

Stage 2C Environmental Investigation - Human Health Risk Assessment – 2017

Executive Summary

**Army Aviation Centre Oakey (AACO), Oakey QLD
Department of Defence**

Stage 2C Environmental Investigation - Human Health Risk Assessment - 2017

Army Aviation Centre Oakey (AACO), Oakey QLD

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Executive Summary

Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by the Department of Defence (Defence) to undertake a quantitative human health risk assessment (HHRA) as part of the 2017 Stage 2C Environmental Investigation (2017 Stage 2C EI) at the Army Aviation Centre Oakey (AACO), in Oakey, Queensland (the Site). The HHRA forms part of Defence's response to the detection of per- and poly-fluoroalkyl substances (PFAS) in the environment in association with the historic use of legacy aqueous film forming foam (AFFF) at the Site.

The HHRA considers both the Site and the surrounding off-Site areas, herein referred to as the Investigation Area (IA). The Site location is shown on **Figure F1, Appendix A**, and the IA is shown on **Figure F2, Appendix A**.

The 2017 Stage 2C EI principally targeted PFAS and was designed to address data gaps identified at the completion of the Stage 2C 2016 EI studies. The Stage 2C 2017 EI built upon the results of the 2015 Stage 2B EI and the 2016 Stage 2C EI.

The Site was constructed in 1943, initially as a training facility and overflow aircraft maintenance depot for RAAF Base Amberley. The Site currently operates as the Army's helicopter training school for pilots and aviation technicians and is also home to a Republic of Singapore Airforce helicopter squadron. As part of typical airbase activities, aqueous film forming foam (AFFF) was used at the Site for fire training and emergency response from the 1970s. The main AFFF product used historically by Defence was 3M Lightwater™, which contained PFAS including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). From 2004, the Department of Defence commenced phasing out its use of legacy aqueous film forming foams (AFFF) containing PFOS and PFOA as active ingredients and progressively transitioned to a product called Ansulite for use on the Defence estate. The product currently used by Defence does not contain PFOS and PFOA as active ingredients, only in trace amounts. AECOM understands that Ansulite is used by Defence only in emergency situations where human life is at risk, or in controlled environments to test equipment, and any Ansulite used by Defence is captured and treated and/or disposed of at licensed waste disposal facilities in accordance with best practice regulations, and standards. Based on anecdotal evidence, for the purposes of this report, it has been assumed that Defence commenced phasing out the use of AFFF products containing PFOS and PFOA at the Site from 2005. This assumption has not been verified by Defence.

Previous investigations, including the 2017 Stage 2C EI and 2016 Stage 2C EI, identified the presence of PFAS on and in the vicinity of the Site in soil, groundwater, surface water, sediment, terrestrial biota and aquatic biota. Groundwater and surface water from the IA are understood to be currently (or to have been historically) used for a range of purposes, including potable water supply and domestic activities.

Previous HHRA reports prepared for the IA include the following:

- AECOM 2016b. Human Health Risk Assessment, Army Aviation Centre Oakey (2016 HHRA), which:
 - provided an evaluation of the potential human health risks from exposures to PFAS in the environment associated with current and ongoing use of the Site and the current land uses within the Detection Area (DA) and the IA
 - included consideration of direct contact exposures to environmental media (e.g. soil, groundwater, surface water, pore water and sediment) as well as secondary exposures via dietary intakes, including fish and home grown plant and animal produce
 - included specialist toxicological advice relating to PFAS, provided by ToxConsult Pty Ltd (ToxConsult), who also provided input to the preparation of the HHRA.

- AECOM 2017a. Addendum to Human Health Risk Assessment, Sensitivity Assessment of Outcomes for Food Standards Australia New Zealand Tolerable Daily Intake (2017 HHRA Addendum), which:
 - assessed whether the adoption of the health based guidance values (HGBVs)¹ developed in 2017 by Food Standards Australia New Zealand (FSANZ) for PFOS, PFOA and perfluorohexane sulfonate (PFHxS) would affect the conclusions of the 2016 HHRA. All other parameters remained consistent with the 2016 HHRA. The final HGBVs for PFAS were released on 3 April 2017 by the Commonwealth Department of Health (DoH). These HGBVs were developed by FSANZ at the request of DoH and replace the interim guidelines released in June 2016 by the Environmental Health Standing Committee (enHealth).

