong> given that the hierarchy of control (i.e. isolation) and the high concentrations of PFAS reported in Sub-Management Areas.</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Best-practice status</td>
</tr>
<tr>
<td>---</td>
<td>----------------------</td>
</tr>
<tr>
<td>8</td>
<td>Verification status</td>
</tr>
</tbody>
</table>
| 9 | Technology assessment | **Infrastructure and energy requirements**  
- No energy is required to support the technology.  
- A sited location will be required prior to implementation.  
**Ability to construct and operating technology**  
- Technology is readily constructible.  
**Reliability of technology**  
- The technology is simple and if constructed correctly, reliable.  
**Ability to monitor effectiveness**  
- Efficacy can be assessed directly during construction and inferred by implementation of provisions in the Ongoing Monitoring Plan.  
**Ability to obtain any necessary approvals**  
- No difficulty is likely in obtaining requisite approvals to construct.  
**Availability of services and materials**  
- Technology can be purchased ‘off the shelf’ and contractors with expertise in implementation of the technology are present within the Australian marketplace. |
| 10 | Risks and mitigation | Primary risks are considered **Medium** and **Manageable**, however durability of the cap over the long-term would warrant ongoing monitoring given seasonal fluctuations.  
Secondary risks pertain to the effect that the above-grade facility has on redevelopment of the Base. Residual risks are relate to ongoing management of the leachate, although this will diminish over time provided infiltration from precipitation is suitably controlled. |
| 11 | Key Dependencies | Administrative controls will be required to define the extent of the treatment area. Hydrology is also a key dependency as the facility cannot become inundated in flood events or exacerbate flooding in other areas. |

**Defence implications**

<table>
<thead>
<tr>
<th>12</th>
<th>Defence capability</th>
<th>Defence capability is unlikely to be significantly impacted given that excavation can be managed to limit impact Base operations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Project fit</td>
<td>The option is low technology that has been utilised in other contaminated land settings.</td>
</tr>
<tr>
<td>14</td>
<td>Scalability</td>
<td>The option is readily and easily scalable through construction of additional cells.</td>
</tr>
</tbody>
</table>
Stakeholder impacts, views and consents

15 Jurisdictional regulator/s
Activities are on-Base so there is no regulation required to advance the technology. Proximity to the airfield could trigger DIRDC consent with respect to impact on the domestic and international airport.

16 Owner / occupier consents and views
RAAF Townsville
Department of Infrastructure, Regional Development and Cities (DIRDC)
Townsville Airport Pty Limited (TAPL)
Sub-Management Areas are proximate to the airfield and so a Method of Working Plan (MoWP) is likely to be required to facilitate the option.

17 Community
No community impacts identified as activities are on-Base.
Isolation of a component of mass flux to the surface water pathway is anticipated to be received positively by the community, although the visibility of the Base may create enquiry from the community.

D2.4 Excavation and off-Base disposal to landfill

<table>
<thead>
<tr>
<th>No #</th>
<th>Remedial Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title (functional)</td>
<td>Excavation and off-Base disposal of PFAS impacted soil to landfill.</td>
</tr>
<tr>
<td>Description</td>
<td>Reduction in the mass in the Sub-Management Areas through excavation and transportation off-Base to a licensed landfill facility.</td>
</tr>
<tr>
<td>Objective</td>
<td>Management control of PFAS in soil through off-Base disposal.</td>
</tr>
<tr>
<td>How this objective contributes to managing the identified risk</td>
<td>Removal of PFAS from Sub-Management Areas, including solid and potentially liquid (groundwater), to a licensed landfill outside the Investigation Area.</td>
</tr>
<tr>
<td>The extent to which this option is expected to meet the objective</td>
<td>Option removes mass from the Base and so serves to achieve measurable reductions in PFAS migrating from the Base in surface water (and potentially the aquifer through over-excavation).</td>
</tr>
<tr>
<td>Whether the option addresses source, pathway, receptor, and/or extended implementation period requirements</td>
<td>Option is a management option to remove PFAS from the Base, thereby eliminating the source.</td>
</tr>
<tr>
<td>Supplementary / complementary options</td>
<td>Option may be complementary to Remedial Option 1.</td>
</tr>
</tbody>
</table>
Cost / effectiveness / impact analysis

1 Cost range estimate

Estimate a cost range for implementation of the option is **Category 2**.

<table>
<thead>
<tr>
<th>Category 2</th>
<th>Medium works notification to PWC required above</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$2 million</td>
</tr>
<tr>
<td></td>
<td>&gt; $1,500,000 &lt; $15,000,000</td>
</tr>
</tbody>
</table>

The cost estimate is based on the very large areas in both Sub-Management Area 1 and Sub-Management Area 2.

2 Effectiveness rating

The effectiveness rating is **High**.

- **High** The option is projected to meet all its objectives or meet a ‘best available’ standard

This option will remove PFAS from the Base; however, the efficacy of the technology diminishes with decreasing concentration.

3 Implementation period / timeframe

**Primary implementation period**
- Short term: 1-12 months from the date of the PMAP.

**Post-implementation period**
- Long term: Nil.

Suitable fill material may need to be sourced prior to excavation.

4 Potential impacts

**Positive** environmental and socio-economic impacts are the removal of PFAS from the Base in at Sub-Management Areas.

**Negative** environmental and socio-economic impacts are expected to be management transportation of soil on Queensland roadways and the distance from the Base to a suitable receiving facility (which may be in Southeast Queensland).

5 Estimated net environmental benefit

The net environmental benefit is **moderate** given that some residual PFAS will continue to be remobilised at low level contaminated areas of the Base where there is no intervention.

Risk-based analysis

6 Proportion of action to risk

The option is considered **Proportionate** given that the efficacy of the activity and the high concentrations of PFAS reported in Sub-Management Areas.

7 Best-practice status

The option is good-practice for managing the source, however the approach transfers the mass to another location.

8 Verification status

Not applicable as there is no technological application.

9 Technology assessment

Not applicable as there is no technological application.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10</strong></td>
<td><strong>Risks and mitigation</strong></td>
</tr>
<tr>
<td></td>
<td>Primary risks are considered <strong>High</strong> and <strong>Manageable</strong>, however the large distances to the landfill may result in the risks becoming unmanageable. Secondary risks pertain to the impact that truck movements and distance to the landfill on the community. Residual risks are considered to be negligible.</td>
</tr>
<tr>
<td><strong>11</strong></td>
<td><strong>Key Dependencies</strong></td>
</tr>
<tr>
<td></td>
<td>Administrative controls will be required to define the extent of the treatment area and ensure appropriate transportation protocols. Landfill requirements may require some pre-treatment and so Remedial Option 2 may be necessary prior to transportation from the Base.</td>
</tr>
</tbody>
</table>

**Defence implications**

| **12** | **Defence capability** |
| | Defence capability is unlikely to be significantly impacted given that excavation and truck movements can be managed to limit impact on Defence operations. |
| **13** | **Project fit** |
| | The option has been utilised at other Bases, however proximity to a receiving landfill is likely to mean the option is not a good project fit. |
| **14** | **Scalability** |
| | The option is readily and easily scalable through extension of the operation period. |

**Stakeholder impacts, views and consents**

| **15** | **Jurisdictional regulator/s** |
| | Excavation activities are on-Base however receiving landfill will be in Queensland so there are regulations regarding waste disposal. Proximity to the airfield could trigger DIRDC consent with respect to impact on the domestic and international airport. |
| **16** | **Owner / occupier consents and views** |
| | RAAF Townsville  
Department of Infrastructure, Regional Development and Cities (DIRDC)  
Department of Environment and Science (DES)  
Transport Main Roads (TMR)  
Townsville Airport Pty Limited (TAPL)  
Sub-Management Areas are proximate to the airfield and so a Method of Working Plan (MoWP) is likely to be required to facilitate the option. |
| **17** | **Community** |
| | Community impacts are expected based on the transportation of the soil in trucks from the Base. Off-Base disposal of the PFAS is anticipated to not be received positively by the community given that landfills are a community asset. |
# D2.5 Extracted groundwater treatment to reduce mass

<table>
<thead>
<tr>
<th>No #</th>
<th>Remedial Option 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title (functional)</td>
<td><em>Ex situ</em> treatment of groundwater as ‘made water’ in excavations.</td>
</tr>
<tr>
<td>Description</td>
<td>Capture and treatment of groundwater from the Sub-Management Areas at the Base.</td>
</tr>
<tr>
<td>Objective</td>
<td>Reduce mass of PFAS in groundwater at the Base to effectively manage made water in excavations.</td>
</tr>
<tr>
<td>How this objective contributes to managing the identified risk</td>
<td>Capturing ‘made water’, which is a term for groundwater that infiltrates into an excavation, and treating prior to discharge and/or backfilling excavation will serve to reduce some PFAS mass at the Base.</td>
</tr>
<tr>
<td>The extent to which this option is expected to meet the objective</td>
<td>Reduction of PFAS concentration in the proximity of the excavation may be large, however this is a management companion to other options.</td>
</tr>
<tr>
<td>Whether the option addresses − source, − pathway − receptor, and/or − extended implementation period requirements</td>
<td>Option is an engineered control to reduce the mass, but does not address the major pathway of PFAS discharge from the Base which is in surface water.</td>
</tr>
<tr>
<td>Supplementary / complementary options</td>
<td>Option does not address the on-Base exposure risk in the HHRA (WSP 2019b) associated with subgrade maintenance workers, however reasonable adoption of hygiene and PPE would assist in closing out this exposure pathway risk.</td>
</tr>
</tbody>
</table>

## Cost / effectiveness / impact analysis

<table>
<thead>
<tr>
<th>1</th>
<th>Cost range estimate</th>
<th>Estimate a cost range for implementation of the option is <strong>Category 3</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 3</td>
<td>Project actions</td>
<td>&gt; $450,000 &lt; $2,000,000</td>
</tr>
<tr>
<td></td>
<td>The cost estimate is based on the expected small size of the treatment plant required to manage ‘made water’ from excavations.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Effectiveness rating</td>
<td>The effectiveness rating is <strong>Medium</strong>.</td>
</tr>
<tr>
<td>Medium with supplementary option</td>
<td>The option, together with a supplementary option, is projected to make significant progress towards meeting its objectives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>This option will assist in manage ‘made water’ in excavations that have PFAS.</td>
<td></td>
</tr>
</tbody>
</table>
### Implementation period / timeframe

**Primary implementation period**
- Short term: 1-12 month from the date of the PMAP.

**Post-implementation period**
- Long term: beyond 3 years.

The option will be required for period that ‘made water’ is produced from an excavation.

### Potential impacts

**Positive** environmental and socio-economic impacts are the reduction of PFAS in groundwater through opportunistic treatment of ‘made water’.

**Negative** environmental and socio-economic impacts are associated with spent media / waste streams from the treatment plant(s) that will require either long-term storage or subsequent destruction.

### Estimated net environmental benefit

The net environmental benefit is **marginal** given that the intervention achieves treatment of PFAS impacted groundwater at the Base but is unlikely to be deployed in isolation of another option.

### Risk-based analysis

#### Proportion of action to risk

The option is considered **disproportionate** if enacted in isolation (i.e. the option is complementary of other options).

#### Best-practice status

The option is best-practice as the technology is a highly practical solution for ‘made water’ at the Sub-Management Areas.

#### Verification status

The technology has been verified at other locations in the Defence estate, including in the treatment of ‘made water’ in excavations. Verification of the option can be proven through direct measurements of the cap (e.g. permeability) and supported by an environmental monitoring program of surface water (including discharge event-based monitoring) based on the Ongoing Monitoring Plan.

### Technology assessment

**Infrastructure and energy requirements**
- Energy and supply will be required to support the technology.
- Infrastructure associate with the treatment plant is likely to be require.

**Ability to construct and operating technology**
- Technology can be modular and readily constructible.

**Reliability of technology**
- The technology is simple and reliable.

**Ability to monitor effectiveness**
- Defence has standardised methodology to assess efficacy.
- Efficacy of mass removal can be assessed through measuring burden on media and/or volume of the concentrate stream.

**Ability to obtain any necessary approvals**
- No difficulty is likely in obtaining requisite approvals to construct.

**Availability of services and materials**
- Technology can be purchased ‘off the shelf’ and contractors with expertise in implementation of the technology are present within the Australian marketplace.
<table>
<thead>
<tr>
<th></th>
<th>Risks and mitigation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Primary risks are considered <strong>Low</strong> and <strong>Manageable</strong> given the capacity of the treatment plants is only to treat a discrete quantity of groundwater. Secondary risks pertain to the management of spent media, the quantity of media required to be available and the potential loss of efficacy in the event of co-contaminants. Residual risks are related to ongoing management of the Sub-Management Areas as the option has an indeterminable period of operation if undertaken in isolation of an option that remedies soil.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Key Dependencies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>This option is dependent on a soil remedial option where the approach involves the production of made-water (i.e. Remedial Options 3 and 4).</td>
<td></td>
</tr>
</tbody>
</table>

**Defence implications**

<table>
<thead>
<tr>
<th></th>
<th>Defence capability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Defence capability is unlikely to be significantly impacted given that technology has a manageable footprint.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Project fit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Technology is currently in use at other Defence estates to manage PFAS impacted groundwater, however this is not considered to be suitable for groundwater alone (i.e. conducted in conjunction with another Option) given that the aquifer has low permeability and groundwater transport is a negligible risk.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Scalability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Treatment plants are generally modular and so can be scalable and transported from location to location.</td>
<td></td>
</tr>
</tbody>
</table>

**Stakeholder impacts, views and consents**

<table>
<thead>
<tr>
<th></th>
<th>Jurisdictional regulator/s</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Activities are on-Base so there is no regulation required to advance the technology. Proximity to the airfield could trigger DIRDC consent with respect to impact on the domestic and international airport. Transport of spent media, by-product and/or concentrate for off-Base destruction may trigger waste tracking provisions under legislation administered by the Queensland Department of Environment and Science.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Owner / occupier consents and views</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>RAAF Townsville Department of Infrastructure, Regional Development and Cities (DIRDC) Townsville Airport Pty Limited (TAPL) Sub-Management Areas are proximate to the airfield and so a Method of Working Plan (MoWP) is likely to be required to facilitate the option.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Community</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>No community impacts identified as activities are on-Base. Remedy of the groundwater mass is anticipated to be received positively by the community.</td>
<td></td>
</tr>
</tbody>
</table>
## D2.6 *Ex situ* surface water treatment through a WTP

