Department of Defence

RAAF Base Tindal

Interim Human Health Risk Assessment (IHHRA)

22 December 2017

When you think with a global mind problems get smaller

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RAAF Base Tindal

Prepared for
Department of Defence

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Executive Summary

Department of Defence has engaged Coffey Environments Australia Pty Ltd (Coffey) to undertake an Interim Human Health Risk Assessment (IHHRA) as a result of the detection of per- and polyfluoroalkyl substances (PFAS) in the environment potentially associated with its use in legacy aqueous film forming foam (AFFF) at Royal Australian Air Force (RAAF) Base Tindal (the Base).

The information and data collected in the Detailed Site Investigation (DSI) being conducted by Coffey informs this IHHRA. Data collection for the assessment of risk is ongoing. The IHHRA is limited in scope and limited to information obtained in the dry season to address the exposure routes most likely to drive risk using the information currently available in the Investigation Area (IA). A more detailed Human Health Risk Assessment (HHRA) will be conducted in early 2018 and will include a broader evaluation of potential health risks based on the detailed conceptual site model (CSM) developed using wet and dry season information. The number of receptor populations will be expanded in the broader HHRA to include commercial workers and Indigenous communities, as well as less significant exposure pathways such as dermal exposures.

Background

Aqueous film-forming foam (AFFF) is a fire-fighting foam that has been used extensively worldwide, and within Australia, from about the 1970s. It was used by civilian and military authorities for its effectiveness in extinguishing liquid fuel fires. PFAS compounds such as perfluorooctane sulfonate (PFOS), perfluorohexane sulfonate (PFHxS) and perfluorooctanoic acid (PFOA) are components of Class B AFFF that was used at the Base. The presence of AFFF on the Base is related to the active suppression of fires, training and storage for emergency use, maintenance of equipment used to store or distribute AFFF, and other historical incidental uses or emissions. The primary source of PFAS compounds is associated with the Fire Training Area and Fire Station. Other secondary sources have also been identified on the Base.

PFAS compounds used in AFFF are known to be highly persistent as they do not readily degrade and hence may be present in environmental media for many years following their release. PFAS contamination in soil and groundwater has been identified at the Base, particularly in the source areas where AFFF has been used, and in offsite areas due to migration in surface water and groundwater.

Nature and Extent of Impact

PFAS has been reported in groundwater (the Tindall Aquifer) beneath RAAF Base Tindal, extending west beyond the rural community at Uralla towards the Katherine township. Groundwater and surface water impacted by PFAS discharges to Katherine River. PFAS compounds have been detected in the Katherine River at Donkey Camp and down-stream locations to the Daly River.