The 2016 HHRA and 2017 HHRA Addendum identified the following suggested precautions that could be followed by people living, working or undertaking recreation in the Oakey IA to minimise potential for PFAS exposure:

- Do not use groundwater for drinking water supply within the IA (including water used for cooking).
- Avoid or minimise use of groundwater for bathing, showering, home swimming, paddling pools and/or sprinkler play in Groundwater Zone 1 and Zone 2.
- Restrict consumption of home grown eggs from backyard poultry exposed to water in Groundwater Zone 1 and Zone 2 containing detectable PFAS (i.e. PFAS reported at concentrations greater than the laboratory limit of reporting [LOR]).
- Minimise consumption of the following until additional data can be collected to refine the HHRA:
 - locally caught fish (entire IA)
 - home grown vegetables (Groundwater Zone 1 and Zone 2)
 - home grown red meat (Groundwater Zone 1 and Zone 2).

Consistent with the findings of the 2016 HHRA and 2017 HHRA Addendum, Queensland Health has published health information for the Oakey area on their website (<https://www.qld.gov.au/environment/pollution/management/incidents/oakey>), which currently states:

The most important thing to do for residents that live in or near a contaminated area is to reduce exposure to PFASs.

In areas where contamination of water has been identified (e.g. in underground springs, water bores, dams, ponds or creeks), human exposure can be minimised by:

- *Not drinking the water or using it to prepare food*
- *Not consuming food products (e.g. eggs, milk, fish, crustaceans (prawns, yabbies/crabs), fruit or vegetables) grown or produced using, or in, contaminated water*
- *Avoiding or minimise the use of the water for showering/bathing, sprinklers or to fill swimming pools due to the possibility of unintentionally drinking the water.*

The 2016 HHRA identified a number of data gaps or uncertainties requiring further assessment. Subsequently, additional investigation works have been conducted as part of the 2017 Stage 2C EI to address these data gaps by further characterising the nature and extent of PFAS impacts and potential for human exposure to PFAS in soil, groundwater, surface water, sediment, home grown produce and seafood. This 2017 HHRA therefore provides a revised assessment of potential human health risk, incorporating additional data to address the data gaps identified in the 2016 HHRA. This 2017 HHRA also adopts the FSANZ (2017a) TDI for PFOS, PFHxS and PFOA, in accordance with the current approach endorsed in Australia for the assessment of potential risks to human health from exposure to PFAS.

¹ The FSANZ HBGV released by DoH was in the form of an oral tolerable daily intake (TDI). The term TDI is used in the remainder of this report to be consistent with the Australian regulatory framework.

Objectives of the HHRA

The objective of this HHRA is to conduct a revised assessment of potential human health risk associated with current and future exposure to PFAS in the environment within the IA, incorporating additional data to address the data gaps identified in the 2016 HHRA.

The HHRA aims to identify:

- Pathways where PFAS exposure is estimated to be low and expected to be associated with no adverse health effects.
- Pathways where PFAS exposure is estimated to have the potential to be elevated in comparison to the TDI, and that can be managed to most effectively reduce exposure to PFAS in the future (as recommended by Queensland Health).

HHRA Framework and Methodology

The assessment of potential human health risks associated with environmental contamination has been conducted in accordance with the *National Environment Protection (Assessment of Site Contamination) Measure 1999*, as amended 2013 (ASC NEPM 2013). The HHRA has been prepared in accordance with the ASC NEPM 2013 and *Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards* (enHealth, 2012a).

Conceptual Site Model

To facilitate preparation of the HHRA, a conceptual site model (CSM) was prepared based on the available information to identify the following:

- a source and mechanism of chemical release
- a retention or transport medium (or media where chemicals are transferred between media)
- a point of potential human contact with the contaminated media
- an exposure route (e.g. ingestion, inhalation) at the point of exposure.

