Fire & Rescue NSW

FRNSW Site Improvement Plan
Armidale - Retention Pond

February 2019

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1. Introduction

Fire and Rescue NSW (FRNSW) engaged GHD Pty Ltd (GHD) to develop a site improvement plan for the management of contamination issues associated with the presence of per- and poly-fluoroalkyl substances (PFAS) at the Armidale FRNSW training facility, located within Lot 1 DP 1068131 at 2-16 Mann Street Armidale, NSW 2350 (the 'site'). The location of the site is shown on Figure 1, Appendix A.

1.1 Project background

FRNSW commissioned GHD to undertake environmental assessments at the site to assess the extent and concentrations of PFAS at the site and surrounding areas. GHD conducted a preliminary site investigation (PSI) in 2016 followed by two phases of detailed site investigations (DSIs) in 2017. The findings of the PSI and DSIs are reported in:

- GHD (2016) Armidale PFAS Investigation, Preliminary Site Investigation and Sampling and Analysis Quality Plan, August 2016 (the PSI).
- GHD (2017a) Fire & Rescue NSW, Armidale Training Facility, Environmental Site Assessment. February 2017.
- GHD (2017b) Fire & Rescue NSW, Armidale Training Facility, Phase 2 Environmental Site Assessment. August 2017.
- GHD (2018) Armidale Tourist Park – Private bore sampling results (letter dated 09 May 2018).

Based on the findings of these studies, GHD prepared preliminary management option approach for FRNSW for the remediation / management of PFAS at the site (provided as Appendix B).

- GHD (2017c) Armidale training facility, PFAS Management Options Assessment. December 2017.

Based on the Options Assessment Report (GHD, 2017c), FRNSW requested GHD to develop a site improvement plan to address the secondary source of PFAS on-site, namely the surface water retention pond adjacent to the fire training area.

1.1 Objectives

This report aims to meet the following key objectives:

- Provide a strategy to manage or mitigate the potential risk posed by the presence of PFAS contamination remaining within the sediments and water in the on-site retention basin adjacent to the fire training area.
- Provide recommendations to manage potential long term risks posed by residual PFAS contamination remaining at the site following completion of the remediation (if any) and detail ongoing monitoring requirements.

Further details on the site improvement works is provided in Section 6.2.

1.2 Scope of work

In order to meet the objectives stated in Section 1.1, GHD has completed the following scope of works:

- Consolidation of existing information, including the key outcomes of the previous stages of site investigation, management options assessment and workshop sessions.
- A teleconference with FRNSW to confirm the preferred approach for addressing the retention basin.
- Development of this site improvement plan based on the preferred management approach.

1.3 Limitations

This report has been developed and should be read in conjunction with the limitations set out in Section 10.

Measurements and volumes outlined in this report are based on estimates using aerial photographs and some assumptions (as outlined within the report). Measurement details are therefore approximate and should be confirmed by the contractor prior to use.

2. Relevant guidelines and legislation

2.1 Site assessment

The principal Commonwealth environmental legislation for consideration in implementation of remediation and validation works is the *Environment Protection and Biodiversity Act* 1999 (EPBC Act, Department of Environment and Energy [DoEE] 1999).

The EPBC Act provides that the Commonwealth is to be involved in matters of "National Environmental Significance" (NES). The EPBC Act vests the Commonwealth Environment Minister, in the absence of a referral, with the power to request referral of a proposal. Under the environmental assessment provisions of the EPBC Act, actions that are likely to have a significant impact on a matter of NES are subject to an assessment and approval process. The EPBC Act identifies seven matters of NES:

- World Heritage properties.
- National Heritage places.
- Ramsar Wetlands of international significance.
- Nationally listed threatened species and ecological communities.
- Listed migratory species.
- Commonwealth marine areas.
- Nuclear actions (including uranium mining).

When there are habitats or species of national significance (as listed under the schedules of the *Environment Protection and Biodiversity Conservation Regulation 2000*) within the project remediation area likely to be impacted negatively upon by the proposed remediation works, then preparation and lodgement of an EPBC Act referral to the Commonwealth for the assessment would need to be considered and addressed accordingly.

The need or otherwise to initiate a referral or approval under the EPBC Act for the works described herein is at the discretion of FRNSW. However, based on the available site information, GHD considers it unlikely to be a requirement for these works.

Specific guidance on-site assessments and remediation is provided in:

- ASC NEPM, "National Environment Protection (Assessment of Site Contamination) Measure", National Environment Protection Council (NEPC), 1999 (as amended in 2013)
- PFAS NEMP 2018: *PFAS National Environmental Management Plan*, Heads of EPAs Australia and New Zealand (HEPA) January 2018
- ANZECC 2000 Australian and New Zealand Environment Conservation Council (ANZECC) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*
- *Contaminated Sites Act 2003* and *Contaminated Sites Regulations 2006*
- DoEE 2016 Department of Environment and Energy (DoEE), October 2016. DRAFT *Commonwealth Environmental Management Guidance on Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFAS)*
- Health 2017. Release of Food Standards Australia New Zealand's (FSANZ) report on: Perfluorinated chemicals in food Supporting Information. Australian Government Department of Health, 31 March 2017

- NHMRC 2011 National Health and Medical Research Council (NHMRC) *National Water Quality Management Strategy, Australian Drinking Water Guidelines 6*
- NSW EPA 2017 *Contaminated Land Management – Guidelines for the NSW Site Auditor Scheme (3rd Edition)*.
- NSW OEH. (2011). *Guidelines for consultants reporting on contaminated sites.* Sydney: NSW Office of Environment and Heritage.