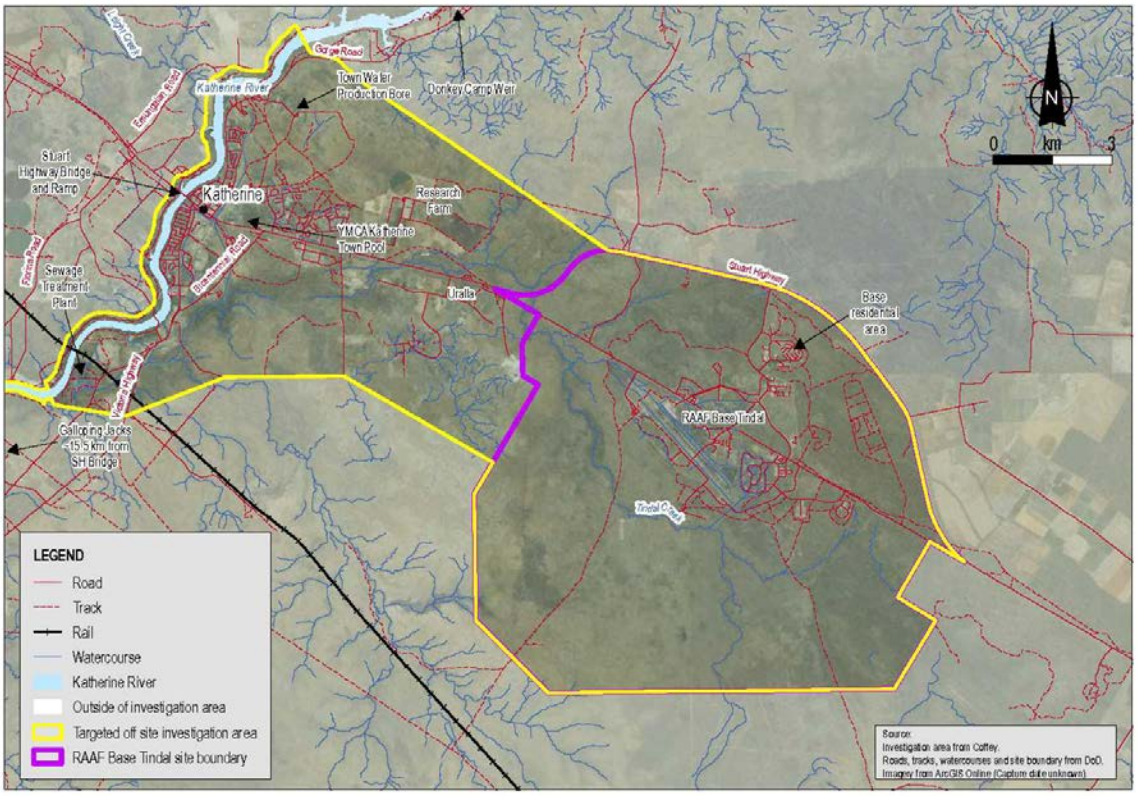

Figure A. Regional Features

Objective

The purpose of the IHHRA is to quantify likely intake of PFAS against the tolerable daily intake (TDI) values to receptor populations with the greatest exposure potential within the Investigation Area. A broader risk evaluation will be completed in early 2018. The IHHRA is limited to dry season data only. The IHHRA is intended to help inform Australian Government decisions relating to further health studies and management measures, if required.

The following receptor groups have been identified for evaluation in the IHHRA, as they represent the scenarios most likely to lead to exposure to PFAS, based on location within the Investigation Area, activities, and food and water sources:

- Off-Base residents in a rural setting.
- Residents in an urban setting such as Katherine township or the residents of RAAF Base Tindal.
- Recreation users of Katherine River.

The residential settings are generally considered to include Indigenous populations residing within the Investigation Area however the consumptions of traditional foods and other specific activities will be addressed in greater detail in the HHRA in early 2018. The broader HHRA will include other receptor populations such as Base personnel, and off-Base commercial and subsurface workers.

Conceptual Site Model

The conceptual site model for RAAF Base Tindal has been developed based on the information gathered during the investigation. PFAS contamination emitted from the primary source areas on the Base is migrating from the site via:

- Leaching to groundwater (Tindall Aquifer) and subsequent flow with groundwater westerly toward the Katherine River, discharging to the river within the Investigation Area ;
- Leaching and surface water run-off via site drains and Tindal Creek, which flows through Uralla and discharges to the Katherine River in Katherine South.

Exposure to contamination, beyond the primary source areas identified at the Base, occurs through groundwater extraction from within the contaminated areas of the Investigation Area or use of surface waters of Tindal Creek or Katherine River (primarily downstream of Stuart Highway (high level) Bridge).

PFAS concentrations detected in off-Base groundwater and in surface waters, indicates that water used for drinking, swimming or domestic uses, as well as irrigating edible plants and watering livestock, could be impacted in areas located hydraulically down-gradient of the Base.

Data Evaluation

Of the twenty eight PFAS compounds analysed for all media in this assessment, PFOS and PFHxS have been the main PFAS compounds detected (generally greater than 80% of the total PFAS concentration in sampled private bore water). The active ingredient in the manufactured AFFF products (i.e. 3M Lightwater™ which was the main product used at the Base) were typically PFOS and PFHxS.

Environmental investigations conducted during the 2017 dry season reported detectable PFAS in water in each residential setting. Fruit and vegetables obtained from residential gardens, eggs from locally raised poultry and fish from Katherine River were found to contain PFAS compounds to varying degrees where PFAS impacted water was present.

Residential Water Use Zones

Residential water use zones were identified to distinguish between water sources and characterise areas by PFAS concentrations, under dry season conditions. Each of the zones are described in the following table.