Where a linkage between a source and receptor via a complete pathway was identified, these were assessed quantitatively in the HHRA.

The 2017 ESA (AECOM, 2017b) identified a number of activities on- and off-Site which are considered to have resulted in PFAS impacts on soil, sediment, surface water and/or groundwater. This information was used to inform investigations that have described the nature and extent of PFAS impact in the environment, which has subsequently been assessed in this HHRA.

The groups of people who may be exposed to the PFAS detected in groundwater, and who were assessed in the HHRA, were:

- residents within the IA surrounding the Site
- recreational users of the land and waterways within the IA surrounding the Site
- commercial (agricultural) workers at the properties within the IA surrounding the Site
- on-Site personnel who work at the Site (this is considered to encompass all personnel who undertake training or other operational works at the Site facility, as well as infrequent visitors).

The key exposure pathways considered in the HHRA are summarised below:

- consumption of groundwater used for domestic drinking water supply and in cooking
- incidental ingestion and dermal contact exposure associated with indoor domestic uses of groundwater (e.g. bathing/ showering, household cleaning, laundry)
- incidental ingestion and dermal contact exposure associated with outdoor domestic uses of groundwater (e.g. swimming in pools, sprinkler play, irrigation, washing vehicles, washing animals)

- consumption of home grown plant produce (e.g. fruit, vegetables) irrigated with groundwater or surface water, grown in soil historically irrigated with groundwater or historically inundated with floodwater.
- consumption of home grown animal produce (e.g. poultry eggs, red meat, milk) where animals drink groundwater or eat plants irrigated with groundwater or surface water, grown in soil historically irrigated with groundwater or historically inundated with floodwater
- consumption of aquatic biota (fish and yabbies) from local waterways and future potential aquaculture farms
- incidental ingestion and dermal contact exposure to surface water, sediment and/or soil associated with outdoor recreation at playing fields or local waterways (e.g. fishing, boating, swimming)
- incidental ingestion and dermal contact exposure associated with commercial agriculture uses of groundwater (e.g. irrigation, washing vehicles, washing animals)
- incidental ingestion, dermal contact and dust inhalation exposures associated with on-Site or off-Site activities that involve direct contact with surface soil

Exposure Assessment

Identification of the potential frequency, extent and duration of exposure to environmental media by the above groups of people via identified exposure pathways was based on information gathered from community surveys and from published data from Australian and international sources.

Human behavioural patterns vary from one individual to another. To account for this while remaining protective of general population exposures, this HHRA considers a range of exposure assumptions:

- A 'typical' exposure was based on mean or median parameters for the general population. It is anticipated that the assessment of the typical scenario will be applicable to the majority of the population.
- Upper range exposure was based on reasonable maximum exposure parameters to provide an estimate of exposure that is reflective of the upper/high end of the range of potential exposure. It is considered that the exposure frequency and quantity assumed by the upper scenario will only apply to small percentage of the population.

Representative exposure point concentrations (EPC) were identified by evaluating the available data characterising environmental media and the current understanding of the potential methods of exposure for the identified groups of people to the PFAS detected in the environment.

The EPC adopted in the HHRA for environmental media (groundwater, surface water, soil and sediment) were maximum concentrations because it was intended that the HHRA provide outcomes that could be applied to all people within each Groundwater Zone of the IA. Using the maximum concentration is likely to overestimate intakes for the average person living, working or undertaking recreation activities in the IA. The EPC adopted in the HHRA for plant and animal produce consumed by humans were the median of detected PFAS concentrations (where sufficient data were available), as these were considered most representative of long term dietary intakes for frequent consumers of those produce. Maximum concentrations were adopted for the assessment of ingestion of livestock milk, red meat and eggs due to the limited number of samples available. It is noted that the combination of upper exposure assumptions (which were based on high exposure frequency and/or high exposure quantity) and maximum concentrations as EPC is considered likely to be highly conservative.