The DSIs were conducted prior to the release of the PFAS NEMP assessment guidelines. The screening values applied in the DSI (GHD, 2017b) are the same for human health in water. However, the soil human health and aquatic/terrestrial ecological assessment criteria has changed since the completion of the DSIs. The PFAS NEMP assessment criteria apply to the same analytes as those assessed in the DSI (GHD, 2017b) and a preliminary screening of results suggests that there are few new PFAS exceedances. The primary change is in the aquatic criterion for PFOS, which is substantially lower. Potential risks to off-site aquatic receptors, including Lake Illawarra, were considered as part of the DSI.

Additionally, GHD notes that the *Australian Drinking Water Guidelines (ADWG) 6* (NHMRC, 2011) were updated to version 3.5 in August 2018, to amend screening criteria for some existing analytes and to include criteria for the sum of PFOS/PFHxS and PFOA. The screening values provided by NHMRC (2011, updated 2018) are the same as those provided in the PFAS NEMP.

Results from previous investigations for PFAS have been provided in Appendix C, with updated relevant guidelines. GHD notes that all results have been screened against all criteria considered applicable to the investigation, and caution should therefore be applied in interpreting noted exceedances.

2.2 Remediation hierarchy

The key principles for remediation and management of contaminated sites presented in *Volume 1* of ASC NEPM indicate that the preferred hierarchy of options for site clean-up and management should include (in descending order):

- On-site treatment of contamination, so that the contaminant(s) are either destroyed or the associated hazard is reduced to an acceptable level.
- Off-site treatment of excavated soil, so that the contaminant(s) are either destroyed or the associated risk is reduced to an acceptable level, after which the soil is returned to the site.

If these options cannot be implemented, then the other options that should be considered include:

- Consolidation and isolation of the soil on-site by containment with a properly designed barrier; and
- Removal of contaminated material to an approved site or facility, followed, where necessary, by replacement with appropriate material;

or,

- Where the assessment indicates remediation would have no net environmental benefit or would have a net adverse environmental effect, implementation of an appropriate management strategy.

Considerations of sustainability and the Waste Avoidance and Resource Recovery (WARR) Act (1997) also support avoiding off-site disposal.

ASC NEPM states that when deciding which option to choose, the sustainability (environmental, economic and social) of each option should be considered, in terms of achieving an appropriate balance between the benefits and effects of undertaking the option, and in cases where no readily available or economically feasible method is available for remediation, it may be possible to adopt appropriate regulatory controls or develop other forms of remediation.

For on-site containment of contamination, whether in a dedicated cell or as part of site development, the NSW EPA Auditor guidelines (2017) requires that containment should only be considered where other preferred approaches from the remediation hierarchy are not applicable. If using a capping and/or containment strategy, it must achieve the following:

- maximise the long-term stability of the capping and/or containment system(s) and any proposed structures above it (from an engineering perspective) and, where applicable, minimises the potential for leachate formation and/or volatilisation
- not include the erection of structures on the capped and/or contained area that may result in a risk of harm to public health or the environment
- include a notification mechanism to ensure that the capped and/or contained areas are protected from any unintentional or uncontrolled disturbance that could breach the integrity of the physical barrier. For example, placing a notation or covenant on the property title, palcing a notation on a s.149 certificate, or issuing an order or placing a covenant on the title to land under the CLM Act to require ongoing maintenance under the Act.

The *Guidelines for the Assessment and Management of Groundwater Contamination* (NSW Department of Environment and Conservation (DEC), 2007) states that ideally, contaminated groundwater should be restored as much as practicable to its natural background quality. However, in practice, cleaning up so natural background concentrations are restored can be technically difficult and extremely costly and in most cases not possible through active means alone. Section 4.3 “Clean up to the extent practicable” (CUTEP) of DEC (2007) acknowledges that in some cases, it may not be practicable to continue clean-up of groundwater to the point where all environmental values are restored, and in such cases an interim clean up goal can be based on protecting environmental values and preventing potential risks to human and ecological health.

The guidelines state that evaluation of the practicable limit of remediation should consider the following factors:

- Technical capability to achieve clean-up
- The clean-up cost
- The value of the groundwater resource
- Threats the contamination poses to human or ecological health.

The guidelines include a number of requirements that must still be met in cases where clean-up to restore environmental values cannot be achieved. These include:

- plume containment to prevent further spreading
- groundwater monitoring
- periodic re-evaluation of the practicability of clean-up
- provision for long-term resourcing and responsibility for any management strategy
- a groundwater management plan specifying measures that will be implemented to mitigate risks to human and ecological health.

3. Site background

The site boundary and key site features are presented in Figure 2, Appendix A.

Key features of the area occupied by FRNSW include the administration buildings and site offices and the primary fire training area located to the west of the main driveway to the site. Additionally, there is an area in the southern portion of the site known as ‘the skid pan’ which is used by the Rotary Club and as a secondary FRNSW training area.