<table>
<thead>
<tr>
<th>No #</th>
<th>Remedial Option 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title (functional)</td>
<td><em>Ex situ</em> treatment of surface water through a WTP.</td>
</tr>
<tr>
<td>Description</td>
<td>Capture, retention and treatment of surface water that interacts with Sub-Management Areas at the Base.</td>
</tr>
<tr>
<td>Objective</td>
<td>Reduce mass of PFAS in surface water discharged from the Base into the surrounding environment.</td>
</tr>
<tr>
<td>How this objective contributes to managing the identified risk</td>
<td>Capturing, retaining and treating surface water prior to discharge will serve to reduce PFAS mass flux from the Base.</td>
</tr>
<tr>
<td>The extent to which this option is expected to meet the objective</td>
<td>Reduction of PFAS concentration in the proximity of the extraction may be large, however this is a potential companion to other management options as the volume of water to treat (very large) and periodicity of WTP operation (infrequent) would not make the option cost-effective.</td>
</tr>
<tr>
<td>Whether the option addresses – source, – pathway – receptor, and/or – extended implementation period requirements</td>
<td>Option is an engineered control to reduce the mass discharged from the Base, but does not address the source which is the interaction of surface water with PFAS impacted soil and so is an ‘end-of-pipe’ solution with an indeterminable end-date. If this management option cannot be enacted and/or is ineffective during periods of elevated rainfall in Townsville (e.g. surface water is allowed to short-circuit), then there is unlikely to be a net environmental benefit from this intervention.</td>
</tr>
<tr>
<td>Supplementary / complementary options</td>
<td>The option is likely to have flow-on effects associated with retaining water on-Base for treatment. The primary concern would be around exacerbating the risk of flooding on-Base (impact to Defence operations) and off-Base (impact to community and domestic airport operations).</td>
</tr>
</tbody>
</table>

### Cost / effectiveness / impact analysis

<table>
<thead>
<tr>
<th>1</th>
<th>Cost range estimate</th>
<th>Estimate a cost range for implementation of the option is <strong>Category 1</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category 1</td>
<td>PWC approval required above $15 million &gt; $13,000,000</td>
</tr>
</tbody>
</table>

The cost estimate is based on the expected large size of the treatment plant required to manage the volume of water that flows across the Base in flood.
### Effectiveness rating

The effectiveness rating is **High**.

| High, on the proviso that the WTP has sufficient scale to treat the mass of water | The option is projected to make significant progress towards meeting its objectives assuming that the WTP can be of sufficient scale to treat the volume of water during periods of high rainfall (e.g. 1:100 year event) |

If surface water is allowed to short-circuit during high flow events (i.e. flow to the environment is greatly larger than the extraction rate for the WTP), then the effectiveness is **Low** as the net environmental benefit will be negligible.

### Implementation period / timeframe

**Primary implementation period**
- Medium term: 1-3 years from the date of the PMAP.

**Post-implementation period**
- Long term: beyond 3 years.

The option will be long-term intervention so long as source areas are not remedied as this remediation does not address the water - soil interactions that result in mobilisation of PFAS into surface water.

### Potential impacts

**Positive** environmental and socio-economic impacts are the reduction of PFAS in discharged from the Base in surface water.

**Negative** environmental and socio-economic impacts are associated with an increase in risk of on-Base and off-Base flooding associated with changing hydrology; and spent media / waste streams from the treatment plant(s) that will require either long-term storage or subsequent destruction.

### Estimated net environmental benefit

The net environmental benefit is **marginal** given that the intervention achieves a reduction in PFAS mass flux from the Base but this remediation option is unlikely have an endpoint for WTP operation as the option does not remedy the source (i.e. ‘end-of-pipe’ solution).

**Risk-based analysis**

### Proportion of action to risk

The option is considered **Disproportionate** given that health-risks to off-Base human receptors are either negligible or acceptable; and actual harm to the environment from PFAS (as opposed to an increase risk of bioaccumulation) has not been identified or quantified. Potential adverse outcomes regarding increasing flooding risk should outweigh the benefit to the community and the environment.

### Best-practice status

The option is good-practice assuming that remediation occurs during periods of high surface water flow and there are no flow-on impacts regarding increased risk to Defence operationality and flood risk to off-Base communities.

### Verification status

The technology has been verified at other locations in the Defence estate although not at the expected flowrate and intermittency of operation. Verification of the option can be proven through environmental monitoring program of surface water (including discharge event-based monitoring) based on the Ongoing Monitoring Plan.
### Technology assessment

- **Infrastructure and energy requirements**
  - Energy and supply will be required to support the technology.
  - Infrastructure associated with the treatment plant is likely to be required, including water capture, retention and distribution infrastructure.

- **Ability to construct and operating technology**
  - Technology can be modular and readily constructible.

- **Reliability of technology**
  - The technology is simple and reliable.

- **Ability to monitor effectiveness**
  - Defence has standardised methodology to assess efficacy.
  - Efficacy of mass removal can be assessed through measuring burden on media and/or volume of the concentrate stream.

- **Ability to obtain any necessary approvals**
  - No difficulty is likely in obtaining requisite approvals to construct the WTP, however approval to change hydrology at the Base may require approval from potentially impacted third parties.

- **Availability of services and materials**
  - Technology can be purchased ‘off the shelf’ and contractors with expertise in implementation of the technology are present within the Australian marketplace.

### Risks and mitigation

Primary risks are considered **Medium** and **Manageable** given the capacity of the treatment plants will most likely be assessed against estimates of rainfall events (e.g. 1:100 rainfall).

Secondary risks pertain to the management of spent media, the quantity of media required to be available and the potential loss of efficacy in the event of co-contaminants. Residual risks are related to the indeterminable period of operation if undertaken in isolation of an option that remedies water - soil interactions.

### Key Dependencies

This option is dependent on the capability of altering the hydrology of the Base to allow capture and retention of surface water at the Base, without creating an unacceptable risk of flooding the Base and/or short-circuiting of impacted surface water from the Base.

### Defence implications

- **Defence capability**
  - Defence capability is likely to be significantly impacted given that retention of surface water at the Base during periods of increase rainfall would more than likely increase risks associated with flooding.

- **Project fit**
  - Technology is currently in use at other Defence estates to manage PFAS impacted surface water and groundwater, however this technology as the sole remedial option is not considered to be suitable for this Base given that scale of plant required and drainage reconfiguration needed to capture and funnel surface water to extraction points.

- **Scalability**
  - Treatment plants are generally modular and so can be scalable.
### Stakeholder impacts, views and consents

|   | Jurisdictional regulator/s | Activities are on-Base so there is no regulation required to advance the technology. Proximity to the airfield could trigger DIRDC consent with respect to impact on the domestic and international airport.
|   |                           | Transport of spent media, by-product and/or concentrate for off-Base destruction may trigger waste tracking provisions under legislation administered by the Queensland Department of Environment and Science. |
|   | Owner / occupier consents and views | RAAF Townsville
Department of Infrastructure, Regional Development and Cities (DIRDC)
Townsville Airport Pty Limited (TAPL)
Townsville City Council (TCC)
|   |                           | Sub-Management Areas are proximate to the airfield and so a Method of Working Plan (MoWP) is likely to be required to facilitate the option. |
|   | Community                 | Community impacts of concern would be associated with the potential for exacerbating flood risk to adjacent land users through changing surface water hydrology to capture and retain surface water. This outcome, if realised, would irrevocably damage Defence’s social licence to operate. |
|   |                           | Remedy of the surface water prior to discharge from the Base is anticipated to be received positively by the community. |
APPENDIX E   References

- AECOM 2015, Town Common Rehabilitation and Maintenance Management, Mt St John WWTP, 10 November 2015
- Australian and New Zealand Governments (ANZG) 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, August 2018.
- Queensland Environmental Protection Act 1994.
- Queensland Environmental Protection Regulation 2008.
- Queensland Environmental Protection and Other Legislation Amendment Act 2014.
- Townsville City Council 2014. Townsville City Plan (Version 2017/04)
- WSP 2019b, RAAF Townsville Ecological Risk Assessment, WSP Australia Pty Limited, December 2019, PS102571-CLM-REP-005 RevG.
- WSP 2018a, RAAF Base Townsville Detailed Site Investigation - PFAS, Volume 1 – 4, WSP Australia Pty Limited, May 2018, PS102571-ENV-REP-002 RevD.
DEPARTMENT OF DEFENCE

RAAF BASE TOWNSVILLE
PFAS ONGOING MONITORING PLAN

DECEMBER 2019
PUBLIC
RAAF Base Townsville
PFAS Ongoing Monitoring Plan

Department of Defence

WSP
Level 3, Northbank Plaza,
69 Ann Street
Brisbane QLD 4000
GPO Box 2907
Brisbane QLD 4001

Tel: +61 7 3854 6200
Fax: +61 7 3854 6500
wsp.com

<table>
<thead>
<tr>
<th>REV</th>
<th>DATE</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15/11/2018</td>
<td>Draft</td>
</tr>
<tr>
<td>B</td>
<td>15/08/2019</td>
<td>Draft</td>
</tr>
<tr>
<td>C</td>
<td>02/12/2019</td>
<td>Final</td>
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</table>

<table>
<thead>
<tr>
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<th>DATE</th>
<th>SIGNATURE</th>
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<tr>
<td>Prepared by:</td>
<td>Philip Schulz</td>
<td>02/12/2019</td>
</tr>
<tr>
<td>Reviewed by:</td>
<td>Helen Jones</td>
<td>02/12/2019</td>
</tr>
<tr>
<td>Approved by:</td>
<td>Philip Schulz</td>
<td>02/12/2019</td>
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# ABBREVIATIONS

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<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>AS</td>
<td>Australian Standard</td>
</tr>
<tr>
<td>ANZECC</td>
<td>Australian and New Zealand Environment and Conservation Council</td>
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<tr>
<td>Base</td>
<td>A defined physical locality or geographical area from which Defence-related activities, operations, training or force preparations are managed, conducted, commanded or controlled.</td>
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<tr>
<td>COC</td>
<td>Chain of Custody</td>
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<td>CSM</td>
<td>Conceptual Site Model</td>
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<td>DSI</td>
<td>Detailed Site Investigation</td>
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<td>DQI</td>
<td>Data Quality Indicators</td>
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<td>DQO</td>
<td>Data Quality Objectives</td>
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<tr>
<td>ERA</td>
<td>Ecological Risk Assessment</td>
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<td>HEPA</td>
<td>Heads of EPAs Australia and New Zealand</td>
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<td>HHRA</td>
<td>Human Health Risk Assessment</td>
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<tr>
<td>LOR</td>
<td>Limit of Reporting</td>
</tr>
<tr>
<td>Management Area</td>
<td>The geographical area subject to Defence response actions</td>
</tr>
<tr>
<td>Monitoring Area</td>
<td>The geographical area within which monitoring is undertaken under the OMP</td>
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<td>NATA</td>
<td>National Association of Testing Authorities</td>
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<td>OMP</td>
<td>Ongoing Monitoring Plan</td>
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<td>PFAS</td>
<td>Per- and polyfluoroalkyl Substances</td>
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<td>PFAS NEMP</td>
<td>PFAS National Environmental Management Framework 2018 developed cooperatively between Australian jurisdictions</td>
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<td>PFOA</td>
<td>Perfluorooctanoic acid</td>
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<tr>
<td>PFOS</td>
<td>Perfluorooctane sulfonic acid</td>
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<tr>
<td>PMAP</td>
<td>PFAS Management Area Plan</td>
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<tr>
<td>QA</td>
<td>Quality Assurance</td>
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<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>Response actions</td>
<td>Actions identified as recommended or potential options to address potential risks</td>
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<tr>
<td>SAQP</td>
<td>Sampling and Analysis Quality Plan</td>
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<tr>
<td>Source area</td>
<td>An area within the Management Area that is, or has the potential to be, a source of PFAS contamination</td>
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<tr>
<td>SWL</td>
<td>Standing Water Level</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>TOC</td>
<td>Total Organic Carbon</td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solids</td>
</tr>
<tr>
<td>µg/L</td>
<td>Micrograms per Litre</td>
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1 INTRODUCTION

Department of Defence (Defence) engaged WSP Australia Pty Limited (WSP) to prepare an Ongoing Monitoring Plan (OMP) for PFAS impacts identified at the RAAF Base Townsville (herein referred to as the ‘Base’) and the associated Monitoring Area.

The PFAS Management Area Plan (PMAP) defines the Management Area as the Base which is distinct from the area within which monitoring is to occur under this OMP, termed the Monitoring Area. Further to the Management Area, there are five Sub-Management Areas in the PMAP, which are areas on-Base where remedial activities have been recommended for consideration.

The location of the Base and the Monitoring Area is shown in Figure 1 (Appendix A).

1.1 OBJECTIVES OF THE OMP

The objectives of this OMP are to define:

— a program of monitoring for PFAS in groundwater, surface water and sediment that allows ongoing assessment of changes in nature and extent of PFAS within the environment, including where there is an identified potentially elevated risk to a receptor, or a potential future risk to a receptor;
— an evidence base for targeted and effective risk management of PFAS contamination to protect human-health and environmental receptors;
— an early warning that additional management of PFAS contamination may be warranted in areas not currently affected by PFAS; and
— a set of guiding principles that can be utilised to monitor PFAS in groundwater, surface water and/or sediment to allow assessment of the efficacy of a management response (where applicable) with respect to chronic risk.

Sampling of biota has not been included in the OMP, although may be considered if PFAS concentrations in the environment increase significantly from those observed during the DSI (WSP, 2018a) and Seasonal Monitoring Events (WSP, 2019b; 2019c). In this event, if the concentrations of PFAS at the point of exposure (as determined by the 95% upper confidence limit) increase to a level such that the outcomes of the Health-Risk Assessment (HHRA) (WSP, 2018b) or Ecological Risk Assessment (ERA) (WSP, 2019a) would result in a change in risk profile, then biota sampling may be reconsidered.

Biota sampling, if advanced, would need to be scoped in liaison with the relevant State Government agencies to ensure currency of investigation method, and that requisite approvals and permits have been attained.

1.2 ROLES AND RESPONSIBILITIES

The responsibilities for the management of environmental issues during the execution of this OMP are detailed below.