Toxicity Assessment

A typical approach adopted in contaminated land risk assessment is to use published generic assessment criteria relevant to the land use being assessed to screen out chemicals that present a negligible risk, thereby allowing CoPC that require quantitative assessment in the HHRA to be identified. This is commonly referred to as a 'Tier 1' assessment.

A Tier 1 assessment is not considered appropriate for this HHRA because PFAS have the potential to bioaccumulate within the food chain. Available Tier 1 guideline values have not been established which are protective of the potential for bioaccumulation via all potential pathways. The identification of CoPC for this HHRA was therefore based on the availability of toxicity reference values (TRV) either released by an authoritative Australian body, such as the DoH, or derived in a manner consistent with relevant Australian guidelines, for those PFAS detected above the laboratory LOR.

It is noted that there is currently no consistent evidence that exposure to the PFAS assessed in this HHRA causes adverse human health effects (FSANZ, 2017). However, because these chemicals have been shown to have health effects in animals and because these chemicals persist in humans and the environment, enHealth (2016b) recommended *'that human exposure to these chemicals is minimised as a precaution'*. The TRV adopted in this HHRA were the tolerable daily intakes (TDI) sourced from FSANZ (2017a) for PFOS, PFHxS and PFOA, and from ToxConsult (2016b) for PFHxA.

The TDI is a daily intake which, over a lifetime, is considered to be without appreciable adverse health effects, based on toxicological studies and incorporating a range of uncertainty (safety) factors. It is noted that exceeding the TDI does not necessarily mean that health effects will occur.

Risk Characterisation

The potential for adverse threshold effects resulting from exposure to an individual CoPC has been evaluated by comparing the intake for each exposure pathway, expressed as daily chemical intake, with the threshold TRV (adjusted to account for background exposure). The resulting ratio is referred to as the hazard quotient (HQ) (ASC NEPM 2013).

A potentially unacceptable chemical intake/exposure is indicated if the intake via the identified exposure pathways exceeds the TDI (i.e. if the HQ is greater than 1). To assess the overall potential for adverse health effects posed by exposure to multiple pathways, the hazard quotients for each chemical and exposure pathway relevant to a receptor are summed.

The threshold HI assumes that there is a level of exposure below which it is unlikely for humans to experience health effects, based on the available toxicological studies. If the exposure level does not exceed the threshold, i.e. if HI is equal to or less than 1, then it is reasonable to conclude that no adverse health effects are likely to be realised (ASC NEPM 2013). These low levels of exposure are considered acceptable from a health perspective because they are not likely to be associated with adverse effects, and as such, the risk estimate is referred to herein as 'low and acceptable'.

Where risk acceptability criteria are exceeded (i.e. HI is greater than 1), the exposure is considered to be above a level which has been determined to have no adverse effects, but this does not necessarily mean that health effects will occur. In this situation, the risk estimate is referred to herein as 'elevated' and a more detailed and critical evaluation of the risk may be conducted, or further investigation, or appropriate exposure mitigation measures may be considered.

Summary

The following conclusions are provided with respect to the potential for PFAS exposure to identified people as a result of PFAS concentrations reported in soil, groundwater, surface water, sediment, terrestrial biota and aquatic biota within the IA.

The additional soil and groundwater data collected as part of the 2017 Stage 2C EI, combined with historical data, has allowed for the refinement of the Groundwater Zones within the IA for which the potential PFAS exposures have been assessed, as follows:

- 'Groundwater Zone 2', located immediately to the south and southwest of the Site, is inferred to have the highest magnitude of PFOS concentrations in the IA given its closer proximity to the Site, along with a potentially greater PFAS contribution from vertical migration of surface water in the vicinity of drainage channels 1 and 2.
- 'Groundwater Zone 1', located further to the south and west of the Site, is inferred to have elevated PFAS concentrations in groundwater as a result of a combination of migration mechanisms, including lateral groundwater migration and vertical migration from surface water.