The primary fire training area comprises hardstand of concrete and asphalt. The concrete was reportedly laid approximately 5 to 10 years ago. There is also a second fire training area located towards the south eastern corner of the FRNSW property, which was anecdotally only used for water based training activities (labelled as ‘water only fire training ground’ on Figure 2, Appendix A).

Immediately adjacent to the primary training area in the north-west portion of the site is a pond, of approximate dimensions 6 m by 16 m (based on aerial photographs). This pond has been referred to as a “surface water retention basin” in previous reports which receives water draining from the primary fire training area. However, there is some doubt over whether it was constructed specifically to act as a stormwater retention pond. This is discussed further in Section 6.1.

3.1 Site setting

The main features of the Armidale site and their relevance to determining appropriate management options are provided in Table 3-1.

Table 3-1 Site features summary

Aspect	Summary	Potential management issues
Site location	Located in a largely semi-rural setting surrounded by agricultural and residential land. The property is owned by NSW State Government and is used for a number of purposes including the ‘Armidale traffic education centre’ and the NSW Rural Fire Service. A portion of the property is currently leased by FRNSW for use as a firefighting training facility, but it is understood that FRNSW also uses other portions of the wider training facility.	Located in an area of multiple land uses. Land ownership obligations may be impacted by PFAS contamination.
Geology and hydrogeology	The site is underlain by Carboniferous Sandon Beds consisting of greywacke, argillite, chert, jasper and basic volcanics. Groundwater is likely to flow northwards towards Dumaresq Creek. Groundwater salinity is fresh to slightly brackish. There is one registered groundwater bore within 500 m of the site and it is considered downgradient of the site (GW966477). This bore is registered for stock watering. A second registered bore is located at the Tourist Park (GW047498), 600 m north-west of the FRNSW site. It is registered for irrigation, domestic and industrial purposes.	Groundwater flow will be controlled by fractures in the underlying geology and groundwater flow velocity and yields may be limited. Salinity is a significant controller of PFAS solubility and therefore, fate and transport. Groundwater is potentially used for human agricultural and commercial beneficial purposes downgradient of the site, and has been shown to be impacted by PFAS.

Aspect	Summary	Potential management issues
Hydrology	The closest surface water body is Dumaresq Creek, located approximately 1 km to the north of the primary fire training area on-site. There are several drainage lines through the wider training facility (as shown on Figure 2, Appendix A). Surface water flows off the site to the north via a surface drain. The drain has three retention dams along its course. The retention pond adjacent to the FRNSW training area overflows to a swale that connects to the primary drainage channel. The dam located near the skid pad (south of the FRNSW area) uses captured water for training purposes at the skid pan and is recycled back into the dam. The drainage line eventually drains to a large off-site dam adjacent to Dumaresq Creek. When overflowing, the dam would likely drain into Dumaresq Creek, approximately 1 km to the north of the primary fire training area on-site.	Surface drains may be a significant migration pathway off-site.
Contaminants of concern	PFAS – notably PFOS, PFHxS, PFOA. Identified in soil, sediment, groundwater and surface water on-site and off-site. Water soluble, can sorb to soil and sediments, leachable, resistant to degradation, may have adverse effects on animals and humans, bioaccumulate in the food chain, long half-lives in humans and high adverse profile in the media.	The physico-chemical characteristics of PFAS make these chemicals very hard to remove from the environment and to destroy. PFAS has been released to the environment and therefore plants, animals and human have the potential to become exposed to PFAS. PFOS_PFHXS exceed screening criteria in surface water and groundwater. PFAS have received very negative reporting in the media and have a high perception of risk to the community.
Contaminant sources	Aqueous Film Forming Foam (AFFF) products containing PFAS are no longer used on the site so no primary sources exist. Secondary sources of PFAS contamination include the retention ponds and dams, and surface water/sediments in drains on-site and off-site. The highest PFAS concentration in groundwater was previously found in on-site well MW03, which is adjacent to the northern boundary of the site (Figure 3A, Appendix A). PFAS is generally higher in the retention pond on-site and dams off-site than in groundwater. The highest PFAS was reported in a surface water retention pond adjacent to the primary fire training ground.	The site remains a potential source of PFAS contamination to off-site receptors. PFAS has migrated from the site via surface drains and possibly via groundwater flow.

3.2 Previous analytical results

A summary of results is provided for various media in the following subsections. Investigation locations are shown on Figure 3A and Figure 3B, Appendix A and a summary of previous analytical results is provided in Appendix C. As discussed in Section 2.1, the DSI was conducted prior to the release of the NEMP (2018). The following discussion is therefore based on the assessment criteria used in the DSI report (GHD, 2017b).

3.2.1 Soil and sediment

Analysis of the soil and sediment samples indicated the following:

- Soil samples recovered from off-site monitoring well locations MW07 to MW09 reported PFAS below the laboratory level of reporting (LOR).
- The highest concentration of PFAS was in the concrete sample collected from SB09 on the skid pan in the wider training area (0.406 mg/kg – WA DER sum of total). However, the concentration of PFAS in soil 0.9 m below this point, was at least an order of magnitude lower for all PFAS analytes (total PFAS 0.0025 mg/kg).
- Concentrations of PFAS in sediments were low and generally below or close to the laboratory LOR. The highest concentrations of PFAS (sum of total) in sediments was located at off-site sampling location SS11 (0.119 mg/kg). The sample was collected off-site and within a dam on a private property.
- Sediment locations SS17, SS21 and SS22 (which were collected from Dumaresq Creek) each reported concentrations of PFAS (sum of total) above the laboratory LOR, potentially representing an on-going source of PFAS to nearby surface water receptors.