1.2.1 DEPARTMENT OF DEFENCE

— Defence will ensure currency of the OMP through requiring reviews and edits to the document by the Environmental Consultant as and when required and such that changes are implemented / reported in future annual interpretive report.
— Defence may review the environmental management performance of their independent Environmental Consultant during the investigative work, and ensure OMP works are completed in accordance with Defence policies.
— Defence will provide an Environmental Clearance Certificate (ECC) to enable the works to be completed in accordance with Commonwealth protocols (Section 2.3) and ensure sampling locations (within Defence control) can be safely accessed and maintained to allow future sampling efforts.
— It is expected Defence will work in collaboration with their Environmental Consultant in providing on-Base assistance, if required, to help achieve the environmental outcomes.
1.2.2 ENVIRONMENTAL CONSULTANT

- The Environmental Consultant will be responsible for:
  - the day-to-day environmental management during the execution of field work.
  - Data management into EsDat in accordance with the Defence Contamination Management Manual Annex L.
  - achieving the objectives stated in the ECC.

- The Environmental Consultant will be responsible for monitoring compliance with the ECC, tracking progress and reporting (including revision of the OMP as required).
- The Environmental Consultant shall ensure that any subcontractors and sub-consultants using this OMP, has possession of the processes and procedures, including documented work instructions, which are consistent with the objectives and management actions stated within the ECC.

1.3 DOCUMENT REVIEW

The science of understanding PFAS impacts and ways of managing PFAS contamination are constantly evolving. There is still a lot that is not established about the behaviour or impacts of PFAS contamination on human health and the environment.

This OMP has been prepared based on information available at the time of writing and relies on the findings of the DSI, risk assessment and strategic management of risks assessed in the PMAP. Defence recognises that there may still be gaps in information that will be progressively addressed while impacted sites are being managed.

This document will be reviewed and updated in accordance with the strategy detailed in Section 5.

1.4 TRAINING AND AWARENESS

The objectives of the OMP will not be achieved if employees, contractors and subcontractors are not properly educated about the potential environmental issues associated with the investigative work. Failure to comply with the environmental management procedures set out in this OMP may pose an otherwise avoidable risk to the environment. Therefore, an essential part in the delivery of the OMP and its objectives is that all workers behave in an environmentally responsible manner, which can be achieved through training and education.

To facilitate an appropriate level of environmental awareness amongst workers, an environmental site induction is deemed mandatory. The induction will be incorporated into the Health, Environment and Safety Plan (HESP) and address the following:

- Site setting and potential environmental issues and hazards associated with the works.
- Implications of their actions on-Base and how their actions can affect the environment negatively and/or positively.
- Inform workers in the field of their duty of care to undertake the appropriate management procedures as outlined in the ECC, and to report any environmental complaints, incidents or hazards.
- Ensure specific responsibilities for implementing management and/or control actions required under the ECC are understood.
- An acknowledgement record is included in Appendix B where the project team (including sub-contractors) sign to acknowledge that they have been made aware of the OMP requirements.

1.5 REGULATORY CONTEXT

In assessing the hierarchy of application of the various legislative instruments and guidelines, due regard was directed to the Department of Defence’s aim to comply with State legislation when it does not conflict with Commonwealth legislative obligations. Relevant Commonwealth legislation and Queensland legislation that is applicable to the OMP has
been presented in this Section, acknowledging that as the Monitoring Area includes both on- and off-Base areas, the OMP meets the spirit and intent of Queensland legislative requirements.

1.5.1 COMMONWEALTH LEGISLATION: ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) protects the environment in relation to matters of National Environmental Significance. It streamlines national environmental assessment and approval processes, protects Australian biodiversity and integrates the management of important natural and cultural places. The investigation involved minimal temporary disturbance to collect samples within already disturbed land. Accordingly, it was assessed as not having sufficient environmental significance to warrant referral pursuant to this legislation. Referral under the EPBC Act may be required if results of the investigation identifies that contamination has the potential to cause significant impacts to matters of national environmental significance.

1.5.2 NATIONAL ENVIRONMENTAL PROTECTION MEASURE

The National Environmental Protection Council, in co-operation with environmental health agencies, prepared national guidelines for contaminated land matters in the National Environment Protection (Assessment of Site Contamination) Amendment Measure 1999 as amended 2013 (No. 1) (“the NEPM”).

The purpose of the NEPM is to establish a nationally consistent approach to the assessment of site contamination to ensure sound environmental management practices by the community which includes regulators, site assessor, contaminated land auditors, land owners, developers and industry.

The NEPM contains a series of schedules of which relevant to this investigation; these include:

— Schedule A which identifies the recommended process for the Assessment of Site Contamination, indicating guiding principles to be applied to preliminary and detailed site investigations.
— Schedule B which identifies nine general guidelines for the Assessment of Site Contamination, including outlines for investigation levels, field activities and health and ecological risk assessments.

The key element applicable from the NEPM is the nomination of investigation levels (i.e. or contaminant concentrations) for the assessment of the risk to human health and ecological receptors from potential contaminants in the soil materials to be removed from the site.

1.5.3 NATIONAL ENVIRONMENTAL MANAGEMENT PLAN

The investigation levels adopted for the nominated monitoring are those identified within the Heads of EPA Australia and New Zealand (HEPA) PFAS National Environmental Management Plan Jan 2018 for which Defence is a signatory. The key element applicable from the NEPM is the nomination of investigation levels (i.e. or contaminant concentrations) for the assessment of the risk to human health and ecological receptors.

1.5.4 RELEVANT STATE LEGISLATION

The Base is located within Queensland, associated works therefore make reference to both federal and state based legislation. It is noted that Defence land is not subject to Queensland regulation, however, it is understood that Defence endeavours, wherever possible, to abide by the ‘spirit and intent’ of that legislation.

Defence responsibilities are under the EPBC Act 1999 and compliance with the ‘spirit and intent’ of Queensland legislation and applicable guidance include the following:

— Australian and New Zealand Environment Conservation Council (ANZECC) 1992, Australia and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.
— Australian and New Zealand Governments (ANZG) 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, August 2018.
— National Environment Protection Council (NEPC) 1999, National Environmental Protection (Assessment of Site Contamination) Measure (NEPM) including Amendment measures 2013 (No.1).
— Queensland Environmental Protection Act 1994.

1.5.5 DEFENCE POLICY

1.5.5.1 DEFENCE ENVIRONMENTAL STRATEGY 2016-2036

Defence’s Environmental Strategy 2016-36 sets out a vision to be a leader in sustainable environmental management and commits Defence to achieving environmental best practice through a holistic approach to sustainable environment and heritage management.

The Environmental Strategic Plan underpins Defence’s operational management requirements, whereby environmental management and maintenance of operational status are integrated as far as practicable.

Under this plan, Defence has a “good neighbour” policy on the environment. Where appropriate Australian Government environmental legislation and policies do not exist, Defence aims to comply with the intent and spirit of relevant State environment legislation and related standards.

1.5.5.2 DEFENCE STRATEGIES AND FRAMEWORKS

The following documents provide guidance for the environmental and heritage management of the respective project areas:

— Defence Environmental Policy.
— Defence Heritage Strategy.
— Defence Heritage Register.
— Defence ContaminatedSites Strategy.
— Defence Contaminated Sites Register (CSR).
— Defence Contamination Risk Assessment Tool (CRAT).
— The management of hazardous wastes and hazardous discharges - environmental health aspects.
— Reporting of environmental incidents within Defence.
— Defence Environmental Risk Management Framework.
— Defence Environmental Risk Tool.

Defence also has an Ecologically Sustainable Development (ESD) Policy based on the National Strategy for ESD endorsed by the council of Australian Governments (NSESD, 1992). The ESD Policy covers all aspects of Defence activities and includes strategic initiatives and roles and responsibilities.
2 HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT

2.1 RISK ASSESSMENT AND METHODOLOGY

For each health, safety and environmental aspect, the issue and/or impact has been identified and an objective set to help define the relevant performance requirements. Each environmental issue has then been assessed within a risk assessment framework and actions and/or controls developed to manage that risk. Issues were then re-assessed to determine the residual risk. The Environmental Consultant is expected to revisit the risk assessment framework (and revise where appropriate) prior to commencement of monitoring to ensure currency and appropriateness of identified mitigation measures in the context of Base-specific relevance.

The risk assessment framework adopted for the OMP is detailed in Table 2.1, which provides a matrix for measuring the probability and consequence of a hazard eventuating. It is noted that the framework presented is a holistic health, safety and environmental framework rather than being limited to environmental risks only.

Steps involved in risk identification include:

— outlining the activity which may pose a risk to the health & safety and/or the environment;
— outlining the potential hazard associated with the risk;
— identifying the ‘initial risk’ by using the risk assessment matrix tables for probability of hazard occurring and the consequence of hazard occurring;
— defining the control measures and actions to be undertaken to mitigate the risk; and
— outlining the ‘residual risk’ by using the risk assessment matrix tables for probability of hazard occurring and the consequence of hazard occurring.

This process is ongoing throughout the project, with risks anticipated to continually be identified and mitigated. Preliminary risk assessment is conducted prior to project commencement; these details are reflected in the HESP.

Control hierarchy’s to be used to mitigate and/or control an identified health & safety and environmental risk should be applied as follows:

— elimination
— re-design or substitution
— engineering controls
— administrative controls
— training
— personal protective equipment (PPE).
2.2 OBJECTIVES AND MANAGEMENT OF KEY ISSUES

This section describes the key health & safety and environmental objectives and minimum management requirements to achieve compliance with the OMP.

2.2.1 HYDROCARBON, CHEMICAL & SPILL MANAGEMENT

2.2.1.1 CONTEXT

Spills and leaks of hydrocarbons and chemicals pose a serious risk to the environment should the contaminants enter waterways. The most likely source of hydrocarbon or chemical spills would be associated with inappropriate storage and transport of fuel and spills/leaks from vehicles.

It is not anticipated that significant volumes of hazardous liquids would be stored on-Base during OMP activities, although minor, incidental amounts of fuel and/or oils may be required by contractors for off-Base works (e.g. sampling from a boat in The Common). The contractors are to avoid storing these types of liquids at the Base.

Contingency measures shall be implemented when spills and/or leaks of hazardous materials occur either at the Base or off-Base. Contingency measures that shall be in place throughout the OMP to protect the surrounding community from hazards posed by chemical spills and leaks include:

- presence of an emergency supply spill control equipment (oil absorbent materials);
- containment of any storage tanks or drums placed on temporary bunded areas on a hard surface area; and
- storage of equipment on hardstand areas, where possible.

2.2.1.2 MANAGEMENT

Controls can be applied to minimise the risk of spillages occurring and, prevent spillages from entering waterways and the environment. Controls to manage this risk can be grouped as procedural controls and physical controls.

Procedural controls are defined as the operational procedures developed for the safe use, storage and disposal of hydrocarbon and chemical substances. They aim at providing preventative measures and minimising the opportunity for hydrocarbon and chemical spills to occur. To meet the objective, the Environmental Consultant will ensure the contractor engaged for accessing waterways in The Common have appropriate and documented controls/ procedures are in place for:

- transfer, storage and transport of hydrocarbons;
- spill response;
- any hazardous or dangerous good brought onto the Base and/or used within the Monitoring Area must be stored appropriately and be accompanied by the product’s Safety Data Sheet (SDS);
- vehicle/machinery maintenance checks; and
- all spills must be reported immediately to Defence.

Physical controls are defined as a physical barrier inhibiting hydrocarbon and chemical substances from contaminating the surrounding environment. Physical controls should be implemented as a back-up control for when procedural controls fail. It is expected that our contractors will enact effective physical controls including:

- Storage areas to be located in designated areas;
- Stormwater drains, or preferential pathways immediately surrounding the work area are to be sandbagged/ bunded during the execution of the works; and
- All equipment will be inspected daily to identify any potential line (fuel, hydraulic, etc.) ruptures.
2.2.2 **ODOUR / VAPOUR CONTROL**

2.2.2.1 **CONTEXT**

Generating odour or vapour is a potential consequence of purging of groundwater during groundwater sampling in the event that co-contamination exists. It should be noted that PFAS is a non-volatile and has no discernible odour at the concentrations being sampled. However, other volatile and odorous contaminants such as hydrocarbons may be present in water being sampled.

2.2.2.2 **MONITORING AND MANAGEMENT**

Sampling of PFAS contaminated sediment and water is not expected to generate odours or vapours. Therefore, the monitoring and management of odours and vapours has been designed in the event of intersecting volatile contamination such as hydrocarbons. The HESP is to include appropriate worker notification, occupational health and safety (OH&S) practices and controls recommended to manage the potential risks posed to employees of the Environmental Consultant, its subcontractors and nearby receptors from exposure to vapours.

2.2.3 **SOLID AND LIQUID WASTE MANAGEMENT**

2.2.3.1 **CONTEXT**

Solid and liquid waste products will be generated throughout OMP activities. Packaging and solid wastes (e.g. nitrile gloves), have the potential to become windborne and pollute both land and waterways, and may harm fauna if accidentally ingested. Liquid wastes (i.e. potentially impacted groundwater) may be generated during water sampling and if handled incorrectly or inappropriately disposed, can potentially impact soil, groundwater and / or the marine environment.

The objective is to manage solid and liquid waste appropriately so that they do not pose a risk of contaminating the environment. Management of waste will be in conjunction with hydrocarbon and chemical spill management practices.

2.2.3.2 **MANAGEMENT**

Handling, containment and disposal of waste materials/substances produced from the investigative work must be appropriately managed to minimise potential impacts to the environment, management strategies include:

- Littering is prohibited. All solid waste and packaging is to be removed off-Base by the Environmental Contractor and their contractors. A temporary bin will need to be provided at the worksite and waste disposed of off-Base each day.
- Fire extinguishers are to be available within each project vehicle and a minimum of one extinguisher within the defined work area, in case of fire from storage of combustible liquids.
- Any PFAS waste material (soil and water) exported from the Monitoring Area will require sampling and classification that complies with the Queensland Department of Environment and Science (DES) requirements for waste tracking and the receiving facility requirements in order to determine an appropriate disposal fate. However, the sampling methods described in this OMP are likely to limit PFAS-impacted waste to the waters generated during decontamination activities.