- The remaining area within the IA is characterised as Groundwater Zone 'Rest of Investigation Area' (ROIA). The majority of the groundwater extraction wells in this zone have not reported detections of PFAS, and are located outside of Groundwater Zone 1 and Zone 2, within the boundary of the IA.

It is noted, however, that the extents of these Groundwater Zones are current as of the 2017 Stage 2C EI, and may be subject to change following the collection of additional data and/or the result of groundwater movement over time. The Groundwater Zones are presented on **Figure F3, Appendix A**.

The HHRA outcomes have been used to identify which aspects of the existing general advice from Queensland Health may be followed to most effectively minimise PFAS exposure in the future (<https://www.qld.gov.au/environment/pollution/management/incidents/oakey>). The suggested precautions on ways to minimise PFAS exposure are based on consideration of both the typical and upper range exposure scenarios assessed in the HHRA, as follows:

- Where both the typical and upper range exposure scenarios are associated with elevated PFAS intakes, it is suggested that the pathway continue to be avoided.
- Where only the upper range exposure scenario is associated with elevated PFAS intakes and the typical exposure scenario was identified to be associated with low and acceptable PFAS intake, it is suggested that the pathway be minimised, in order to avoid the upper range exposures assessed in this HHRA.

The estimated PFAS intakes for on-Site personnel, off-Site recreational users of publicly accessible areas (excluding consumption of fish) and off-Site commercial (agricultural) workers (excluding consumption of home grown food) were identified to be low and acceptable in comparison to the TDI. Therefore the following discussion focuses on residents in the IA, plus the food pathways mentioned above.

Groundwater Zone 2

The potential health risks to residents from exposure to PFAS through the following exposure pathways are considered to be low and acceptable:

- dermal contact with groundwater as a result of indoor domestic use (excluding drinking water), outdoor domestic use (e.g. irrigation of gardens, washing animals or vehicles, playing in a sprinkler)
- inhalation of dust as a result of outdoor activities or dust tracked back into the home
- incidental ingestion of soil as a result of outdoor activities.

Exposure of residents to PFAS through the following exposure pathways may result in elevated PFAS intakes under scenarios considered representative of upper level and/or typical exposure:

- ingestion of groundwater extracted within Groundwater Zone 2
- incidental ingestion of groundwater extracted within Groundwater Zone 2 as a result of indoor use, outdoor use and irrigation, specifically:
 - showering and bathing using extracted groundwater
 - food preparation and clean-up
 - recreational swimming in backyard swimming pools and children's wading pools filled with extracted groundwater
 - sprinkler play with extracted groundwater.
- consumption of home grown leafy green vegetables irrigated with water containing detectable PFAS or grown in soil that has been irrigated with water containing detectable PFAS
- consumption of home grown red meat and offal from sheep or cattle that have consumed water containing detectable PFAS and/or consumed soil or plants that have accumulated PFAS from irrigation water

- consumption of home grown milk from cattle that have consumed water containing detectable PFAS and/or consumed soil or plants that have accumulated PFAS from irrigation water
- consumption of home grown eggs from backyard poultry that have consumed water containing detectable PFAS and/or consumed soil or plants that have accumulated PFAS from irrigation water.

Consistent with Queensland Health advice, it is suggested that consideration be given to the following within Groundwater Zone 2:

- continue to not drink groundwater or use it in cooking
- continue to not shower and/or bathe using extracted groundwater
- continue to not fill swimming pools and children's wading pools with extracted groundwater
- continue to not undertake sprinkler play with extracted groundwater.
- continue to not consume home grown leafy green vegetables that have been irrigated with water containing detectable PFAS or grown in soil that has been irrigated with water containing detectable PFAS
- continue to not consume red meat or offal from home grown cattle or sheep located in Groundwater Zone 2 that have been exposed to water containing detectable PFAS and/or soil or plants that have accumulated PFAS from irrigation water (this precaution is also relevant to commercial agriculture workers who may consume home grown food from the property at which they work)
- continue to not consume milk from home grown cattle or sheep located in Groundwater Zone 2 that have been exposed to water containing detectable PFAS and/or soil or plants that have accumulated PFAS from irrigation water
- continue to not consume eggs from backyard poultry exposed to water containing detectable PFAS and/or soil or plants that have accumulated PFAS from irrigation water
- minimise consumption of fish caught in Oakey Creek by people who undertake recreational fishing in this area.