	Zone 1	Zone 2	Zone 3	Katherine Township and Base Residential Area
Water source description	Extracted groundwater from private bores	Extracted groundwater from private bores	Katherine River water piped from downstream of Stuart Highway Bridge	Town Water supply (2)
Health Based Guideline for PFAS in Drinking Water (1)	PFOS+PFHxS concentrations **above** drinking water guideline	PFOS+PFHxS concentrations **above** drinking water guideline	PFOS+PFHxS concentrations **above** drinking water guideline	PFOS+PFHxS concentrations **below** drinking water guideline
Health Based Guideline for Primary Contact Recreation (ie swimming) (1)	PFOS+PFHxS concentrations **above** recreational water guideline	PFOS+PFHxS concentrations **below** recreational water guideline	PFOS+PFHxS concentrations **below** recreational water guideline	PFOS+PFHxS concentrations **below** recreational water guideline

1 *Guidelines for PFAS compounds: PFOS+PFHxS and PFOA. Federal Department of Health, 2017*

2 *Power & Water. Treated water from Katherine River, drawn from Donkey Camp Weir, located upstream of the Investigation Area.*

The residential water use zones are presented in Figure B below. Zone 1 and Zone 2 are based on PFAS concentrations measured in the dry season. Concentrations of bore water are not expected to change significantly in wet season conditions, however, the boundaries of these zones should be

considered general in nature as the average concentration of PFAS in water may vary between wet and dry seasons and over time. Rural properties that draw water from the Katherine River are included in Zone 3 and are unlikely to exceed PFAS drinking water guidance values during the wet season.

The zones are not defined by property title boundary but rather by the concentrations of PFOS and PFHxS measured at each bore during the 2017 dry season. Individual properties within Zone 1 and Zone 2 may also change Zones or intersect both Zone 1 and Zone 2, depending on factors such as the location of their bores in relation to the centreline of the PFAS plume.

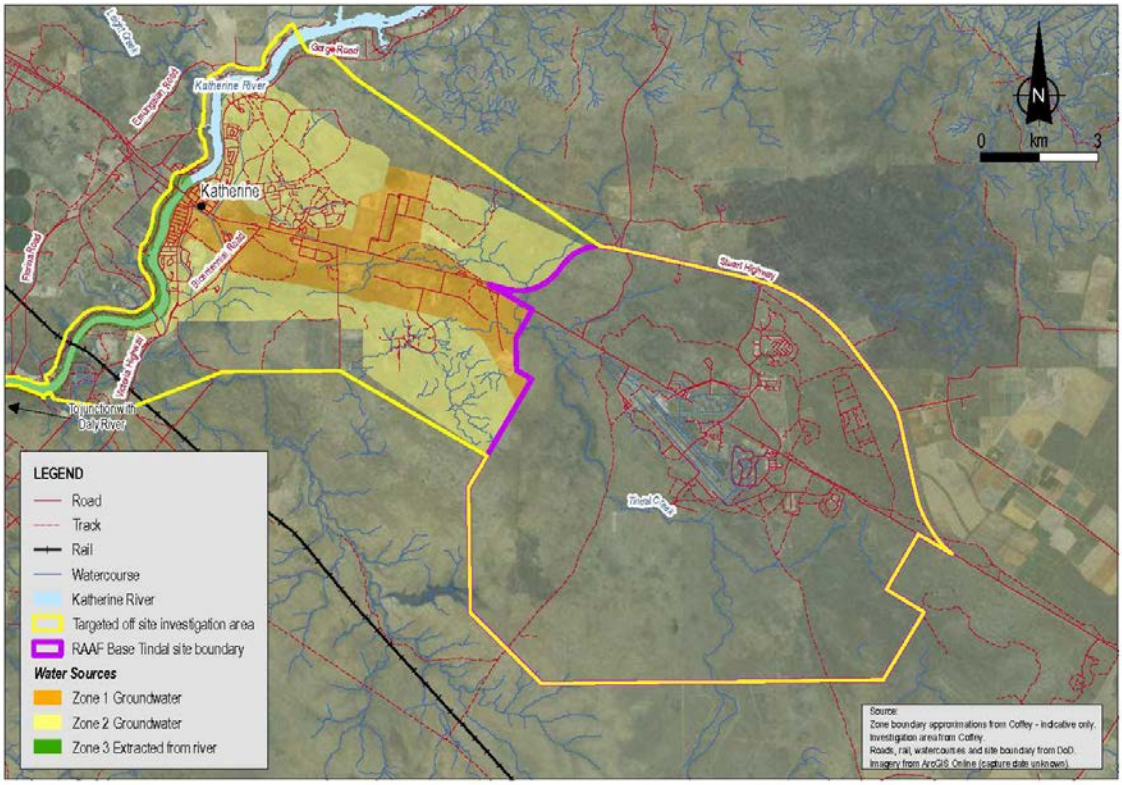

Figure B. Residential Water Use Zones

PFAS impacted media evaluated in the IHHRA, relevant to each residential or recreational setting, are presented in the following table.