2.2.4 **BUSHFIRE**

2.2.4.1 **CONTEXT**

The Common and other areas of the Base have reeds and long grasses that could be prone to ignition either during field works or as a result of field works (e.g. heat and/or spark from plant or vehicle exhaust). The objective is therefore to minimise the risk of ignition within the worksite and evoke processes for managing risk as a result of ignition outside the worksite.
2.2.4.2 MANAGEMENT

— Ensuring there is adequate telecommunication so that emergency services can be alerted, both in the event of an occurrence within the work area, or to manage egress where the event has occurred outside the work area.
— Fire extinguishers are to be available within each project vehicle and a minimum of one extinguisher within the defined work area, in case of fire from storage of combustible liquids.
— Attachment of spark arrest devices to plant and vehicle exhaust where used in the proximity of dry grass.
— Position plant and vehicles, where practicable, away from areas of dry grass.
— Where necessary, such as in the event of hot works, appoint one of the field crew to be a firewatcher and ensure the fire extinguisher is within reach for rapid deployment.

2.2.5 FLORA AND FAUNA

2.2.5.1 CONTEXT

Vehicle movements and general site works have the potential to disturb or destroy native flora and fauna. Further to this, caution needs to be taken not to introduce non-endemic species (particularly seeds/weeds) as they may impact the established ecosystems.

There has been an outbreak of yellow crazy ant adjacent to and within The Common in the past, however this pest is understood to have been eradicated.

The objective is therefore to minimise the impact of monitoring on native flora and fauna, and to ensure no threatened/endangered species are collected during the program (in the event of biota collection). In addition, the minimisation of disturbance to native flora and fauna and the potential of introducing weeds and spreading of pests is required.

2.2.5.2 MANAGEMENT

The manage fauna and flora impacts during the sampling program the following will be implemented:
— Consider equipment location setup and vicinity to nearby vegetation to minimise any resultant impact (i.e. trampling/emissions) to vegetation that might be a habitat for resident species;
— Restrict vehicle and plant movements to designated roadways/paths when moving;
— If a snake is sighted do not approach and only commence works when it is safe to do so;
— When driving, be aware of and slow down when near native fauna when driving during early morning/evenings;
— All wastes (particularly food scraps) to be disposed in accordance with solid waste requirements; and
— No plants or animals are permitted to be brought onto Base or The Common.

2.2.6 FRESHWATER ENVIRONMENT / WATERWAYS

2.2.6.1 CONTEXT

Environmental sampling will be undertaken in The Common, Bohle River and creeks and drainage channels that flow from the Base into the surrounding environment. Sampling will be undertaken from a boat in some instances and the potential exists for water contamination from fuel spills and chemicals associated with biota sampling (e.g. preservation alcohol).

2.2.6.2 MANAGEMENT

Management measures that may be used to control sediment and run-off include appropriate hydrocarbon and chemical storage, solid/liquid waste management and flora and fauna management (previously discussed in Sections 2.2.1, 2.2.3 and 2.2.4 respectively).
Additional management measures for the sampling include:

- Vehicles to be refuelled at a designated refuelling station;
- Boats to be refuelled on-shore (no on-water refuelling is to be conducted) and if a designated area cannot be accessed, additional controls such as a spill-kit and placement of sorbent socks across drains to be incorporated; and
- Sampling chemicals to be stored correctly in the appropriate, dedicated containers.

### 2.2.7 ENVIRONMENTAL COMPLAINT MANAGEMENT

#### 2.2.7.1 CONTEXT

In the event that complaints are received during the monitoring works, it is important that a system be established to record and action the complaints received. A complaints register will be established and administered by the Environmental Consultant, in collaboration with any local Defence processes.

#### 2.2.7.2 MANAGEMENT

The Environmental Consultant will be responsible for activities relating to environmental complaint management during monitoring works. The protocols for environmental complaint management will be established by the Environmental Consultant and Regional Environmental and Sustainability Officer (RESO) and incorporated into the ECC.

### 2.2.8 DECONTAMINATION OF EQUIPMENT

#### 2.2.8.1 CONTEXT

Sampling of potentially contaminated sediment and/or water will require the decontamination of equipment, including hand tools and field meters used in the sampling process.

#### 2.2.8.2 MANAGEMENT

- All vehicles to be clean of soils and plant matter before entry to Base or The Townsville Town Common and prior to exiting the Base.
- Decontamination on the Base, where deemed necessary, will consist of high pressure vehicle or equipment washed down and will be done at a dedicated, hardstand wash down area.
- Field equipment shall be decontaminated using a PFAS free detergent such as Liquinox.
- Wash down will be undertaken on a hardstand area to allow evaporation of water to occur and run-off will be prohibited so as not to impact uncontaminated areas.
- Decontamination wastewater from sampling equipment will be contained within an appropriately sealed and labelled container.
- All waste generated during the decontamination process should be managed as per the requirements in Section 2.2.3 (solid and liquid waste management).

### 2.3 ENVIRONMENTAL CLEARANCE CERTIFICATES AND PERMITS TO WORK

A Defence ECC will need to be issued prior to works being undertaken.

Details of the required work such as timeframes and potential disruptions to Base operations must be included in order to arrange access to the Base that does not disrupt Defence capability and Base activities.

Off-base permitting / access considerations are included in Section 3.4.2.
2.4 ENVIRONMENTAL INCIDENT REPORTING

Incident reporting procedures will be used by staff and its contractors of the Environmental Consultant to report any of the following:

- Environmental Events (e.g. spills, wildlife encounters, vegetation clearance, etc.);
- Near Misses;
- Visit by Regulatory Authority to the work site;
- Hazard observations; and
- Positive observations.

All environmental incidents are to be reported immediately to Defence, and upon direction from Defence, a formal investigation and root-cause-analysis be conducted. Where any doubt exists as to the presence of an environmental hazard or risk, such risk should be deemed to exist and this should be reported accordingly.

2.5 COMMUNICATIONS

The following will be shared with relevant State authorities and made publicly available:

- OMP.
- monitoring data collected during the implementation of the OMP.
- decisions made in response to the data collected during implementation of the OMP.
- changes to the OMP in response to incoming data over the implementation period.
### Table 2.1 Risk assessment framework

<table>
<thead>
<tr>
<th>Probability</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ALMOST CERTAIN to happen</td>
</tr>
<tr>
<td>B</td>
<td>LIKELY to happen at some point</td>
</tr>
<tr>
<td>C</td>
<td>MODERATE possible, it might happen</td>
</tr>
<tr>
<td>D</td>
<td>UNLIKELY not likely to happen</td>
</tr>
<tr>
<td>E</td>
<td>RARE practically impossible</td>
</tr>
</tbody>
</table>

### Maximum reasonable consequence

#### Health and safety

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Catastrophic</strong> – Could kill, permanently disable or cause very serious damage</td>
</tr>
<tr>
<td>2</td>
<td><strong>Major</strong> – Could cause serious injury (major lost time injury), illness or major damage</td>
</tr>
<tr>
<td>3</td>
<td><strong>Moderate</strong> – Could cause injury or illness requiring visit to doctor, lost time injury or moderate damage</td>
</tr>
<tr>
<td>4</td>
<td><strong>Minor</strong> – Could cause first aid injury, minor illness or minor damage</td>
</tr>
<tr>
<td>5</td>
<td><strong>Insignificant</strong> – Could not cause injury, illness or damage</td>
</tr>
</tbody>
</table>

#### Environment

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Catastrophic</strong> – Intense local impacts with short to medium term effects and/or major potential for widespread impacts in the medium to long term. These impacts are clearly apparent and may be irreversible.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Major</strong> – Major local impacts with short to medium term effects and/or moderate potential for widespread impacts.</td>
</tr>
<tr>
<td>3</td>
<td><strong>Moderate</strong> – Moderate local impacts with medium term effects and/or low potential for widespread impacts in the short to medium term.</td>
</tr>
<tr>
<td>4</td>
<td><strong>Minor</strong> – Minor local impacts with short term effects or minor widespread impact.</td>
</tr>
<tr>
<td>5</td>
<td><strong>Insignificant</strong> – Minor impact with negligible effects.</td>
</tr>
</tbody>
</table>
## Risk ranking matrix

<table>
<thead>
<tr>
<th>PROBABILITY</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSEQUENCES</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>9</td>
<td>13</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>14</td>
<td>18</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>19</td>
<td>22</td>
<td>24</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRITICAL</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HIGH RISK</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 – 10</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MODERATE RISK</th>
<th>MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 – 15</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOW RISK</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 – 25</td>
<td></td>
</tr>
</tbody>
</table>

## Hierarchy of control – hazard management

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eliminate</td>
</tr>
<tr>
<td>2</td>
<td>Re-design or substitute</td>
</tr>
<tr>
<td>3</td>
<td>Engineering Controls</td>
</tr>
<tr>
<td>4</td>
<td>Administrative Controls</td>
</tr>
<tr>
<td>5</td>
<td>Training</td>
</tr>
<tr>
<td>6</td>
<td>PPE (Personal Protective Equipment)</td>
</tr>
</tbody>
</table>
3 ENVIRONMENTAL MONITORING

3.1 TECHNICAL FRAMEWORK

The scope of work is to be undertaken with reference to the following guidelines:

— ANZG 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, August 2018.
— NSW Environment Protection Authority (EPA) 2016, Guidance Note: Designing Sampling Programs for Sites Potentially Contaminated by PFAS, November 2016.
— Queensland Environmental Protection Act 1994.
— Queensland Environmental Protection Regulation 2008.

3.2 DATA QUALITY OBJECTIVES

Systematic planning is critical to successful implementation of an environmental assessment and is used to define the type, quantity and quality of data needed to inform decisions. The United States Environmental Protection Agency (US EPA) has defined a process for establishing data quality objectives (DQOs) (US EPA, 2006), which has been referenced in NEPC (1999, Amended).

DQOs ensure that:

— the study objectives are set;
— appropriate type of data is collected (based on contemporary land use and chemicals of concern); and
— the tolerance levels are set for potential decision making errors.

The DQO process is a seven-step iterative planning approach. The outputs of the DQO process are qualitative and quantitative statements which are developed in the first six steps. They define the purpose of the data collection effort, clarify what the data should represent to satisfy this purpose and specify the performance requirements for the quality of information to be obtained from the data. The output from the first six steps is then used in the seventh step to develop the data collection design that meets all performance criteria and other design requirements and constraints. The DQO process adopted for the assessment program across the Monitoring Area is outlined in Table 3.1.
Table 3.1  DQO process

<table>
<thead>
<tr>
<th>STEP</th>
<th>DESCRIPTION</th>
<th>OUTCOMES</th>
</tr>
</thead>
</table>
| 1    | State the problem. | The purpose of the OMP is to quantify contaminant concentrations and document contaminant trends in on-Base and off-Base media (sediment, surface water and groundwater) to assist in:  
— quantifying the efficacy of pragmatic and technical defensible remediation options implemented to management PFAS impacts at the Base; and  
— quantifying the residual risk to on- and off-Base receptors associated with PFAS use at the Base, both pre- and post-remediation. |
| 2    | Identify the decisions/goal of the OMP. | The decisions to be made based on the results of the investigation are listed below.  
— Do the analytical results and field observations allow for an assessment of risk(s) associated with complete or potentially complete PFAS source-pathway-receptor pathways?  
— Do the analytical results and field observations allow for the interpretation of PFAS trends and do these trends warrant a re-evaluation of management actions?  
— Does the OMP need to be refined to address uncertainty and would such a change(s) result in greater efficacy with respect to ongoing management or future intervention. |
| 3    | Identify the inputs to the decision. | The inputs required to make the above decisions are the monitoring points (surface water, sediment and groundwater monitoring wells) that were utilised / initiated as part of the DSI (WSP, 2018a) and Seasonal Monitoring Reports (WSP, 2019b; 2019c) activities as the basis against which trends (increasing, decreasing, stable) can be assessed. These monitoring points have allowed for the development of the monitoring framework for assessing PFAS impacted media from the Base. Revision/improvements to the OMP sample design (i.e. addition or retirement of monitoring points) will be based on changes or further understanding to the:  
— physical setting;  
— behaviour of PFAS in the environment;  
— concentrations of PFAS in media;  
— site assessment criteria (outlined in Section 3.5);  
— observation data including presence of ‘foaming’, field water quality parameters and presence of other contaminants (e.g. non-aqueous phase liquid);  
— distribution, extent and severity of identified contamination; and  
— trends of contaminant concentrations, where applicable. |
| 4    | Define the study boundaries / constraints on data. | The boundaries of the investigation have been identified as follows:  
— Spatial boundaries: the spatial boundary of the Monitoring Area is defined as the extent shown on Figure 1, Appendix A, and the depth of the investigation point.  
— Temporal boundaries: the date of the OMP preparation / revision (March 2019). |
| 5    | Develop a decision rule. | The purpose of this step is to define the parameters of interest, specify the action levels and combine the outputs of the previous DQO steps into an ‘if…then…’ decision rule that defines the conditions that would cause the decision maker to choose alternative actions.  
The parameter of interest is the concentrations of PFAS contaminants of concern in media. If there is exceedance of a PFAS investigation level, the location of the sample point is to be assessed to determine:  
1 If PFAS at the location is demonstrating an increasing trend from that defined in the DSI (WSP, 2018a) and Seasonal Monitoring Reports (WSP, 2019b; 2019c), then additional investigation(s) may be recommended to quantify risk to receptor(s) in line with the HHRA (WSP, 2018b) and/or the ERA (WSP, 2019a) framework; or  
2 If PFAS at the location is demonstrating a stable or decreasing trend from that defined in the DSI (WSP, 2018a) and Seasonal Monitoring Reports (WSP, 2019b; 2019c), then no additional investigation(s) are warranted other than ongoing monitoring in accordance with this OMP.  
If the analyte concentration is below the IL, laboratory LOR and/or PFAS has been delineated towards receptors, then no additional action may be necessary other than ongoing monitoring in accordance with this OMP.  
All recommendations are to be grounded in the Conceptual Site Model (CSM) in the DSI (WSP, 2018a) and Seasonal Monitoring Reports (WSP, 2019b; 2019c) and an informed judgement of practicality and benefit. |
| 6    | Specify limits on decision errors. | The acceptable limits on decision errors to be applied in the investigation and the manner of addressing possible decision errors have been developed based on the data quality indicators (DQIs) of precision, accuracy, representativeness, comparability and completeness and are presented in Table 3.2. |
Optimise the design for obtaining data.

The purpose of this step is to identify a resource-effective data collection design for generating data that satisfies the DQOs. This assessment has been designed considering the information and data obtained from the Detailed Site Investigation (DSI) (WSP, 2018a). The resource effective data collection design that is expected to satisfy the DQOs is described in detail in Section 3.4 (methodology).