3.2.2 Groundwater and surface water

Analysis of the groundwater and surface water samples indicated the following:

- The inferred groundwater flow was in a northerly direction. Groundwater depths range from approximately 9 m to 27 mTOC.
- Groundwater was fresh to slightly brackish.
- PFAS was detected above the laboratory LOR in a private bore to the north of the site. The extent of the groundwater plume down gradient of the site is not fully delineated.

3.2.3 Tourist park private bore

Based on the findings of the works undertaken by GHD in 2017, PFAS was reported in groundwater migrating off-site from the FRNSW training facility, however, the extent of the impact was not fully delineated. The private bore on the tourist park (GW047498) was identified by GHD as part of the PSI stage of works as being potentially hydraulically down-gradient of the FRNSW training facility however access was not available to the bore during the site investigations completed in 2017.

The bore is located approximately 600 m north-west of the FRNSW site. Concentrations of PFAS in both the primary and duplicate samples were reported below the laboratory LOR. However, GHD recommended that the private bore is included in future monitoring events to confirm the findings of these works and assess whether the results are influenced by seasonal variability.

4. Conceptual site model summary

4.1 Source-pathway-receptor linkages

A conceptual site model (CSM) was provided as part of the DSI reports (GHD, 2017b), based on the additional data collected in May 2017. This has been provided as Table 4-1 in this report, and as a pictorial CSM is provided in Figure 4, Appendix A.

Table 4-1 Refined CSM (GHD, 2017b)

Potential source	Primary pathway	Receptor	Pathway present?
Soils in firefighting training areas (main fire training area and skid pan) contaminated with PFAS	Dermal contact	FRNSW and wider training facility commercial workers and intrusive maintenance workers	Unlikely – PFAS impact detected in shallow soil samples from these areas, however impact below adopted assessment criteria.
	Vertical/horizontal migration of leachate through unsaturated zone	Groundwater – subsequent migration in groundwater (secondary)	Possible – PFAS impact in MW01, MW03, MW07, private bore (GW966477) and MW08, down gradient of training facility and off-site in private residential properties. While the PFAS is leachable, the mass of PFAS in the surface water could be the main contributing factor for PFAS to the groundwater.
	Surface runoff and sediment transport	Surface waters (including drainage systems – secondary pathway)	Yes – PFAS detected in sediment samples from surface waters and drainage lines associated with this area.
		Off-site rural residential and commercial properties	Yes – sediment samples at the northern boundary and along drainage line contained PFAS.
		Off-site ecological	Yes – off-site dams indicated PFAS impact above ecological screening criteria, which is likely to be associated with dissolved PFAS originating from soils in fire training areas in the FRNSW site.
Soils in firefighting training areas (water use only area)	Vertical/horizontal migration of leachate through unsaturated zone	Groundwater and surface waters	Possible – PFAS detected in soil samples soil bores and sediments in the FRNSW site area. Leachate results indicate that leaching of PFAS from these samples is possible, and impact observed in down-gradient groundwater sample (MW01).
	Dermal contact	FRNSW and wider training facility commercial workers and/or intrusive maintenance workers	No – no contamination detected in soil samples from this area.
	Surface runoff and sediment transport	Surface waters and subsequent off site receptors	Possible – PFAS detected in soil samples from soil bores and sediments in the FRNSW site area.

Potential source	Primary pathway	Receptor	Pathway present?
Surface water retention pond (Pond 1) located to the north of the main fire training area (FRNSW site) contaminated with PFAS	Dermal contact and ingestion	FRNSW and wider training facility commercial workers	Unlikely – PFAS impact present greater than drinking water and recreational criterion at SW01. However, the area has been cordoned off with warning signs in place.
	Vertical/horizontal migration of water through unsaturated zone	Groundwater – subsequent migration in groundwater (secondary)	Yes – PFAS impact in MW01, MW03, MW07, private bore GW966477 and MW08, down gradient of training facility and off-site in private residential properties
		Down gradient surface waters	Yes – Private dams down gradient report PFAS impact
	Surface water flows when overflowing	Down gradient surface waters, which may be used for stock watering	Yes – Private dams down gradient report PFAS impact greater than the ecological screening criteria
Surface water retention ponds and dams in wider training facility contaminated with minor levels of PFAS (Pond 2, Dam 1 and Dam 2)	Dermal contact and ingestion	FRNSW and wider training facility commercial workers	Possible – PFAS above the recreational assessment criteria at SW02, SW03, SW04 and SW13 and greater than the drinking water criteria at SW14 and SW15.
	Vertical/horizontal migration of water through unsaturated zone	Groundwater – subsequent migration in groundwater (secondary)	Unlikely – groundwater at MW04 contained low levels of PFAS in 2016, and was less than the LOR in 2017. Similarly at MW05, low PFAS (sum of total) concentration despite being an order of magnitude greater in SW02 (Pond 2, adjacent). Location MW06 was not sampled (refer to GHD, 2017b for further discussion).
		Down gradient surface waters	Unlikely – Private dams down-gradient report PFAS impact, however these dams are unlikely to be the major contributing source (low levels of PFAS)
	Surface water flows when overflowing	Down gradient surface waters, which may be used for stock watering	Possible – Private dams down gradient report PFAS impact however these dams are unlikely to be the major contributing source (low levels of PFAS)
Surface water dams off-site on private properties (secondary sources) contaminated with PFAS	Surface water flows when overflowing	Down gradient surface water storage, which may be used for stock watering	Yes – PFAS detected in all off-site dam sample locations above recreational criteria (SW05, SW09, SW16, SW06 and SW07).
		Down gradient ecological receptors	Yes – SW08, SW11 and SW12 samples collected in Dumaresq Creek had detectable levels of PFAS but were below both human health and ecological assessment criteria. Creek not directly hydraulically connected to unnamed tributary/drainage lines but could be in times of high flow/rainfall.