	Food or Water Source				
Settings	**Urban - Town Water**	**Zone 1**	**Zone 2**	**Zone 3**	**Recreational**
Drinking water and domestic uses	Katherine town water supply	Extracted bore water	Extracted bore water	Katherine River (1)	-
Recreational uses (swimming)	Katherine town water supply	Extracted bore water	Extracted bore water	Katherine River (1)	Katherine River Katherine Aquatic Centre
Soils	Soil irrigated with Katherine town water supply	Soil irrigated with bore water	Soil irrigated with bore water	Soil irrigated with Katherine River water (1)	-
Terrestrial foods	NA(2)	Home grown fruit and vegetables irrigated with bore water	Home grown fruit and vegetables irrigated with bore water	Home grown fruit and vegetables irrigated with Katherine River water (1)	-
	Locally raised poultry eggs, watered with town water.	Locally raised poultry eggs watered with bore water.	Locally raised poultry eggs watered with bore water.	Locally raised poultry eggs watered with Katherine River water (1	-
Aquatic foods	-	-	-	-	Fish Crustaceans

- *Not applicable*

1 *Downstream of Stuart Highway Bridge (High level crossing).*

2 *Fruit and vegetables watered with town water, or water sourced from outside of the IA, have not been quantitatively assessed, as there is no evidence that concentrations exceed trigger values. Further data is being collected and this pathway will be documented in the 2018 HHRA.*

The data used to inform the IHHRA has been based on water, soil and food samples collected during the dry season. .Private bore water samples were collected from rural properties and samples of surface water, soils, aquatic biota and locally grown fruits, vegetables and poultry eggs were obtained in both rural and urban settings. The dry season fruits and vegetables sampled, and the types of fish are presented in the table below. Based on information provided by the community to date, private bores in urban settings are not widely used for irrigation of home grown produce or livestock watering.

Fruit	Vegetables	Fish and Crustaceans
Bananas	Beetroot and leaves	Barramundi
Cherry tomatoes	Brazilian spinach	Sooty Grunter
Jackfruit	Carrot	Bony Bream
Lemons	Cassava	Butler's Grunter
Limes	Corn cob	Mullet
Mangos	Drumstick (Moringa)	Sleepy Cod
Melons	Eggplant	Blue Catfish
Mulberries	Okra	Cherabin (prawn)
Paw Paw	Radish	
Tomatoes	Snake beans	
Watermelons	Spinach	
	Sweet potato	

Toxicity Assessment

The PFAS toxicity criteria adopted in this assessment were published by the Australian Department of Health. Tolerable daily intake values for chronic exposure were derived by Food Standards Australia New Zealand for PFOS, PFHxS and PFOA, as these were the compounds studied in the majority of toxicity studies to date. The main PFAS compounds found in the AFFF relevant for RAAF Base Tindal are PFOS and PFHxS.

Exposure Assessment

The focus of the IHHRA is on ingestion and incidental ingestion pathways, which are considered to be the exposure route of greatest significance. PFOS, PFHxS and PFOA are not readily absorbed through the skin and these compounds are not considered to be volatile, therefore exposures via dermal contact and inhalation are considered to be insignificant to total exposure and were not evaluated in the IHHRA.

The exposure pathways quantitatively evaluated were:

- Ingestion of PFAS impacted water by urban and rural residents for drinking water.
- Incidental ingestion of PFAS impacted water by urban and rural residents for domestic uses such as showering / bathing, cleaning / washing and irrigation purposes.
- Incidental ingestion of water by urban and rural residents using a swimming pool filled with PFAS impacted water.
- Incidental ingestion of PFAS impacted water by urban and rural residents during sprinkler play.
- Ingestion of home grown fruit and vegetables irrigated with PFAS impacted water.
- Incidental ingestion of soils irrigated with PFAS impacted water whilst gardening.
- Ingestion of eggs produced from poultry watered with PFAS impacted water.
- Incidental ingestion of Katherine River water by recreational users whilst swimming.
- Incidental ingestion of pool water by recreational users whilst swimming at Katherine Aquatic Centre.
- Ingestion of fish and crustaceans caught in the Katherine River, specifically downstream of the High Level Bridge (Stuart Highway).