To ensure the design satisfies the DQOs, DQIs (for accuracy, comparability, completeness, precision and reproducibility) have been established to set acceptance limits on field methodologies and laboratory data collected.

All ongoing monitoring is to be undertaken under the delegation of a Suitably Qualified Person (SQP) in accordance with the Queensland Environmental Protection Act 1994.

DQIs for sampling techniques and laboratory analyses of samples define the acceptable level of error required for the assessment. The adopted field methodologies and data obtained have been assessed by reference to DQIs. A summary of the field and laboratory DQIs for the assessment are provided in Table 3.2.

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>FIELD TECHNIQUES</th>
<th>LABORATORY TECHNIQUES</th>
</tr>
</thead>
</table>
| **Precision**<br>A quantitative measure of the variability (or reproducibility) of data. | Standard Operating Procedure (SOP) or Work Method Statement (WMS) appropriate and complied with. | Analysis of laboratory duplicates for groundwater for the same analyses as primary samples. Acceptable limits for organic and inorganic analyses used by the laboratory are as follows:
  — Where the sample result is less than 10 times the PQL, RPD limits cannot be applied;
  — Where the sample result is 10 to 20 times the PQL, RPDs between 0–50% are considered acceptable; and
  — Where the sample result is more than 20 times the PQL, RPDs between 0–20% are considered acceptable. Laboratory prepared trip spike blanks are not recommended for this OMP. |
| | Collection of inter-laboratory and intra-laboratory duplicates. | All analysis performed should be National Association of Testing Authorities (NATA) accredited and undertaken by certified laboratories. |
| **Accuracy**<br>A quantitative measure of the closeness of reported data to the true value. | SOP / WMS appropriate and complied with. Collection of field and trip blanks and trip spikes. | Analysis of laboratory prepared trip blanks (one per esky) for PFAS. Analytical results should be below the PQLs for all contaminants analysed. Analysis of rinsate blanks (one per day per media sampled) for PFAS. Analytical results should be below the PQLs for all contaminants analysed. Analysis of trip blanks (one per esky) for PFAS. Analytical results should be below the PQLs for all contaminants analysed. Analysis of laboratory blanks. Results should be below the PQLs for all contaminants analysed. Analysis of laboratory matrix spikes, laboratory control samples and surrogate recoveries for PFAS. Recoveries (as per the laboratories QA/QC limits) should be:
  — 70–130% for inorganics/metal,
  — 60–140% for organics; and
  — 10–40% for semi-volatile organic compounds. |
| | SOP / WMS appropriate and complied with. | Analysis of field blanks (one per day per media sampled) for PFAS. Analytical results should be below the PQLs for all contaminants analysed. Analysis of rinsate blanks (one per day per media sampled) for PFAS. Analytical results should be below the PQLs for all contaminants analysed. Labor prepared trip spike blanks are not recommended for this OMP. Analysis of trip blanks (one per esky) for PFAS. Analytical results should be below the PQLs for all contaminants analysed. Analysis of laboratory blanks. Results should be below the PQLs for all contaminants analysed. Analysis of laboratory matrix spikes, laboratory control samples and surrogate recoveries for PFAS. Recoveries (as per the laboratories QA/QC limits) should be:
  — 70–130% for inorganics/metal,
  — 60–140% for organics; and
  — 10–40% for semi-volatile organic compounds. |
<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>FIELD TECHNIQUES</th>
<th>LABORATORY TECHNIQUES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Representativeness</strong></td>
<td>The confidence (expressed qualitatively) that data are representative of each media present on the site.</td>
<td>Analysis of laboratory duplicates as with acceptable limits as per ‘precision’.</td>
</tr>
<tr>
<td></td>
<td>Appropriate media sampled.</td>
<td>All required samples analysed as per Section 3.4.4 of this OMP.</td>
</tr>
<tr>
<td><strong>Comparability</strong></td>
<td>A qualitative parameter expressing the confidence with which one data set can be compared with another.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Same SOP / WMS used on each occasion.</td>
<td>Sample analytical methods used (including clean-up), as per NEPC (1999, Amended).</td>
</tr>
<tr>
<td></td>
<td>Experienced sampler.</td>
<td>Same units.</td>
</tr>
<tr>
<td></td>
<td>Climatic conditions (temperature, rainfall, wind) and seasonal conditions.</td>
<td>Same laboratories. Soil and sediment sample variance is unlikely to be influenced by climatic or seasonal conditions during the investigation period. Surface water and groundwater sample variance may be influenced by climatic conditions in the event of severe rainfall event and seasonally between wet and dry (monsoonal) seasons.</td>
</tr>
<tr>
<td></td>
<td>Same type of samples collected.</td>
<td>Sample practical quantification limits (PQLs) to be less than nominated assessment criteria.</td>
</tr>
<tr>
<td><strong>Completeness</strong></td>
<td>A measure of the amount of useable data (expressed as a percentage) from a data collection activity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SOP / WMS appropriate and complied with.</td>
<td>All critical samples analysed.</td>
</tr>
<tr>
<td></td>
<td>All required samples collected.</td>
<td>All required analytes analysed. Appropriate methods and PQLs as per NEPC (1999, Amended).</td>
</tr>
<tr>
<td></td>
<td>Sample holding times should comply with laboratory requirements.</td>
<td>Sample documentation complete as per NEPC (1999, Amended). Sample holding times complied with as per NEPC (1999, Amended).</td>
</tr>
</tbody>
</table>

### 3.3 SAMPLING AND ANALYSIS DESIGN

#### 3.3.1 SAMPLE NAMING CONVENTION

The naming convention is to in accordance with the Defence Contamination Manual (Department of Defence 2018a). The convention is described below.

- **PPPP_XX000_ZZZ_YYMMDD**
  - **PPPP** is the property identifier and for this project is 0874.
  - **XX** refers to the type of sample recovery.

Refer to Table 3.3 for sample recovery identifier that pertain to this OMP.

<table>
<thead>
<tr>
<th>ABBREVIATION (XX)</th>
<th>MEANING</th>
<th>MATRIX</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>Monitoring well</td>
<td>Groundwater</td>
<td>Soil samples may be collected from monitoring well locations.</td>
</tr>
<tr>
<td>SW</td>
<td>Surface water</td>
<td>Water</td>
<td>No comment.</td>
</tr>
<tr>
<td>SD</td>
<td>Sediment</td>
<td>Sediment</td>
<td>Depth of sediment sample (where not surface) should be included similar to soil samples.</td>
</tr>
</tbody>
</table>
— 000 pertains to the location specific identification.
— ZZZ indicates the depth where the sample was taken.
— For groundwater, the water bearing unit or portion of the water bearing unit is nominated (note that the screen interval should be recorded on the borehole log sheet / well construction record and in the well master). Indicative screen interval identifiers are below:

<table>
<thead>
<tr>
<th>P is for perched</th>
<th>S is for shallow</th>
<th>I is for intermediate</th>
<th>D is for deep</th>
</tr>
</thead>
</table>

— YYMMDD pertains to the sample date in numerical format, in the order of year (YY), month (MM) and day (DD).

Examples of the naming convention are below.

— Water
  — Groundwater: 0874_MW104_S_120119 (note the absence of the ZZZ component, is one identifier).
  — Surface water: 0874_SW002_130406 (note the absence of the ZZZ component).
— Sediment:
  — Sediment: 0874_SD027_100823 (note the absence of the ZZZ component).

The naming convention of quality assurance (QA) samples is detailed below.

— Duplicate: 0874_QC1XX_YYMMDD
— Triplicate / split: 0874_QC2XX_YYMMDD
— Rinsate: 0874_QC3XX_YYMMDD
— Field blank: 0874_QC4XX_YYMMDD
— Trip blank: 0874_QC5XX_YYMMDD
— Trip matrix spike: 0874_QC6XX_YYMMDD

3.3.2 SAMPLE RATIONALE

The rationale for sampling and field observations within the Monitoring Area are detailed below.

Table 3.4 Sampling rationale

<table>
<thead>
<tr>
<th>TASK</th>
<th>FIELD ACTIVITIES</th>
<th>APPROACH &amp; RATIONALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
<td>Collection of surface water samples from designated surface water monitoring sites.</td>
<td>The sample design is for surface water and sediment samples to be collected up-gradient (i.e. coming onto Base), from areas proximate to secondary sources, and down-gradient of source areas and/or remedial areas. Periodic monitoring of surface water provides not only a line of evidence of on-going mobilisation of PFAS along and/or into surface water features within the Monitoring Area, but also allows for trends to be established to assess the efficacy of implemented PFAS management actions at the Base. Sediment sampling allows for an ongoing assessment as to whether there is migration of solid matrix and/or surface water transport is impacting on sediment quality. The rationale for sample collection of surface water and sediment falls into either of the following categories: 1. Monitoring sites where the HHRA (WSP, 2018b) and/or the ERA (WSP, 2019a) demonstrated that the exposure pathway to PFAS-impacted surface</td>
</tr>
<tr>
<td>TASK</td>
<td>FIELD ACTIVITIES</td>
<td>APPROACH &amp; RATIONALE</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sediment sample</td>
<td>Collection of sediment samples from designated sediment monitoring sites.</td>
<td>water could be potentially completed and that this completed exposure could result in an unacceptable risk to the receptor.</td>
</tr>
<tr>
<td>collection.</td>
<td></td>
<td>2. Monitoring sites where the PMAP nominates an intervention is required (or has been undertaken) to reduce PFAS flux from the Base and pre- and post-remediation trend monitoring is necessary to assess remediation efficacy.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sampling surface water and sediment allows determination of:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— the behaviour of PFAS from source areas at the Base, including temporal fluctuations due season and ‘first flush’ events;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— monitoring background concentrations in surface water features that are up-gradient of the Base and thereby assessing the ‘background’ burden in surface water; and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— the efficacy of remedial intervention that affect surface water discharges from the Base.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surface water samples are only to be collected where ponded water is present. Whilst the proposition is to collect surface water samples collocated with sediment samples, where a location is dry, the sediment sample may be the only sample collected.</td>
</tr>
<tr>
<td>Groundwater sample</td>
<td>Collection of groundwater samples from designated monitoring sites.</td>
<td>The sample design is for groundwater samples to be collected from locations up-gradient (i.e. coming onto the Base), from source areas and down- and cross-gradient of source areas. PFAS has been confirmed from off-Base source(s) which are unlikely to be associated with Defence activities and so is ‘background’.</td>
</tr>
<tr>
<td>collection.</td>
<td></td>
<td>Groundwater, whilst being a ‘lesser’ media for exposure in the Monitoring Area given that transport of PFAS is dominated by surface discharge, warrants ongoing monitoring as the behaviour of the groundwater plumes (especially in the southeast of the Monitoring Area) still have the potential to impact on groundwater amenity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The rationale for sample collection of groundwater falls into either of the following categories:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Monitoring sites where the IHRA (WSP, 2018b) and/or the ERA (WSP, 2019a) demonstrated that the exposure pathway to PFAS-impacted groundwater could be potentially completed and that this completed exposure could result in an unacceptable risk to the receptor.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Monitoring sites where the PMAP nominates an intervention is required (or has been undertaken) to reduce PFAS flux from the Base and pre- and post-remediation trend monitoring is necessary to assess remediation efficacy.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sampling groundwater allows determination of:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— the behaviour of PFAS from source areas at the Base, including temporal fluctuations due season events (wet season versus dry season);</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— monitoring background concentrations in groundwater that are up-gradient of the Base and thereby assessing the ‘background’ burden in groundwater;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— the efficacy of remedial intervention that affects the groundwater plume mass and extent.</td>
</tr>
</tbody>
</table>

### 3.3.3 SAMPLE DESIGN

#### 3.3.3.1 SURFACE WATER

To achieve the objectives of the OMP, sampling will be undertaken at the frequency outlined in Table 3.5. A ‘high rainfall event’ is defined as a forecast of 50mm in a day and/or a cumulative rainfall of 100mm in a seven-day period. The proposed sample locations for the first 12 months of OMP implementation are shown on Figure 2, Appendix A. Note that sediment sample locations mirror surface water sampling locations (refer Section 3.3.3.2).
Table 3.5  PFAS screening for surface water locations

<table>
<thead>
<tr>
<th>SIX MONTHLY FREQUENCY</th>
<th>SURFACE WATER MONITORING LOCATIONS</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>ON-BASE</strong></td>
<td><strong>OFF-BASE</strong></td>
</tr>
<tr>
<td>October (dry season)</td>
<td>SW001A, SW010S, SW013, SW014, SW016, SW019, SW021, SW102, SW106, SW112, SW121, SW123, SW125, SW126, SW131 - SW132</td>
<td>SW017, SW107 - SW111, SW113 - SW120, SW127, SW129, SW201 - SW210</td>
</tr>
<tr>
<td>April (wet season)</td>
<td>SW010S, SW014, SW016, SW102, SW112, SW121, SW123, SW125, SW131 - SW132</td>
<td>SW017, SW108 - SW109, SW115 - SW118, SW127, SW129</td>
</tr>
<tr>
<td>High rainfall event (event-based)</td>
<td>SW010S, SW014, SW016, SW102, SW112, SW121, SW123, SW125, SW131 - SW132</td>
<td>SW017, SW108 - SW109, SW115 - SW118, SW127, SW129</td>
</tr>
</tbody>
</table>

The months of April and October have been nominated above as they are six months apart and transitional months where the seasonal change is likely to occur, noting that sampling can be drawn forward or pushed back when warranted to allow for seasonal variability. A late wet season is known to occur in April and so drawing this period forward to February/March without tracking the season risks missing the wet season and the associated surface water flux.

3.3.3.2  SEDIMENT

To achieve the objectives of the OMP, sampling will be undertaken at the frequency outlined in Table 3.6. The proposed sample locations for the first 12 months of OMP implementation are shown on Figure 3, Appendix A. Note that sediment sample locations mirror surface water sampling locations (refer Section 3.3.3.1).

Table 3.6  PFAS screening for sediment locations

<table>
<thead>
<tr>
<th>SIX MONTHLY FREQUENCY</th>
<th>SEDIMENT MONITORING LOCATIONS</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>ON-BASE</strong></td>
<td><strong>OFF-BASE</strong></td>
</tr>
<tr>
<td>October (dry season)</td>
<td>SD001A, SD010S, SD013, SD014, SD016, SD019, SD021, SD102, SD106, SD112, SD121, SD123, SD125, SD126, SD131 - SD132</td>
<td>SD017, SD107 - SD111, SD113 - SD120, SD127, SD129, SD201 - SD210</td>
</tr>
<tr>
<td>April (wet season)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In line with the justification for surface water sampling in Section 3.3.3.1, sediment sampling has also been nominated for the months of April and October, noting that sampling can be drawn forward or pushed back when warranted to allow for seasonal variability.