Potential source	Primary pathway	Receptor	Pathway present?
Contaminated groundwater	Vertical/horizontal migration	Down gradient surface waters recharged by groundwater	Unlikely – groundwater levels are below the surface water dams and are therefore not in connection. Connection with Dumaresq Creek is highly likely but water results (SW08, SW11 and SW12) are below adopted screening criteria.
		Abstraction bores (stock and/or domestic use)	Yes – Impact above adopted assessment criteria detected in private bore off-site and MW07 and MW08.

4.2 Risk assessment

A number of potentially complete pathways were identified for soils, sediments, surface water and groundwater, as shown in Table 4-1. Identified soil impacts are not considered to be posing direct human health risks, however relatively low concentrations of PFAS in soil can leach to groundwater and surface water and result in exceedances of recreational and ecological guidelines.

Based on the available data set, there appears to be a potential risk to off-site ecological receptors and potentially human recreational users of Dumaresq Creek and from extractive use of groundwater. However, risks to human health associated with the consumption of groundwater are considered to be low and acceptable based on the outcomes of the previous sampling program (GHD, 2017b).

Whilst the works completed to date suggested that potential risks to human health may be low, GHD notes that the presence of PFAS in off-site media poses a potential reputational risk for FRNSW. There is a high level of public concern over PFAS contamination in the Armidale area, which could have a detrimental effect on resources, property values and the reputation of the polluter.

4.3 Site investigation data gaps

The findings of the previous stages of site investigation indicated that PFAS contamination exists both onsite and off-site. The primary mode of transport appears to be in surface water, however there is some evidence to suggest groundwater migration is also occurring (noting that the origin of this groundwater impact may also be from surface water bodies rather than directly from AFFF leaching). A number of data gaps were identified at the completion of second stage of site investigations (GHD, 2017b) which relate to the wider assessment of the site.

Whilst the focus of this plan is the evaluation and development of an appropriate strategy to manage further off-site migration from the primary retention pond on-site, the data gaps identified at the completion of the stage two investigations (GHD, 2017b) are summarised in Table 4-2 for completeness.

Table 4-2 Data gap summary

Data gap	Details	Status
Surface water pathways	Samples for surface water and sediment were co-located where possible. No samples were undertaken on Black Gully Creek as the topography suggests there is no plausible pathway to this Creek from the site except where the Creek meets Dumaresq Creek. Samples were collected from Dumaresq Creek and the area surrounding and therefore negated the need to sample from this Creek. All dams and surface water was sampled along all potential drainage paths both on and off-site. Sampling was undertaken in summer and winter to gain an understanding of seasonal variation.	The most recent round of sampling was completed winter 2017 and current status of PFAS in surface water and sediment samples is unknown. The surface water sampling program would benefit from additional locations, including locations up-gradient of SW14, up-gradient of SW13 and up-gradient of SW12 collected from Dumaresq Creek to better understand the potential for up-gradient sources to be impacting on the Creek.
Groundwater pathways	Three additional groundwater wells were installed off-site during the DSI (GHD, 2017b). An additional groundwater well was proposed on Cookes Road near Brown Street, however, due to overhead wires and water logged ground surface, no monitoring well could be installed at this location during the works. The groundwater flow direction is towards the Dumaresq Creek. There is a slight flow direction off-site to the north north-west due to the natural topography and based on the distance to the receptor and the hydraulic gradient to the water depth of Dumaresq Creek the groundwater is highly likely to be in connection with this creek. There is a private bore located within the Tourist park that is a potential receptor based on groundwater flow (GW047498). However, access was not given to sample the bore during the 2017 sampling event. PFAS concentrations in groundwater at MW09 (located off-site to the north) were less than the laboratory LOR and therefore has delineated the groundwater PFAS plume in that direction. However, there is no well coverage between MW08 and the private bore further down-gradient of. The PFAS concentrations within these wells (MW08 and GW966477) shows that concentrations were lower than in MW03 (on-site) and a similar order of magnitude to MW07 (off-site and approximately cross-gradient to MW08).	Private bore GW047498 sampled April 2018 (refer to information in Section 3.2.3). Results below laboratory limit of detection. The groundwater monitoring program would benefit from installation of one additional groundwater location on Mann Street, west of the site, to assess the extent of groundwater contamination identified in MW08 and to provide additional triangulation for groundwater flow direction. Additional to previously sampled registered bores (GW047498 and GW966477), sampling of five registered bores not previously sampled (GW301016, plus four north of the final dam down-gradient of the site which are believed to be used for spraying a turf farm) to confirm the absence/presence of PFAS at these identified receptors. The most recent round of groundwater sampling for all on-site and off-site locations was completed in winter 2017. Additional monitoring data would be required to assess longer term trends. The use of data loggers and hydraulic conductivity testing in selected groundwater wells would provide additional information to assist with understanding of groundwater flows and potential connectivity between surface and groundwater.