The general approach taken for the exposure assessment was to adopt exposure parameters (these are inputs such as how many hours per day or days per year someone is exposed) that would reflect the typical experiences of the majority of the receptor group. It is acknowledged that individual human behaviours vary within any group and therefore a more conservative approach has also been evaluated using upper estimates of exposure assumptions to represent a higher level of exposure. The upper estimate approach is likely to only apply to a few individuals for some pathways.

Adults and young children were evaluated separately, as the relative intake for young children (aged 0 to 6 years) is known to differ from older children and adults based on weight to food intake ratios and hygiene behaviours. The exposure parameters and adopted PFAS concentrations were based on typical and upper estimate exposures as defined here:

- Typical scenarios are based on a mixture of average or maximum (i.e. 365 days per year) exposure parameters and average exposure concentrations. This results in a conservative estimate of the average population exposure and is likely to represent most of the population. As an example, it was assumed adults would drink 2 litres of water containing average concentrations of PFAS measured in each water source, every day over their adult life.
- Upper estimate scenarios are based on a mixture of upper estimates (i.e. the 90th percentile) and maximum exposure parameters, and the upper estimate of PFAS concentrations in food or water consumed, resulting in a cumulative overestimate of exposures. The scenario not likely to be representative for many individuals in the population. For example, it was assumed adults would drink 10 litres of water containing 90th percentile concentrations of PFAS measured in each water source, for every day over their adult life.

Risk Characterisation

The outcomes of all exposure pathways assessed for both young children and adult residents are presented below in Figures C and D respectively.

Based on the available data collected during dry season conditions, the exposure modelling and parameters adopted, the following exposure pathways were identified as resulting in potential intakes that may exceed the tolerable daily intake (TDI) over chronic periods (i.e. over a lifetime for adults or 6 years for young children), for the following residential receptor populations:

- Ingestion of drinking water sourced from groundwater extracted from private bores within Zone 1 by residents in both typical and upper estimate exposure scenarios.
- Ingestion of drinking water sourced from groundwater extracted from private bores within Zone 2 by residents evaluated in the upper estimate exposure scenario.
- Ingestion of drinking water drawn from the Katherine River down-stream of the Stuart Highway Bridge in Zone 3, by residents evaluated in the upper estimate exposure scenario.
- Ingestion of eggs obtained from poultry in Zone 1 by young children in typical and upper estimate scenarios, and by adults in upper estimate exposure scenarios.
- Ingestion of large quantities of dry season vegetables irrigated with bore water from Zone 1, by young children as represented in the upper estimate scenario.
- Ingestion of large quantities of dry season fruit irrigated with bore water from Zones 1 or 2, or river water from Zone 3, by young children as represented in the upper estimate scenario.
- Ingestion of fish and crustaceans caught in Katherine River (specifically downstream of the High Level Bridge (Stuart Highway)) by recreational fishers in both the typical and upper estimate exposures.

Exposure pathways were defined as marginal where the estimated intake was 75% or more of the tolerable daily intake, as this may result in exceedance of the tolerable daily intake when combined

with other pathways. Marginal risks were identified for upper estimate exposures in young children who may:

- Frequently swim in pools filled with bore water extracted from Zone 1.

Fruit and vegetables watered with town water, or water sourced from outside of the IA, have not been quantitatively assessed, as there is no evidence that concentrations exceed trigger values and therefore risk is interpreted to be low and acceptable. Further data is being collected and this pathway will be explicitly documented in the 2018 HHRA.

Refinement of exposures and risk characterisation

Given that individual exposures within receptor groups within the Investigation Area are likely to vary, a process has been provided to estimate risks via the selection of appropriate exposure pathways, media sources and whether the behaviour or concentration is likely to be typical or at the upper end for each pathway. The process for estimating the potential risk for a resident within the Investigation Area or a recreational user/fisher of Katherine River, is presented in an appendix of the IHHRA report.