3.3.3.3  GROUNDWATER

To achieve the objectives of the OMP, sampling will be undertaken at the frequency outlined in Table 3.7. The proposed sample locations for the first 12 months of OMP implementation are shown on Figure 4A and Figure 4B, Appendix A.
Table 3.7 PFAS screening for groundwater monitoring wells

<table>
<thead>
<tr>
<th>SIX MONTHLY FREQUENCY</th>
<th>GROUNDWATER MONITORING WELLS</th>
<th>JUSTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>October (dry season)</strong></td>
<td>MWRB5, MW002, MW004 - MW005, MW009, MW013, MW015, MW016, MW021, MW026, MW033 - MW034, MW038, MW043, MW046, MW049, MW054 - MW057, MW061, MW063, MW081, MW090, MW109 - MW110, MW112, MW114, MW116, MW118, MW120 - MW122, MW125 - MW126, MW129, MW135 - MW136, MW138 - MW140, MW142, MW222 - MW224, MW226 - MW227, MW229 - MW230, MW232, MW234, MW241 - MW251, MW255, MW265</td>
<td>Monitoring wells are in source areas, at the boundary of the Base, adjacent to migration pathways and adjacent to receptors to provide ongoing monitoring of migration of PFAS to assess plume behaviour. October has been nominated for a condensed monitoring program as this coincides with the dry season where PFAS concentrations may be lower due to falling standing water level (SWL).</td>
</tr>
<tr>
<td><strong>April (wet season)</strong></td>
<td>MWRB5, MW002, MW004 - MW005, MW009, MW013, MW015, MW016, MW021, MW026, MW033 - MW034, MW038, MW043, MW046, MW049, MW054 - MW057, MW061, MW063, MW081, MW090, MW109 - MW110, MW112, MW114, MW116, MW118, MW120 - MW122, MW125 - MW126, MW129, MW135 - MW136, MW138 - MW140, MW142, MW222 - MW224, MW226 - MW230, MW232, MW234 - MW235, MW241 - MW251, MW255, MW265</td>
<td>Monitoring wells are in source areas, at the boundary of the Base, adjacent to migration pathways and adjacent to receptors to provide ongoing monitoring of migration of PFAS. April has been nominated as the period for extended monitoring as this coincides with the scheduled end of the wet season in Townsville and the period where PFAS migration may be intensified by surface water flow.</td>
</tr>
</tbody>
</table>

To allow ongoing interpretation of surface water / groundwater interactions groundwater sampling has been nominated to occur in the months of April and October, which are consistent with the monitoring months nominated in Section 3.3.3.1, noting that sampling can be drawn forward or pushed back when warranted to allow for seasonal variability.

3.4 FIELDWORK METHODOLOGY

3.4.1 PRELIMINARIES

Prior to fieldworks, a site-specific HESP will need to be developed for the OMP works. All works will need to be undertaken in accordance with the HESP. Further to the HESP, a companion Environmental Management Plan (EMP) may need to be prepared upon direction from the RESO to facilitate the ECC such that the works comply with Defence and Base-specific processes.

3.4.2 ACCESS APPROVALS

3.4.2.1 ON-BASE APPROVALS

The ECC will be prepared using the approved form (AB081) and submitted to the Environment & Sustainability Manager (ESM) for approval. Liaison with the ESM will need to be undertaken at least two weeks in advance of the work (in consideration of an approval period up to 10 days) to discuss the ECC requirements applicability to specific works area and/or to a specific phase of works, which may result in multiple ECCs needing to be submitted.

As there are airside sample locations, liaison by the Environmental Consultant with the Base and Townsville Airport will be necessary to determine protocols for accessing airside areas. Airside Awareness Training will be required along with
the engagement of Work Safety Officer (WSO) to talk to Air Traffic Control (ATC). Depending on discussions with stakeholders in advance of works, a Method of Working Plan (MoWP) could possibly not be required provided the worksite can be evacuated under a nominated ‘recall’ period. Furthermore, as access to airside areas can be via the Base, an Aviation Security Identification Card (ASIC) may also not be required. Advice from the WSO, the Base and Townsville Airport will assist in navigating access to airside areas.

DCAC applications for field personnel will need to be attained, with all field team members to have as a minimum a ‘red’ contractor DCAC passes to enable access to the Base without an escort.

3.4.2.2 OFF-BASE APPROVALS

As investigation points are required outside the boundary of the Base, there are a number of local Council and State approvals that would be needed by the Environmental Consultant (not Defence) prior to accessing non-Defence land. Details of the approvals that the Environmental Consultant will need to obtain are noted in Table 3.8.

Table 3.8 Off-Base approvals summary

<table>
<thead>
<tr>
<th>LANDOWNER</th>
<th>DETAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road corridors controlled by Townsville City Council</strong></td>
<td></td>
</tr>
<tr>
<td>Rationale</td>
<td>Road easements not classified as Queensland State-controlled Roads are governed by Townsville City Council (TCC). There are a number of surface water, sediment and groundwater monitoring locations within TCC easements and so authority to access will be required to deliver the OMP works.</td>
</tr>
<tr>
<td>Approval</td>
<td>The process for accessing the road easement (i.e. roadway, shoulder, verge and footpath) is subject to approval by TCC. Some areas may not require permitting, however to complete and submit a request to the Building and Planning Approval Department at TCC.</td>
</tr>
<tr>
<td><strong>Townsville Town Common Conservation Park</strong></td>
<td></td>
</tr>
<tr>
<td>Rationale</td>
<td>The Townsville Town Common Conservation Park is a National Park and is administered by the DES (Parks and Forests). There are several surface water, sediment and groundwater monitoring locations within The Common and so approval to access will be required to deliver the OMP works.</td>
</tr>
<tr>
<td>Approval</td>
<td>The process to access the Townsville Town Common Conservation Park involves submission of an application for ‘scientific research’ to DES. The approval timeframe can take up to 40 business days (~2 months) based on the conditions in the permit.</td>
</tr>
</tbody>
</table>

3.4.3 SAMPLING METHODOLOGY

The recommended sampling methodology to be adopted for each target media is provided in Table 3.9, although other sampling methods may be appropriate and implemented (e.g. automated samplers for surface water) through an update to the OMP. Where there is a PFAS specific protocol (e.g. HDPE rather than LDPE), please refer Table 3.12.

Table 3.9 Sampling methodology

<table>
<thead>
<tr>
<th>TASK</th>
<th>METHODOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment sampling</td>
<td>Sediment samples collected from areas accessible by land will be collected using a hand trowel or hand-auger extended to a maximum depth of 0.2 mBGL. Due to the health and safety risks associated with crocodiles, management approaches outlined in the HESP will need to be followed adjacent to ponded water and waterways. Where sediment samples are collected from waterways, a stainless steel ‘bomb sampler’ will be deployed into the water column to facilitate sample collection. Sediment samples will be transferred directly into the laboratory-supplied containers. All jars will be labelled clearly in accordance with the naming convention (refer Section 3.3.1), and then placed into an esky with double-bagged ice present (refer Table 3.12). The samples will be delivered directly to the laboratory for analysis. Decontamination practices to be consistent with, and meet the objective of, Section 3.6.1.1.</td>
</tr>
</tbody>
</table>
### METHODOLOGY

#### Surface water sampling

Surface water samples will be collected using a telescopic pole sampler with stainless steel scoop. Due to the health and safety risks associated with crocodiles, management approaches outlined in the HESP will need to be followed adjacent to ponded water and waterways.

Surface water samples will be decanted directly into the laboratory-supplied containers. All bottles will be labelled clearly in accordance with the naming convention (refer Section 3.3.1), and then placed into an esky with double-bagged ice present (refer Table 3.12). The samples will be delivered directly to the laboratory for analysis.

Observations of weather conditions, and estimates of flow rate (velocity and cross-sectional area) at the sample point are to be collected. The cross-sectional area of the sample point will need to be collected during each dry season (October) sampling event.

Decontamination practices to be consistent with, and meet the objective of, Section 3.6.1.1.

#### Groundwater sampling

All monitoring wells will be gauged using a decontaminated oil/water interface probe to detect standing water level and possible non-aqueous phase liquids (NAPLs).

Groundwater samples will be collected from monitoring wells using a Hydrasleeve™ with samples decanted into clean laboratory-supplied containers. All bottles will be labelled clearly in accordance with the naming convention (refer Section 3.3.1).

The methodology for Hydrasleeve™ sampling is as follows:

- The Hydrasleeve™ (with anchor attached) will be affixed to nylon-twine and lowered to the base of the monitoring well for a period consistent with the manufacture’s direction (typically 24-hours in low permeability aquifers).
- The Hydrasleeve™ will then be retrieved drawing with it a volume of groundwater.
- The groundwater will be transferred directly from the Hydrasleeve™ into the laboratory-supplied bottles.
- A number of deploys and retrievals of the Hydrasleeve™ may be necessary to attain sufficient groundwater to fulfil the volume for all analysis.
- Following sealing of the sample bottles, the bottles will be transferred into an esky with double-bagged ice present (refer Table 3.12). The samples will be delivered directly to the laboratory for analysis.

Water quality measurements will be recorded *in situ* following sample collection and observations recorded once quality parameters have stabilised.

Decontamination practices to be consistent with, and meet the objective of, Section 3.6.1.1.

#### Waste

**Solid:** The generation of solid waste is unlikely as sediment samples are ‘grab’ samples and so excess sediment can be returned to the point of collection. Any retained sediment that is not submitted to the laboratory will need to be stored in 205 L close-top drums for off-Base disposal to landfill in accordance with the ECC.

**Liquid:** The generation of liquid during sampling works is expected to be minimal as surface water samples are grab samples and groundwater is a no purge sample. However, waste water from decontamination processes will be generated and so this waste stream will need to be stored in a close-top 205L drum or 1 m³ IBC for off-Base disposal in accordance with the ECC.

### 3.4.4 LABORATORY ANALYTICAL SCHEDULE

Table 3.10 outlines the primary laboratory analysis programs for the OMP. The selected primary and secondary laboratories will be NATA accredited for all analyses scheduled.

<table>
<thead>
<tr>
<th>MATRIX</th>
<th>ANALYSIS SUITE</th>
<th>TYPICAL CONTAINER TYPE &amp; PRESERVATION</th>
<th>HOLDING TIMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water</td>
<td>28-PFAS suite.</td>
<td>250mL unpreserved plastic (PTFE free), chilled.</td>
<td>6 months.</td>
</tr>
<tr>
<td>Sediment</td>
<td>28-PFAS suite.</td>
<td>250mL unpreserved plastic (PTFE free) jar, chilled.</td>
<td>6 months.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>28-PFAS suite.</td>
<td>250mL unpreserved plastic (PTFE free), chilled.</td>
<td>6 months.</td>
</tr>
</tbody>
</table>

### 3.5 ASSESSMENT CRITERIA

Investigation levels (ILs) have been selected in accordance with NEPC (1999) with Australian endorsed criteria referenced and presented in the following sections. In the event that an analyte is reported in excess of the laboratory level of reporting (LOR) and no Australian endorsed and/or defensible criteria exists, an IL may be sourced from a
guidance authored by a reputable international agency utilising methodologies applicable to the derivation of criteria in Australia. Agencies that may be considered include those in North America (United States and Canada) and Europe (United Kingdom and the Netherlands).

3.5.1 SEDIMENT ASSESSMENT CRITERIA

No sediment ILs have been established for PFAS in Australia and given the unique environment of Australia, no criteria have been proposed from international guidance as per the methodology in NEPC (1999, Amended). Thus, analyte trends have been nominated as an assessment criteria as one of the objectives of the OMP is to assess whether the risk is increasing. The proposed undiluted (i.e. laboratory limit of reporting) PFAS analyte concentration in sediment is expected to be 0.2 mg/kg to allow for the ongoing assessment of trends at sample locations.

3.5.2 WATER ASSESSMENT CRITERIA

Water ILs have been selected from publications in accordance with the methodology in NEPC (1999, Amended). Water ILs were selected based on water environmental values of the Ross River Basin and Magnetic Island Environmental Values and Water Quality Objectives (DEHP, 2013c) for Groundwaters, The Common, Ross Creek, Bohle River and Pallarenda waters. Prescribed environmental values for groundwater and surface water exposure pathways that are potentially ‘complete’ as per the HHRA (WSP, 2018b) and ERA (WSP, 2019a) are listed below:

— aquatic ecosystem (estuarine and marine environments);
— human consumer (seafood, homegrown produce, etc.);
— irrigation (non-potable domestic irrigation); and
— recreation (direct contact).

Thus, ILs for which criteria have been established are presented in Table 3.11 and have been adopted from the following guidelines:

— Freshwater and marine water, 95% level of protection (% species) due to the moderately disturbed ecosystems of The Common, Bohle River and Cleveland Bay (DEHP, 2013c).
— NHMRC 2019, Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water.
— Recreational water health based guidance values.

Table 3.11 Water investigation levels

<table>
<thead>
<tr>
<th>ANALYTE</th>
<th>EXPECTED UNDILUTED LEVEL OF REPORTING</th>
<th>RELEVANT PRESCRIBED ENVIRONMENTAL VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RECREATION</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FRESH</td>
</tr>
<tr>
<td>PFOS</td>
<td>0.01 µg/L (1)</td>
<td>2 µg/L (1)</td>
</tr>
<tr>
<td>PFHxS</td>
<td>0.01 µg/L (1)</td>
<td>NE</td>
</tr>
<tr>
<td>PFOA</td>
<td>0.01 µg/L (1)</td>
<td>10 µg/L (1)</td>
</tr>
</tbody>
</table>

Notes

(1) NHMRC 2019, Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water.
(3) Lower LORs may be required for areas deemed as areas of high ecological value or slight disturbance under the Water EPP. In that eventuality, 99% species protection criteria will need to be applied and the LOR will need to allow assessment against that criteria.

NE Not established.
3.6 QA/QC

3.6.1 FIELD QA/QC

3.6.1.1 SAMPLE COLLECTION, HANDLING AND PRESERVATION

Field sampling procedures conforming to regulatory guidelines and QA/QC procedures are to be used to minimise potential for cross-contamination and to preserve sample integrity.