Data gap	Details	Status
Receptors / human dietary consumption	There are five private properties located down-gradient along the drainage pathway. Each of these properties have private dams that receive water through the drainage channel from on-site and the owners have completed water use surveys.	Following discussions with owners of these properties, GHD understands that water in the dams is not used for watering plants or home grown produce. The start of a redevelopment project is understood to be occurring west of the drainage line. This could have further implications on the proximity of residential receptors and should be reviewed in the context of the outcomes of additional surface water sampling.
Dam water use	At the time of the previous works, two owners were understood to keep horses and Shetland ponies on their property which had access to water in the dams. At the time of the DSIs, GHD understood that access to the surface water dam on the property with horses has been restricted and an alternative water supply had been provided for the horses.	Status of alternative water supply and management requirements to be reviewed in the context of additional off-site surface water sampling event.
Recreational use of local waters	From the water use survey, one survey respondent indicated use of local creeks for recreational purposes although they did not specify what kind of recreational activities they used these water sources for. Another respondent indicated that they used the dams on their property for swimming.	Potential recreational use of surface water bodies to be reviewed in the context of additional off-site surface water sampling event.
Potential ecosystem receptors	The PFOS concentrations in the surface water samples collected in Dumaresq Creek (SW02, SW11 and SW12) were below the ecological screening criteria and therefore not considered a potential risk. However, during periods of flood, or if the last dam located before Dumaresq Creek was to overflow, there is a potential risk to Dumaresq Creek. It is likely however that large rain event may also result in a dilution of the PFAS in the creek	The most recent round of sampling was completed winter 2017 and current status of PFAS in surface water and sediment samples is unknown.

4.4 Drivers for site management

Based on the analytical results and site CSM, there appears to be potential risks to off-site ecological and human receptors from groundwater, the drainage channel and Dumaresq Creek.

Discussions with FRNSW indicated that the site is intended to continue to be used as a fire training facility.

Overall, the main drivers for site management therefore include:

- The prevention of any further migration of PFAS from on-site sources to the off-site environment.
- Addressing the potential reputational risk for FRNSW.

It is noted that prevention of further PFAS migration from on-site surface water sources will benefit the local ecosystems and also help to address any potential reputational risk for FRNSW. Also, addressing the surface water source on site will reduce PFAS mass migration to groundwater and therefore migration off-site via groundwater (to be assessed upon completion of the site improvement works and through the implementation of a groundwater monitoring program).

5. Options approach

In order to determine the optimal management strategy for the site, GHD has undertaken an assessment of the various available management options, in accordance with the hierarchy endorsed by NEPM (2013) discussed in Section 2.2.

5.1 Previous options assessment report summary

A management options assessment report was prepared by GHD (2017c) which outlined potential management options to address on-site and off-site contamination of soil, groundwater and surface water. This has been provided in Appendix B.

As outlined in the Options Assessment Report (GHD, 2017c), GHD surmises that:

- Impacted PFAS sources include the retention pond and sediment on-site. Surface water and sediment are also impacted in drains off-site. The extent of soil contamination has not been systematically assessed. PFAS is also present in sediment and water from Dumaresq Creek.
- Groundwater contamination appears to have extended off-site and has impacted an extractive bore to the north of the site.
- PFAS in surface water, including Dumaresq Creek, is available to terrestrial biota and aquatic biota and to humans consuming tainted biota.

The main driver for management is the prevention of any further migration of PFAS from on-site sources to the off-site environment, focussing on surface water migration. Addressing the main source of PFAS contamination on-site (the retention pond) should be a priority to achieve this outcome. Based on this, FRNSW have chosen to focus on removing a primary mass of PFAS at the site being stored in soils, sediments and surface water associated with the retention basin immediately adjacent to the primary FRNSW training area.

5.2 Management principles

Management of the retention pond does not necessarily address all contamination, but rather provides a means of mitigating further impact through a combination of source reduction and isolation of a key source of contamination.

The overarching approach principles are:

- PFAS mass reduction through destruction, isolation and/or removal; or
- Control of migration through interception or isolation; or
- A combination of the two.

The surface water and associated sediments in the retention pond and site drains appear to represent the main potential sources of off-site PFAS impact. The mass in the retention pond has the most likely potential to migrate off-site and impact on-site drainage lines and groundwater as well as off-site drains and surface water bodies. These are readily accessible at the surface on-site and therefore, are amenable to removal or treatment.

The PFAS identified to date in on-site soils does not represent a significant risk to human health based on a commercial/industrial setting. Therefore, physical removal of all impacted soil is not considered a practicable immediate response or commensurate with the risks posed by the soil. For both retention basin approach options (discussed in Section 6.3), soil excavation followed by either off-site disposal, encapsulation or on-site treatment has only been considered as a target management opportunity associated with works to reduce PFAS mass in the surface water and sediments.