Uncertainty and variability

Health risk assessments require a number of assumptions regarding site conditions, human behaviours and activities relating to exposure, and chemical toxicity. Even though site-specific parameters were included where available (e.g., local food information and analytical data), it is not possible to fully describe current and future conditions and human activities in the Investigation Area. The assumptions considered for this risk assessment were generally conservative in nature, to account for uncertainty and variability in the parameter estimates by providing a deliberate margin of safety. The inclusion of upper estimate exposures is considered to provide a very conservative estimate of maximum plausible exposures.

Whilst the quantification of risk estimates can be tailored for individuals or groups based on their location, diets and activities, some uncertainty will remain.

Conclusions

The key foods and activities that are indicated to result in intake above the tolerable daily intake are:

- Sourcing drinking water from private groundwater bores in the Investigation Area in Zone 1 and Zone 2, or from the Katherine River downstream of Stuart Highway Bridge in Zone 3.
- Young children in swimming pools filled with groundwater extracted from private bores within Zone 1, where swimming exposures are representative of upper estimate assumptions.
- Consumption of eggs (representative of upper estimate assumptions) where poultry is watered from private groundwater bores located in Zone 1.
- Consumption of fish and crustaceans from Tindal Creek or Katherine River (based on both typical and upper estimate assumptions).

The variability associated with PFAS uptake by different fruits and vegetables has also resulted in a conservative conclusion that consumption of large amounts home grown fruits irrigated with PFAS impacted water from Zone 1 or Zone 2, or river water from Zone 3, (and large amounts of vegetables from Zone 1) may exceed the tolerable daily intake for sensitive groups in the population (i.e. young children).

Exposure pathway and risk characterisation - YOUNG CHILD Receptor								
Water Media Source	Residential Town Water		Residential Zone 1 Bore Water		Residential Zone 2 Bore Water		Residential Zone 3 River Water	
Exposure Pathway	Typical Exposure	Upper Estimate Exposure	Typical Exposure	Upper Estimate Exposure	Typical Exposure	Upper Estimate Exposure	Typical Exposure	Upper Estimate Exposure
Ingestion of drinking water								
Incidental ingestion of water showering /bathing.								
Incidental ingestion of water during domestic uses such as cleaning / washing & irrigation purposes								
Incidental ingestion of water swimming in a pool								
Incidental ingestion of water during sprinkler play								
Incidental ingestion of water swimming in Katherine River								
Incidental ingestion of water swimming in Katherine Aquatic Centre								
Ingestion of local dry season fruit								
Ingestion of local dry season vegetables								
Ingestion of local poultry eggs								
Incidental ingestion of soils irrigated								
Ingestion of local finfish (dry season)								
Ingestion of local crustaceans (dry season)								

Figure C: Estimated Hazard Index - Young Child Receptor Scenarios

Exposure pathway and risk characterisation - ADULT Receptor								
Water Media Source	Residential Town Water		Residential Zone 1 Bore Water		Residential Zone 2 Bore Water		Residential Zone 3 River Water	
Exposure Pathway	Typical Exposure	Upper Estimate Exposure	Typical Exposure	Upper Estimate Exposure	Typical Exposure	Upper Estimate Exposure	Typical Exposure	Upper Estimate Exposure
Ingestion of drinking water								
Incidental ingestion of water showering /bathing.								
Incidental ingestion of water during domestic uses such as cleaning / washing & irrigation purposes								
Incidental ingestion of water swimming in a pool								
Incidental ingestion of water during sprinkler play								
Incidental ingestion of water swimming in Katherine River								
Incidental ingestion of water swimming in Katherine Aquatic Centre								
Ingestion of local dry season fruit								
Ingestion of local dry season vegetables								
Ingestion of local poultry eggs								
Incidental ingestion of soils irrigated								
Ingestion of local finfish (4) (dry season)								
Ingestion of local crustaceans (5) (dry season)								

Figure D: Estimated Hazard Index - Adult Receptor Scenarios

Green shaded cells indicate the potential exposures for the exposure scenario have been identified as low and acceptable

Yellow shaded cells indicate cumulative potential exposure may be above the TDI, if other pathways are also present.

Orange shaded cells indicate an exposure exceeding the tolerable daily intake has been identified and management may be required for this pathway.