Non-disposable sampling equipment is to be decontaminated by triple washing between each sample location. The triple washing technique comprises washing equipment with PFAS-free and phosphate-free detergent, scrubbing with water, followed by a final rinse with demineralised water. Disposable nitrile gloves are to be worn and replaced before collecting each sample.

All samples collected are to be placed into laboratory supplied containers. All samples are to be placed on ice in coolers for transport to the NATA accredited laboratories. Standard chain of custody documentation will accompany the samples to the laboratories.

Table 3.12 has been reproduced from WA DER (2017), with minor deviation regarding decontamination which is specific to this project. The table details protocols necessary for managing the risk of potential PFAS cross-contamination.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>MITIGATION PRACTICE</th>
<th>ALTERNATIVE PRODUCT OR PRACTICE WHEN PFAS SAMPLING IS TO BE UNDERTAKEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOTHING AND FOOD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New clothing</td>
<td>Prohibited for sampling personnel(1)</td>
<td>All field clothing to be washed a minimum of six times after purchase before using at the site.</td>
</tr>
<tr>
<td>Clothing with stain-resistant, rain resistant, or waterproof coatings/ treated fabric (e.g. GORE-TEX®)</td>
<td></td>
<td>Avoid sampling during rain if possible; polyethylene rain gear (e.g. disposable LDPE), vinyl, or polyvinyl chloride (PVC) clothing are acceptable.</td>
</tr>
<tr>
<td>Tyvek® clothing</td>
<td></td>
<td>None.</td>
</tr>
<tr>
<td>Fast food wrappers and containers</td>
<td></td>
<td>Use rigid plastic containers or bags or stainless steel containers for all food brought to site.</td>
</tr>
<tr>
<td>Pre-wrapped foods and snacks (e.g. chocolate bars, energy bars, granola bars, potato chips etc.)</td>
<td></td>
<td>Food brought to the site must be contained in plastic (rigid containers or bags) or stainless steel containers.</td>
</tr>
<tr>
<td>SAMPLING EQUIPMENT AND CONTAINERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teflon®-containing or -coated field equipment (tubing, bailers, tape, plumbing paste, etc.)</td>
<td>Prohibited at site(2)</td>
<td>High Density Polyethylene (HDPE) or silicone tubing, and HDPE or polypropylene field equipment recommended.</td>
</tr>
<tr>
<td>Teflon®-lined lids on containers (e.g. sample containers, rinsate water storage containers)</td>
<td>Prohibited at site(2)</td>
<td>Polypropylene lids(4) for sample containers and polypropylene or HDPE containers for rinsate.</td>
</tr>
<tr>
<td>Glass sample containers with lined lids</td>
<td>Contact with samples</td>
<td>Use polypropylene or HDPE for sample containers(4); glass jars are acceptable provided lids are unlined or are lined with HDPE.</td>
</tr>
<tr>
<td>OTHER PRODUCTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium foil</td>
<td>Prohibited at site(2)</td>
<td>Thin HDPE sheeting (commonly used as drop cloths for painting or home improvement) can be used.</td>
</tr>
<tr>
<td>Self-sticking notes and similar office products (e.g. 3M Post-it notes)</td>
<td>Prohibited at site(2)</td>
<td>Avoid the use of these products at the site.</td>
</tr>
<tr>
<td>PRODUCT</td>
<td>MITIGATION PRACTICE</td>
<td>ALTERNATIVE PRODUCT OR PRACTICE WHEN PFAS SAMPLING IS TO BE UNDERTAKEN</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Waterproof paper, notebooks, and labels</td>
<td>Prohibited at site(^{(2)})</td>
<td>Standard paper and paper labels.</td>
</tr>
<tr>
<td>Drilling fluid containing PFAS</td>
<td>Prohibited for use at site(^{(2)})</td>
<td>PFAS-free drilling fluids.</td>
</tr>
<tr>
<td>Detergents and decontamination solutions (e.g., Decon 90® Decontamination Solution)</td>
<td>Prohibited for all equipment</td>
<td>Decontamination using Liquinox ® detergent (PFAS-free and phosphate-free) follow water-only decontamination approach. (^{(4)})</td>
</tr>
<tr>
<td>Reusable chemical or gel ice packs (e.g., BlueIce®)</td>
<td>Prohibited for sample storage and transport</td>
<td>Ice contained in plastic (polyethylene) bags (double bagged).</td>
</tr>
</tbody>
</table>

**Notes**

(1) Sampling personnel includes all personnel who:

- are directly involved in the collection, handling, and/or processing of samples prior to the samples leaving the site;
- handle any part of well development equipment that directly contacts bore water being sampled;
- handle any part of equipment that directly contacts surface water or aquatic sediment;
- are within 2–3 m of the borehole during soil sampling; or
- are within 2–3 m of the collection and processing area on aquatic vessels during sediment or surface water sampling.

Personnel are not included as sampling personnel if they remain at least 2–3 m away from sample collection areas prior to and during sampling.

(2) Entire sample collection and processing area, including vehicles used by sampling personnel.

(3) USEPA and ASTM method for the analysis of PFAS in solid and liquids specify polypropylene or HDPE with polypropylene lids. Check with the laboratory in regards to preference for polypropylene or HPDE.

(4) Deviation from WA DER (2017).

3.6.1.2 FIELD DUPLICATES

Field intra-laboratory duplicate samples are to be collected at a rate of 1 per 10 samples and inter-laboratory duplicate samples are to be collected at a rate of 1 per 10 (NEMP, 2018).

3.6.1.3 TRIP BLANKS

Trip blank samples comprise de-ionised water supplied by the laboratory placed within the cooler containing all the other sample containers. Trip blank samples remain within the cooler for the extent of the ‘trip’. The purpose of the trip blank samples is to assess if any contaminants have entered the sample containers during their journey from either an outside source or from the sample container itself.

One trip blank sample will be included with each sample shipment submitted to the laboratory and will be analysed for PFAS.

3.6.1.4 CALIBRATION

All field meters will be externally calibrated prior to commencement of fieldworks.

Field meters for water sampling will be field challenged daily using tap water, while the water quality meter calibration will be assessed prior to the commencement of each day’s work using buffer solution and recalibrated where necessary.

Calibration certificates will be retained, while field challenge outcomes will be recorded on field sheets.
3.6.2 **ASSESSMENT OF DATA QUALITY**

Data quality is typically discussed in terms of precision, accuracy, representativeness, comparability and completeness. These are referred to as the PARCC parameters. The PARCC and additional QA parameters are discussed in what follows as indicators of data quality. The QA criteria to be examined include:

- relative percent difference (RPD) evaluation of laboratory matrix duplicates;
- RPD evaluation of field duplicates;
- matrix spike results;
- surrogate spike results;
- sample method blank results;
- laboratory blank results;
- laboratory control sample results;
- holding times; and
- sample handling and analysis protocols (e.g. correct sample preservation, correct sample containers, chilling of the samples, compliance with the requirements outlined in Table 3.12).

3.6.2.1 **PRECISION**

Precision is a measure of the ability to reproduce results, and is assessed on the basis of agreement between a set of replicate results obtained from duplicate analyses. The precision of a set of duplicates is measured as RPD, and is calculated from the following equation:

\[
RPD = \left( \frac{X1 - X2}{\frac{X1 + X2}{2}} \right) \times 100
\]

where:  
- \(X1\) is the first duplicate value
- \(X2\) is the second duplicate value

Laboratory personnel calculate the RPDs of laboratory duplicates (also referred to as matrix duplicates) as a measure of precision. Laboratory duplicates are a sample which has been split by the laboratory and both portions are subject to the same analytical processes as if they were individual samples. Laboratory duplicates are generally analysed at a rate of 1 duplicate per 20 samples. The target RPD values range depending on the sample matrix and analyte as shown in Table 3.13.

<table>
<thead>
<tr>
<th>ANALYTE</th>
<th>(&gt;10 X PQL) %RPD</th>
<th>(4-10 PQL) %RPD</th>
<th>(&lt;4 X PQL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organics</td>
<td>±30</td>
<td>±70</td>
<td>±2 X PQL</td>
</tr>
</tbody>
</table>

If the RPD for a sample does not fall within the control limits, laboratory based corrective action may be taken depending on the analyte; however, the sample is not necessarily re-analysed.

It should be noted that a laboratory batch may contain samples from other sources; therefore, laboratory duplicates may be analysed on other samples from the batch. However, the laboratory’s QA/QC procedures require all batch laboratory duplicates to conform to prescribed criteria.

**FIELD DUPLICATES**

An assessment of the precision of the laboratory’s results is also to be undertaken following a similar method. A sample is split into three representative samples termed the primary, intra-laboratory duplicate and inter-laboratory duplicate samples. Primary samples and intra-laboratory duplicates are analysed by the nominated primary laboratory, while the inter-laboratory duplicate sample is submitted to a secondary laboratory. RPD values are calculated between the primary sample and the intra-laboratory duplicate sample, and the primary sample and the inter-laboratory duplicate sample.
3.6.2.2  ACCURACY

Accuracy is a measure of the agreement between an experimental determination and the true value of the parameter being measured.

MATRIX SPIKES

The determination of accuracy can be achieved through the analysis of known reference materials or assessed by the analysis of matrix spikes. Matrix spikes are analysed by splitting a field sample. Each portion is spiked with known quantities of the target compound in order to ascertain the effects of the specific sample matrix on the recovery of analytes. Accuracy is measured in terms of percentage recovery as defined by the following equation:

\[
\%R = \frac{SSR - SR}{SA} \times 100
\]

where:  
\%R = percentage recovery of the spike  
SSR = spiked sample result  
SR = sample result (native)  
SA = spike added

Laboratory personnel calculate percentage recoveries of spiked compounds, which are evaluated against control or acceptance limits taken from the appropriate method or the Laboratory Program Statement of Work. If the spike recovery for a sample does not fall within the prescribed control limits, laboratory based corrective action is taken, although the sample is not necessarily re-analysed. Matrix spikes are analysed at a rate of 1 matrix spike per 20 samples. Acceptance criteria for matrix spikes are shown in Table 3.14.

<table>
<thead>
<tr>
<th>ANALYTE</th>
<th>MATRIX</th>
<th>ACCEPTANCE CRITERIA (% RECOVERY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organics</td>
<td>Water</td>
<td>70 – 130</td>
</tr>
</tbody>
</table>

Typically, results are qualified when percentage recovery is below QA acceptance criteria, indicating that sample results may be biased low. However, results are also qualified when percentage recovery is above QA acceptance criteria, indicating that sample results may be biased high.

The sample batch may contain samples from other sources. Therefore, matrix spikes may be analysed on other samples from the batch. However, the laboratory’s QA/QC procedures require all batch matrix spikes to conform to the prescribed criteria. The laboratory may report this analysis as laboratory control samples, which may be used to assess the laboratory’s methods and procedures.

LABORATORY CONTROL SAMPLES

A laboratory control sample comprises de-ionised water and is spiked with a known quantity of a target analyte. The laboratory control sample is extracted and analysed with the other samples. The aim of the laboratory control sample is to evaluate the efficiency of the extraction and analysis. The target recovery is 100%, although the range of acceptable results can vary depending on the type of analysis. The laboratory control sample also confirms the accuracy of the calibration, as the target analytes are obtained from an alternate source to the calibration standards.

SURROGATE SPIKES

A surrogate spike is a sample which has been spiked with a pure substance that has similar chemical properties to the target analyte, and is unlikely to be found in the environment. The spiked compounds are expected to behave during analysis in the same way as the target compounds. Every sample is spiked prior to extraction or analysis with known concentrations of surrogate compounds that are representative of the analysis. If surrogate spike recovery does not meet the prescribed control limits, samples are generally re-analysed. It should be noted that for inorganic analyses no surrogate spikes are conducted.
LABORATORY METHOD BLANKS

Laboratory method blanks monitor externally introduced contaminants that potentially derive from glassware, cleaning reagents and digestion reagents during the analysis process. The method blank consists of de-ionised water and is prepared in the laboratory. The method blank is treated as a sample in the laboratory, going through the same sample preparation and analysis procedures as the corresponding batch.

To meet the acceptance criteria, the laboratory blanks should have no detectable concentrations of the target compounds. The laboratory blank results are presented in the laboratory analytical reports. Laboratory blanks are analysed at a rate of 1 laboratory blank per 20 samples.

3.6.3 REPRESENTATIVENESS

Representativeness expresses the degree to which sample data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, or an environmental condition.

Representativeness is primarily dependent on the design and implementation of the sampling program and is partially ensured by the avoidance of cross-contamination, adherence to sample handling and analysis protocols, and use of proper chain of custody and documentation procedures. Sample blanks, holding times and field duplicates are QA parameters that can assist in the analysis of representativeness.

HOLDING TIMES

Holding times from field sampling to laboratory analysis must be minimised to ensure the representativeness of the result obtained. Delays between sampling and analysis can lead to analytes changing due to such processes such as volatilisation, mineralisation and biological modification.

Where standard holding times are exceeded, professional judgement as to the integrity of the data will be required, taking into account such factors as field storage, laboratory storage and even sample-bottle characteristics.

3.6.4 COMPARABILITY

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. This will be achieved through maintaining a level of consistency in techniques used to collect samples and ensuring analytical laboratories used consistent analysis techniques and reporting methods. Comparability is also achieved by ensuring that precision and accuracy objectives were met.

3.6.5 COMPLETENESS

The following information is required to check for completeness of data sets:

- chain of custody forms;
- sample receipt notification or sample receipt advice;
- certificates of analysis;
- quality control report;
- all sample results reported;
- all blank data reported;
- all laboratory duplicates reported and RPDs calculated; and
- NATA stamp on reports.

3.6.6 SENSITIVITY

Sensitivity criteria are used to monitor achievement of quantification using method detection limits. Method detection limits depend on the method of analysis, the instrument's ability to measure analytes, and the sample matrix, in particular, background interferences. When interferences are present in the sample, a loss of sensitivity can occur resulting in an increase in the method detection limit. In some instances (e.g. where one or more compounds have particularly high concentrations) the sample must be diluted for analysis. This increases the method detection limit by the dilution factor.
4 REPORTING FRAMEWORK

After each monitoring event, the information and laboratory data collected as part of the works will be documented and reported to Defence.