Assessment of groundwater has not been considered further in this report, as it is not a contributing factor to the retention basin. The Options Assessment Report (GHD, 2017c) does provide management options for impacted groundwater at the site. Refer to the Options Assessment Report (GHD 2017c, provided in Appendix B) for further discussion of strategies for management of specific environmental media (soils, groundwater, surface water and sediments) across the site.

5.2.1 Management constraints

A number of site improvement constraints were identified as part of the Options Assessment report (GHD, 2017c) as outlined in Table 3-1 and Table 5-1.

Table 5-1 Management constraints

	Summary	Discussion
Contaminant fate and transport	PFAS can leach from soil into groundwater and migrate off-site. PFAS can migrate off-site in drains. PFAS may partition to sediments upon contact with more saline surface water, although such conditions do not occur in this area. Dissolved PFAS can be taken up by plants. Smaller PFAS molecules are more soluble and less able to sorb to organic material than larger molecules. Potential receptors include extractive use, terrestrial biotas and aquatic biota in Dumaresq Creek.	PFAS can migrate considerable distances in groundwater although this is restricted by hydraulic gradients and permeability. Permeability in the fractured rock aquifer may be low. Groundwater will discharge into Dumaresq Creek where concentrations of PFAS will be diluted. Migration via drains may therefore be more significant that in groundwater.
Regulatory constraints	Screening criteria for ecological receptors tend to be very low. The criteria protective of human consumption of impacted biota is generally below laboratory LORs. Waste disposal criteria for PFAS were not available at the time of DSI reporting.	Off-site disposal to a landfill requires assessment to determine if it is an available option. Off-site disposal to a treatment facility is a potential alternative option.
Management constraints	PFAS can be destroyed thermally but at very high temperatures i.e. >1400oC. Many other technologies have been tested at bench scale but not full scale. There are method that can remove PFAS from water including filtration methods and reverse osmosis.	Remedial methods are not well established and may be cost-prohibitive if volumes of water and/or soil are large. Options are discussed further in the Options Assessment Report (GHD, 2017c).
Land ownership	Land parcel owned by NSW State Government. A portion of the property is leased by FRNSW for use as a training facility. The lease area has been occupied by FRNSW since 1997.	Land works will require the permission of NSW State Government.

5.3 Outcomes of teleconference

A teleconference was held between GHD and FRNSW on Tuesday 22 January 2019. Representatives from various FRNSW departments which manage aspects of the site were present, including Program Management Office, Strategic Capability, Property and Assets, and Education and Training. A draft version of this report (completed up to Section 6.3 inclusive) was provided to FRNSW by GHD to provide a framework for the discussion.

The following provides a brief outline of topics discussed and relevant outcomes;

- It is believed that FRNSW installed the pond associated with the primary fire training area (Pond 1, Figure 2 in Appendix A) initially, however there are no records of design at present.
- FRNSW confirmed that the pond is not currently used for training purposes.
- The site lease is currently due to expire in 2023, however FRNSW intend to renew the lease (if possible) to continue using the site for fire training purposes.
- There are no timeframe goals on possible management strategies from FRNSW perspective, however they would like to address ongoing liability stemming from the site.
- In summary based on the current proposed options by GHD, FRNSW consider decommissioning of the pond with backfill to ground surface as the most appropriate option.

6. Retention pond strategy options

6.1 Retention pond profile

6.1.1 Pond features

The surface area of the pond is approximately 96 m^2 (based on the dimension 16 m x 6 m, measured based on aerial photographs). For the purpose of this document, an average depth of 1 m to 2 m has been assumed. The volume of water in the pond would therefore range from approximately 96 m^3 to 192 m^3 (96,000 L to 192,000 L).

Photographs of the pond are shown in Figure 6-1 and Figure 6-2.

Figure 6-1 Facing south, showing the pond and the central fire training area

Figure 6-2 Facing west, showing the drainage swale passing to the west of the pond

6.1.2 Current functionality

The pond currently receives limited surface water runoff from the primary fire training area as it is not directly connected (as shown in Figure 6-1).

No underground or above ground pipe network is known to be connected to this pond. There is a drainage swale from the western portion of the site which leads around the pond, and which would receive any overflow water from the pond. This swale passes under Mann Street where it connects to the primary drainage line flowing to the north of the site.

A second retention pond adjacent to the skid pan (southern portion of the site, labelled as 'Pond 2' on Figure 2 in Appendix A) holds run-off from the skid pan and recycles water from that area. No pump infrastructure is known to be associated with Pond 2.

A preliminary assessment of the retention pond indicated that it has not been adequately designed to perform the functions of a detention or retention basin in itself from a stormwater management perspective, as indicated by limited overflow capacity/design and its permanent retention of water (i.e. no capacity to hold additional stormwater).

There is a possibility that the basin holds some benefit as a 'settling tank' where the turbidity and overall water quality of overflow water is improved by allowing particulate matter to settle prior to discharge. However, the overall net benefit from removing a PFAS source is likely to outweigh the advantages of possible general water quality improvement.

6.2 Pond 1 improvement goals

PFAS target

The overarching aim of these works is to reduce the mass of PFAS associated with the retention basin immediately adjacent to the primary fire training area to reduce potential off-site risks to ecology and human health posed by PFAS migration in surface water and sediments (as outlined in Section 4.4).

The implementation of the works should not impact on the site operational functionality as a training facility, and following its completion the site must remain/be made suitable for its intended ongoing use a training facility.