The exposure pathways noted as presenting an elevated or marginal risk of exceeding the tolerable daily intake, require management measures to reduce or minimise potential exposures. It is noted that residents in Zone 1 and Zone 2 have already been confirmed to have alternative drinking water. As residents are identified in Zone 3, access to alternative drinking water is being confirmed or provided. Rural residents in Zone 1 and Zone 2 using bore water, or in Zone 3 using river water to irrigate produce and water livestock should be advised to find alternative water sources or balance consumption with food from other sources. Similarly, the ingestion of fish and crustaceans obtained in Katherine River, in the vicinity of the Katherine township and downstream to the junction with the Daly River, should be restricted until sufficient information is available to define suitable dietary limits.

The objective of the IHHRA was to evaluate the most significant exposure pathways to receptor populations with the greatest exposure potential within the Investigation Area. Whilst the IHHRA provides an indication of the likely outcomes of the broader HHRA, the HHRA will be broader in scope as it will include wet and dry season information and more receptor specific exposure behaviour information. The outcomes for the scenarios addressed in this interim HHRA may vary as a result.

Key assumptions and limitations of the IHHRA

This IHHRA is based on the following key assumptions and limitations:

- Data was collected from sampling of dry season fruits, vegetables and eggs, and water obtained during dry season conditions only.
- Study was limited to residential populations residing within the Investigation Area and recreational users of Katherine River. Other receptor populations within the Investigation Area will be evaluated in the 2018 HHRA.
- Only chronic exposures (over a lifetime) associated with long term continuous exposure to PFAS in food and water were assessed. Acute exposures (i.e. short term up to 14 days) are not evaluated in this assessment.
- Dermal contact and inhalation exposure pathways were not evaluated quantitatively as they are not considered to contribute significantly to the overall exposure.
- Limited routes of exposure were quantified, and were associated with the consumption of local or home grown foods (fruit, vegetables and eggs), water (including drinking water and incidental ingestion whilst undertaking other activities such as bathing, swimming and cleaning) and soils irrigated with impacted water in a residential setting. In this instance, local refers to home grown food and water sources within the Investigation Area only.
- The determination of Zones adopted in this assessment is based on the available dry season data set collected in the Investigation Area and is based on the water source and PFAS concentrations in relation to the drinking water and primary recreational guideline levels.
- Site specific information was used wherever possible to calculate potential intakes by residents.
- The mean concentrations of PFOS + PFHxS and PFOA reported in the dry season investigations were utilised in this assessment in order to represent a reasonable worst case scenario. The upper estimate 90th percentile concentrations of PFOS + PFHxS and PFOA reported in the dry season investigations were utilised in this assessment in order to represent a plausible maximum or very high exposure scenario.
- The assessment of health risk is based on data obtained in 2017. The estimation of historical exposures is not possible as the concentrations in various media cannot be known.
- A number of conservative exposure assumptions were included in the risk assessment. For example, it was assumed that in a residential setting the same individual would be exposed to the same concentration for 365 days/year for 35 years for the more significant exposure pathways such as drinking water and domestic water usage. When combined, the assumptions deliberately

overestimate the most likely exposure. The estimated exposures using upper estimates are considered to reflect plausible maximum exposures as the 90th percentile contaminant concentrations are multiplied by 90th percentile or maximum exposure parameters.

- Young children were included in the quantitative evaluation on the basis their exposures are potentially greater given their activities and body weight to ingestion rates. The exposure characteristics of a 2 to 3 year old child were adopted and generally drive the calculated risks in scenarios where they are a nominated receptor.
- Biota sampling was conducted at selected properties or locations and was limited to a number of foods sources based on surveys, seasonal availability and accessibility. The adoption of mean concentrations of PFAS measured in each food type are generally considered to be representative of likely intakes, however, concentrations of some PFAS contaminants are higher in some locations than others.
- The bioavailability of each PFAS compound varies depending on the exposure route, the media ingested and many other factors, therefore it was conservatively assumed to be 100%.
- The toxicity reference values adopted for comparison with the estimated intakes by residents were consistent with those derived by Food Standards Australia and New Zealand (FSANZ) in April 2017. FSANZ applied a number of safety factors to account for issues related to data extrapolation relating to species variability and human variability.
- The adopted exposure assumed to be representative of background concentrations across Australia was based on the upper estimate calculated from data available in 2016.