The data set will be reviewed at the end of each monitoring period (i.e. six monthly). An interpretative report is to be drafted annually, including recommendations for any potential changes in the location and frequency of sampling, with consideration to the points contained in Section 5.2. Factual reports prepared after each monitoring event will need to highlight any statistical significant deviations from historical PFAS concentrations at individual sampling locations.

4.1 INTERPRETATIVE REPORT

Sample results and field observations are to be presented in the Annual OMP Report. The structure and content of the report is to be compliant with NEPC (1999, amended) and NEMP (HEPA, 2018), to meet the intent of Module 6 of the Queensland Auditor Handbook for Contaminated Land (DES, 2018) as they pertain to ongoing environmental monitoring.

The annual report should include, as a minimum:

- field works completed (including scope unable to be achieved, such as monitoring well access
- description of the sampling methodology
- compliance with the requirements of the Sampling, Analysis and Quality Plan (SAQP) and meeting stated objectives of the OMP
- findings from well gauging including any changes with the monitoring well network including access and damage issues
- relevant figures depicting sampling locations and site specific hydrogeological features
- laboratory results and analysis including comparison with relevant screening criteria identified in Section 3.5
- assessment and commentary on appropriate QA/QC procedures
- data interpretation including trends in groundwater concentration, gradient and flow directions
- assessment of statistically based trends that may inform decision making (refer to Section 5.4)
- provision, at a minimum, of groundwater sampling forms, laboratory analytical certifications and calibration certificates.

4.2 STAKEHOLDER ENGAGEMENT

Analytical results from each monitoring round will be provided to the relevant State regulator, including the annual interpretative report.

Where off-site residential sampling is proposed, a separate letter will be produced to provide to the resident with the analytical results of the monitoring event and assessment against relevant guideline values.
5 MONITORING AND MANAGEMENT MEASURES AND POTENTIAL RISKS

This section of the OMP details uncertainties in investigations, monitoring and management that may require consideration of contingency measures and/or reassessment of risk with changes in conditions (higher concentrations of surface water, migration of groundwater), further investigations establishing a greater extent of characterisation than currently identified, or implementation of management measures. Additional contingency measures and mitigation strategies, if necessary, will be developed by the Environmental Consultant in liaison with Defence upon review and interpretation of monitoring results and trends.

5.1 MONITORING OF MANAGEMENT MEASURES

Further to the overall monitoring of PFAS nature and extent in groundwater and surface water outlined in this OMP, specific monitoring of management measures should be undertaken to assess the efficacy of implementation. Each Remediation Action Plan developed for a management option should establish the requirement of an individual ongoing management plan, which may include:

— changes in monitoring frequency utilising the existing monitoring network
— changes to the monitoring network, e.g. through the establishment of additional monitoring locations or inclusion of existing monitoring locations at the Base
— the development of contingency measures to be implemented at specified changes in condition
— the development of trigger points, below PFAS concentrations in the environment are assessed to have reduced to a level where risks previously identified as elevated may have been reduced to acceptable levels, or where PFAS exposure potential in the environment has reduced to the extent where further risk assessment and/or cessation of continued monitoring may be warranted.

The HHRA (WSP, 2018b) and the ERA (WSP, 2019a) field investigations for the Base included baseline monitoring of off-Base biota, including aquatic plants, aquatic species and semi-terrestrial species. Demonstrating that concentrations of PFAS in biota have reduced may be an important metric to understand that the potential for PFAS exposure in the environment (i.e. to human consumers of recreationally caught seafood, ecological receptors, etc.) however as the range of species is dynamic, the efficacy of biota trend data is problematic as statistical significance may not be achievable.

Where an intervention has been implemented at the Base to reduce PFAS migration from the Base, reconsideration should be given to biota monitoring as the management measures are implemented and the monitoring outlined within this OMP demonstrates improvements in the source of impacts to biota, primarily being PFAS identified within the surface water and sediments within The Common, Mundy Creek and Three Mile Creek.

5.2 TRIGGERS FOR OMP REVIEW

Updates to the OMP may be required for several reasons.

Data on changes in the distribution, concentration, transport (pathways and flow rates) and transformation of the contaminants and assessment against appropriate guideline values provides an evidence base for targeted and effective risk management of PFAS contamination to protect human health and environmental receptors currently impacted by PFAS.

Changes in our understanding of these risks, triggered by this data assessment may inform:

— an early warning that additional management of PFAS contamination may be warranted in areas not currently affected by PFAS
changes detected through the implementation of the OMP may inform a number of risk-management decisions including:

— additional investigations.
— re-assessment of one or more remediation or containment actions.
— additional remediation or containment actions.
— changing risk management actions at receptor level (e.g. provision or cessation of alternate drinking water supplies).

An update to the OMP may also be triggered by policy changes or through stakeholder engagement activities including:

— changes to State advice on types of exposure-minimisation behaviours (e.g., consumption of home produce or seafood)
— changes to State advice on boundaries of a designated management area and the sub-management zones within
— feedback and information received as a result of on-going community consultation
— any significant changes of land use which may occur in the area within the Monitoring Area or adjoining land
— changes to Defence’s strategic approach to managing PFAS contamination.

5.3 TRIGGERS FOR RISK ASSESSMENT REVIEW

Revision of the risk assessment may be triggered by:

— changes in conditions (consistently higher concentrations in surface water, migration of groundwater)
— further investigations establishing a greater extent of groundwater than identified; or
— monitoring of implementation of management measures.

The assessment of risk should include consideration of the source, exposure pathway and receptors relevant to the downstream environment. An outline of the elements of the risk assessment is provided below:

— **Source** – identify the origin of the impact, the magnitude of the chemical or trend, the timeframe of the source (intermittent, repeated, seasonal).
— **Exposure pathway** – review completeness of exposure pathway by reassessing water quality results and potentially obtaining more downstream data points.
— **Receptors** – Assess the existing downstream users, has use of waters changed, how long is water used etc.

If risk profile has been assessed to have changed or cannot be adequately characterised through loss of sample point or a paucity of data (e.g. dry monitoring wells), develop a response plan commensurate with the circumstance to enable the selection and implementation of a response or combination of measures to action in a timely manner before an imminent environmental impact to off-Base surface waters or groundwater users is likely to occur. Note that the response / contingency action may be to wait for the next sample period or to resample to assess whether the change is ‘real’ and not bias of some variety.

Contingency measures must be capable of meeting the following criteria:

— be implemented in a timely manner, commensurate with the risk posed by the impact
— achieve a level of control that addresses the immediate risk, noting that restoration of beneficial uses is not the primary short term objective
— response must be easily implemented and take into account the specific logistical factors, technical and time constraints
— the response is implemented as a short-term risk mitigation measure and is not intended to provide a long-term solution for addressing site-wide impacts.

The details of the response will be determined based upon the situation at hand.
5.4 MONITORING POTENTIAL FUTURE RISKS

Findings from the ongoing monitoring will be used to evaluate whether changes have occurred to the risk posed by PFAS contaminated groundwater, sediment and surface water across the Monitoring Area. This may be achieved through:

- comparison of the current understanding of the nature and extent of the plume as presented in the DSI (WSP, 2018a) and Seasonal Monitoring Reports (WSP, 2019b; 2019c)
- trigger re-evaluation of the monitoring program and an updated scope of works
- include relevant site-specific considerations, such as potential changes in known concentrations within receiving environments or ecological receptors.

Fluctuations in concentrations of contaminants in surface water on-Base or off-Base, or the migration of impacts in groundwater may change the risk profile. The DSI (WSP, 2018a) identified surface water as the primary migration pathway to surface water features and groundwater in the Monitoring Area and so ongoing transport of PFAS from the Base in surface water may change the risk profile in the HHRA (WSP, 2018b) and the ERA (WSP, 2019a).

Through scaling any new analytical results against the 95% upper confidence limit (UCL) concentrations adopted for the risk assessment reports, the risk calculations can be utilised by the Environmental Consultant to determine whether there is the potential to change the risk profile for an exposure scenario.

The DSI (WSP, 2018a), the HHRA (WSP, 2018b) and the ERA (WSP, 2019a) have identified a number of uncertainties that do not affect current risk to receptors, but are sources of risk that should be considered for further investigation such that management controls can be implemented to protect future risk to receptors, including changes in the behaviour of the community with respect to surface water and groundwater usage.

Ongoing liaison with the community may identify that that source-pathway-receptor linkages that were previously determined to be negligible or incomplete that may become a concern due to changes in behaviour. Thus, the exposure pathway is to be reassessed to determine currency (or not) with the HHRA (WSP, 2018b) and the ERA (WSP, 2019a) and this may require incorporation of additional assessment criteria (refer Section 3.5) into the OMP.

In the event that further investigations are completed, on- and off-Base, then a review of this OMP should be undertaken and updated where these locations are considered necessary to monitor source-pathway-receptor linkages into the future.

5.5 DOCUMENT REVIEW FREQUENCY

The OMP will be reviewed regularly by the Environmental Consultant in liaison with Defence. The review frequency will be based on site-specific characteristics and the existing data trend available. The review frequency may be revised during the implementation period as more data becomes available.

Based on the current understanding and existing data, this OMP should be implemented for an initial three-year period, and subsequently revised if the monitoring reports trigger this change.

5.5.1 EXISTING KNOWLEDGE

The document has been developed on the basis of existing knowledge, current government policy settings, and available scientific methodologies and technology at the time of publication. PFAS management is a field that is rapidly evolving.

Over the primary implementation period of the PFAS Management Area Plan, Defence will review and update (where necessary) the PMAP at intervals of 12 months to ensure that the document is current, and its recommendations are valid.

The OMP should be subsequently updated in light of the considerations outlined in Section 5 as well as reviews and updates to the PMAP to ensure the document is current and its recommendations valid.
6 LIMITATION STATEMENT: ONGOING MONITORING PLAN

This Report is provided by WSP Australia Pty Limited (WSP) for the Commonwealth of Australia as represented by the Department of Defence (Client) in response to specific instructions from the Client and in accordance with the Deed of Standing Offer with the Client dated 10 October 2016 (Deed).

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Except as otherwise stated in the Report and to the extent that statements, opinions, facts, conclusion and or recommendations in the Report (Conclusions) are based in whole or in part on information provided by the Client and other parties identified in the report, those Conclusions are based on assumptions by WSP of the reliability, adequacy, accuracy and completeness of the Information and have not been verified. WSP accepts no responsibility for the Information. WSP has prepared the Report without regard to any special interest of any person other than the Client when undertaking the services described in the Deed or in preparing the Report.

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7 REFERENCES

- Australian and New Zealand Environment Conservation Council (ANZECC) 1992, Australia and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.
- Australian and New Zealand Governments (ANZG) 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, August 2018.
- National Health and Medical Research Council (NHMRC) 2019, Guidance on Per and Polyfluoroalkyl Substances (PFAS) in Recreational Water.
- NSW Environment Protection Authority (EPA) 2016, Guidance Note: Designing Sampling Programs for Sites Potentially Contaminated by PFAS, November 2016.
- Queensland Environmental Protection Act 1994.
- Queensland Environmental Protection Regulation 2008.
- Queensland DEHP 2013c, Ross River Basin and Magnetic Island Environmental Values and Water Quality Objectives.
— WSP 2018a, RAAF Base Townsville Detailed Site Investigation - PFAS, Volume 1 – 4, WSP Australia Pty Limited, May 2018, PS102571-ENV-REP-002 RevD.

— WSP 2018b, RAAF Base Townsville Human Health Risk Assessment, WSP Australia Pty Limited, October 2018, PS102571-CLM-REP-004 RevI.

— WSP 2019a, RAAF Townsville Ecological Risk Assessment, WSP Australia Pty Limited, December 2019, PS102571-CLM-REP-005 RevG.

— WSP 2019b, RAAF Townsville Seasonal Monitoring Report 1, WSP Australia Pty Limited, December 2019, PS102571-CLM-REP-006 RevC.

— WSP 2019c, RAAF Townsville Seasonal Monitoring Report 2, WSP Australia Pty Limited, December 2019, PS102571-CLM-REP-007 RevB.
Sub-Management Area 1:
Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Mundy Creek Catchment. Develop and implement a RAP to limit mass flux discharge.

- Remedial Option 1 (Hydraulic control of surface water to limit runoff from source areas) is expected to provide the highest efficacy at this location.
- Remedial Option 3 (Excavation and containment of PFAS impacted soil within purpose-built above-grade engineering facility) or Remedial Option 4 (Excavation and off-Base disposal of impacted soils) potentially for targeted implementation of hotspots.

Sub-Management Area 2:
Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Louisa Creek Catchment. Develop and implement a RAP to limit mass flux discharge.

- Remedial Option 1 (Hydraulic control of surface water to limit runoff from source areas) is expected to provide the highest efficacy at this location.
- Remedial Option 3 (Excavation and containment of PFAS impacted soil within purpose-built above-grade engineering facility) or Remedial Option 4 (Excavation and off-Base disposal of impacted soils) potentially for targeted implementation of hotspots.

Sub-Management Area 3:
Soil / surface water interactions in this area result in PFAS mass flux discharging the Base in the Louisa Creek Catchment. Develop and implement a RAP to limit mass flux discharge.

- Remedial Option 1 (Hydraulic control of surface water to limit runoff from source areas) is expected to provide the highest efficacy at this location.
- The efficacy of other Remedial Options is likely to have limited value at this location.
Legend
- Sediment Sample Locations
- Major Watercourse
- Road
- Railway
- Investigation Area
- RAAF Base Townsville
- Runway Pavement

RAAF TVL Ongoing Monitoring Plan - Addendum
Townsville, Queensland, 4810

Figure 3
Sediment Sample Location Map

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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I acknowledge that I have read and understand the foregoing Ongoing Monitoring Plan as part of my induction to works within the Monitoring Area, and agree to implement the procedures outlined in the document.

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<th>ORGANISATION</th>
<th>SIGN &amp; DATE</th>
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APPENDIX C

PFAS ANALYTE SUITE
## C1 PFAS ANALYTICAL SUITE

Table C.1 Minimum PFAS analytical suite

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C1.1 REFERENCE

ABOUT US

WSP is one of the world's leading engineering professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals. We design lasting Property & Buildings, Transportation & Infrastructure, Resources (including Mining and Industry), Water, Power and Environmental solutions, as well as provide project delivery and strategic consulting services. With 36,000 talented people in more than 500 offices across 40 countries, we engineer projects that will help societies grow for lifetimes to come.