Groundwater Zone 1

The potential health risks to residents from exposure to PFAS through the following exposure pathways are considered to be low and acceptable:

- dermal contact with groundwater as a result of indoor domestic use (excluding drinking water), outdoor domestic use (e.g. irrigation of gardens, washing animals or vehicles, playing in a sprinkler)
- inhalation of dust as a result of outdoor activities or dust tracked back into the home
- incidental ingestion of soil as a result of outdoor activities
- consumption of home grown milk from cattle that have consumed water containing detectable PFAS and/or consumed plants that have accumulated PFAS from irrigation water.

Exposure of residents to PFAS through the following exposure pathways may result in elevated PFAS intakes under scenarios considered representative of upper level and/or typical exposure:

- ingestion of groundwater extracted within Groundwater Zone 1
- incidental ingestion of groundwater extracted within Groundwater Zone 1 as a result of indoor use, outdoor use and irrigation, specifically:
 - showering and bathing using extracted groundwater
 - food preparation and clean-up
 - recreational swimming in backyard swimming pools and children's wading pools filled with extracted groundwater

- sprinkler play with extracted groundwater.
- consumption of home grown red meat from sheep or cattle that have consumed water containing detectable PFAS and/or consumed soil or plants that have accumulated PFAS from irrigation water
- consumption of home grown leafy green vegetables irrigated with water containing detectable PFAS or grown in soil that has been irrigated with water containing detectable PFAS
- consumption of home grown eggs from backyard poultry that have consumed water containing detectable PFAS and/or consumed soil or plants that have accumulated PFAS from irrigation water.

Consistent with Queensland Health advice, it is suggested that consideration be given to the following within the Groundwater Zone 1:

- continue to not drink groundwater or use it in cooking
- minimise showering and bathing using extracted groundwater
- minimise filling swimming pools and children's wading pools with extracted groundwater
- minimise conducting sprinkler play with extracted groundwater
- minimise consumption of red meat and offal from home grown cattle or sheep located in Groundwater Zone 1 that have been exposed to water containing detectable PFAS and/or soil or plants that have accumulated PFAS from irrigation water (this precaution is also relevant to commercial agriculture workers who may consume home grown food from the property at which they work)
- minimise consumption of leafy green vegetables grown in areas currently or historically irrigated with water containing detectable PFAS and/or areas inundated by flooding
- continue to not consume home grown eggs from backyard poultry exposed to water containing detectable PFAS and/or soil or plants that have accumulated PFAS from irrigation water
- minimise consumption of fish caught in Oakey Creek by people who undertake recreational fishing in this area.

Groundwater Zone RoIA

Based on the typical exposure scenario assessed herein, the potential health risks to residents from exposure to PFAS through all the exposure pathways assessed in this HHRA are considered to be low and acceptable for all pathways combined.

Exposure of residents to PFAS through the following exposure pathways may result in elevated PFAS intakes under conservative scenarios considered representative of upper level exposure:

- ingestion of groundwater extracted within Groundwater Zone RoIA

The HHRA outcome indicates that PFAS exposure via drinking groundwater would be low and acceptable under typical exposure scenarios in the Groundwater Zone RoIA. Further, the FSANZ (2017) drinking water guideline values could be used to identify specific locations where the PFAS concentrations in groundwater are acceptable for drinking. However, because Queensland Health recommends that residents that live in or near a contaminated area reduce exposure to PFAS, and because the HHRA has estimated that residents' PFAS exposure via drinking groundwater would be greater than for all other pathways combined, it is suggested that as a precautionary measure residents continue not to use groundwater for drinking or in cooking in Groundwater Zone RoIA.

It is also suggested that people who undertake recreational fishing in this area minimise consumption of fish caught in Oakey Creek.

Managing Future PFAS Exposure

For the purpose of communicating these outcomes and suggesting precautions for managing future PFAS exposure, Defence has adopted the following nomenclature:

- **Management Area:** the area identified as the IA during the Stage 2C Environmental Investigation will be referred to as the Management Area. It will be divided into three Management Zones, as follows:
 - **Management Zone 1:** the area identified as Groundwater Zone 2 for the purpose of this HHRA will be referred to as Management Zone 1.
 - **Management Zone 2:** the area identified as Groundwater Zone 1 for the purpose of this HHRA will be referred to as Management Zone 2.
 - **Management Zone 3:** the area identified as Groundwater Zone RoIA for the purpose of this HHRA will be referred to as Management Zone 3.

Conclusions

The assessment undertaken within this HHRA concludes that if people living, working or undertaking recreation within the Management Area follow the existing precautionary advice from Queensland Health to minimise their intake of PFAS, they are unlikely to exceed the TDI. Conversely, it is concluded that unrestricted exposure to PFAS across the Management Area is likely to result in an exceedance of the TDI.

The HHRA conclusions are summarised in **Table ES1** for residents, **Table ES2** for commercial agriculture workers, **Table ES3** for recreational users of publicly accessible areas and **Table ES4** for on-Site personnel.

These conclusions are based on consideration of the theoretical scenarios identified in the HHRA that could be associated with elevated PFAS intakes, the data gaps and uncertainties inherent in these assessments, and that PFAS concentrations measured in the blood of Oakey residents are elevated above typical background concentrations for people in Australia.

These conclusions should be read in conjunction with the data gaps presented in **Section 4.2.4** and sensitivity assessment presented in **Section 8.3**.

Table ES1 Summary of HHRA Conclusions for Residents

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
Groundwater							
Drinking groundwater or using it in cooking	Elevated	Elevated	Elevated	Elevated	Elevated	Low & Acceptable	Management Zone 1 and Zone 2: Continue to follow Queensland Health advice to not drink groundwater or use it in cooking. Management Zone 3: Because Queensland Health recommends that residents that live in or near a contaminated area reduce exposure to PFAS, and because the HHRA has estimated that residents' PFAS exposure via drinking groundwater would be greater than for all other pathways combined, it is suggested that as a precautionary measure residents continue not to use groundwater for drinking or in cooking in Management Zone 3.
Incidental ingestion of groundwater as a result of indoor domestic use (excluding drinking water) and outdoor domestic use	Elevated	Elevated	Elevated	Low & Acceptable	Low & Acceptable	Low & Acceptable	Management Zone 1: Continue to follow Queensland Health advice to avoid the use of groundwater for: showering and bathing; filling swimming pools and children's wading pools; and sprinkler play. Management Zone 2: Continue to follow Queensland Health advice to minimise the use of groundwater for: showering and bathing; filling swimming pools and children's wading pools; and sprinkler play. Management Zone 3: No precaution suggested

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
<i>Dermal contact with groundwater</i> as a result of indoor domestic use (excluding drinking water) and outdoor domestic use	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
Soil							
<i>Incidental ingestion of soil</i> as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
<i>Dermal contact with soil</i> as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
<i>Inhalation of dust</i> as a result of outdoor activities or dust tracked back into the home	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
Locally sourced food							
Consumption of vegetables that have been irrigated with water containing detectable PFAS, or have been grown in soil that has been irrigated or flooded with water containing detectable PFAS	Elevated	Elevated	Elevated	Low & Acceptable	Low & Acceptable	Low & Acceptable	<p>Management Zone 1: Continue to follow Queensland Health advice to avoid consumption of home grown leafy green vegetables that have been irrigated with water containing detectable PFAS, or have been grown in soil that has been irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 2: Minimise consumption of home grown leafy green vegetables that have been irrigated with water containing detectable PFAS, or have been grown in soil that has been irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 3: No precaution suggested</p>

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
Consumption of red meat or offal from sheep or cattle that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS	Elevated	Elevated	Elevated	Low & Acceptable	Low & Acceptable	Low & Acceptable	<p>Management Zone 1: Continue to follow Queensland Health advice to avoid consumption of red meat and offal from home grown cattle or sheep that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 2: Minimise consumption of red meat and offal from home grown cattle or sheep that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 3: No precaution suggested</p>
Consumption of milk from livestock that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS	Elevated	Elevated	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	<p>Management Zone 1: Continue to follow Queensland Health advice to avoid consumption of milk from home grown cattle or sheep that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 2 and Zone 3: No precaution suggested</p>

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
<p>Consumption of eggs from backyard poultry that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS</p>	Elevated	Elevated	Elevated	Elevated	Low & Acceptable	Low & Acceptable	<p>Management Zone 1 and Zone 2: Continue to follow Queensland Health advice to avoid consumption of eggs from backyard poultry that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 3: No precaution suggested</p> <p>Under circumstances where exposure of backyard chickens to media containing detectable PFAS can be prevented Scolexia (2017) estimated that a withholding period of 100 days after cessation of PFAS exposure to hens would likely be required for all four PFAS studied to reduce to less than the laboratory LOR in eggs from backyard poultry in the Management Area.</p>

Table ES2 Summary of HHRA Conclusions for Commercial Agriculture Workers

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
Groundwater							
Incidental ingestion of groundwater as a result of outdoor commercial agriculture use	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
Dermal contact with groundwater as a result of outdoor commercial agriculture use	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
Soil							
Incidental ingestion of soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
Dermal contact with soil as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested
Inhalation of dust as a result of outdoor activities	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	Low & Acceptable	No precaution suggested

Exposure Pathway	Potential PFAS Exposures – Management Zone 1		Potential PFAS Exposures – Management Zone 2		Potential PFAS Exposures – Management Zone 3		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	Upper	Typical	Upper	Typical	
Locally sourced food							
Consumption of red meat and offal from sheep or cattle that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS	Elevated	Elevated	Elevated	Low & Acceptable	Low & Acceptable	Low & Acceptable	<p>Management Zone 1: Continue to follow Queensland Health advice to avoid consumption of red meat and offal from home grown cattle or sheep that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 2: Minimise consumption of red meat and offal from home grown cattle or sheep that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS.</p> <p>Management Zone 3: No precaution suggested</p>
Consumption of milk from livestock that have consumed water containing detectable PFAS, or have grazed in areas irrigated or flooded with water containing detectable PFAS	Not a Complete Pathway	Not a Complete Pathway	Not a Complete Pathway	Not a Complete Pathway	Low & Acceptable	Low & Acceptable	No precaution suggested

Table ES3 Summary of HHRA Conclusions for Recreational users of publicly accessible areas

Exposure Pathway	Potential PFAS Exposures – Entire Management Area		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	
Surface Water			
Incidental ingestion of surface water as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
Dermal contact with surface water as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
Soil and Sediment			
Incidental ingestion of soil and sediment as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
Dermal contact with soil and sediment as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
Inhalation of dust as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
Locally sourced food			
Consumption of fish from local waterways by recreational fishers	Elevated	Low & Acceptable	Minimise consumption of fish from Oakey Creek.
Consumption of fish sourced from future aquaculture systems where groundwater or surface water containing detectable PFAS is used to supply the system	Elevated	Elevated	The potential risk to human health should be further evaluated based on Site-specific data prior to undertaking aquaculture in the Management Area using groundwater or surface water containing detectable PFAS in the future.

TableES4 Summary of HHRA Conclusions for On-Site Personnel

Exposure Pathway	Potential PFAS Exposures – On-Site		Suggested Precautions to Minimise Future PFAS Exposure
	Upper	Typical	
Soil			
<i>Incidental ingestion of soil</i> as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
<i>Dermal contact with soil</i> as a result of outdoor activities	Low & Acceptable	Low & Acceptable	No precaution suggested
<i>Inhalation of dust</i> as a result of outdoor activities or dust tracked back into the workplace	Low & Acceptable	Low & Acceptable	No precaution suggested