Costs

FRNSW are seeking a cost efficient solution to meet the overall project objectives, especially considering the potential need for further site improvement works in the future.

Time frame

Based on the outcomes from a teleconference between FRNSW and GHD, there are no specific timeframe goals associated with pond improvement works at this site (refer to Section 5.3). However, to address reputational risk, GHD advises that FRNSW undertake the intended works as soon as reasonably practicable.

6.3 Pond improvement approach

Based on the functional requirements and improvement goals outlined in Section 6.1 and Section 6.2 (respectively), potential options for addressing surface water and sediment contamination associated with the retention basin are shown in Figure 6-3. Each option would require a staged approach with further options in the final form of the retention basin area.

In order to appraise the above-mentioned techniques, a number of technical, economic, and policy related issues need to be assessed. A summary of the specific issues which need to be addressed and an evaluation of the possible management methodologies are presented in Table 6-1**.** GHD notes that based on the outcomes of the teleconference, FRNSW do not consider allowing the pit to refill with water to retain it as a collection pond for future PFAS-impacted runoff an option for this site. However, this option has been retained in Table 6-1 for completeness, as these factors were discussed in the teleconference.

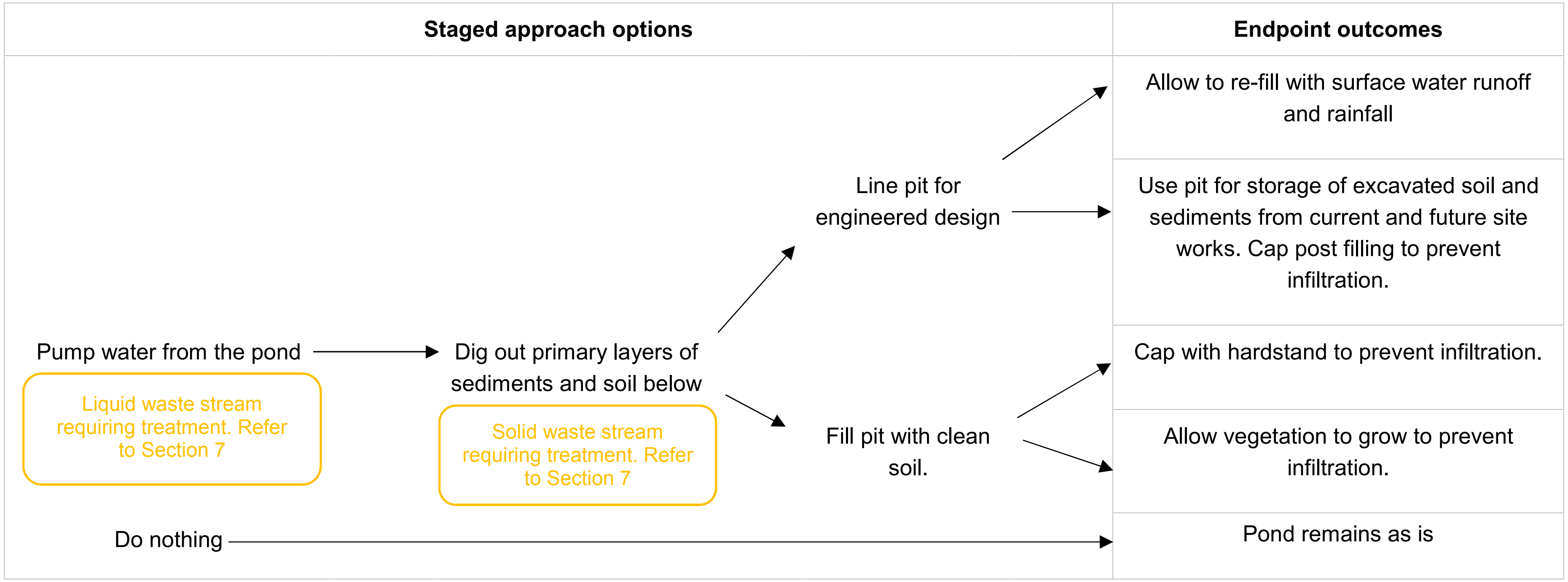


Figure 6-3 Flow chart showing pond option approaches

Table 6-1 Evaluation of improvement options for the retention basin

Issues	Retain as pond	Retain as soil containment cell	Decommission pond and fill with clean soil	Do nothing
Advantages	Once relined, maintains a method of capturing surface water runoff from the hard stand area which may contain PFAS. This water can be regularly removed and treated while contaminated hard stand remains.	Potential for future use of the area for a cap/contain strategy of other PFAS impacted soils and hardstand from the broader site area. Installation of an impermeable barrier above and below impacted soils to fully encapsulate soil and prevent further infiltration of water and subsequent leaching of PFAS to groundwater.	Permanent removal of water (potentially contaminated with PFAS) from this portion of the site. Increased usable ground surface area on the site if capping option is selected. Alternatively, increased ecological support if vegetation is used to decrease infiltration. Installation of an impermeable barrier above impacted soils to prevent further infiltration of water and subsequent leaching of PFAS to groundwater.	No capital cost. No land disturbance on or off site.
Disadvantages	Uncertainty in the concentration of PFAS in surface water run-off. Further ongoing water treatment will be required if potential overflow is considered to contain elevated concentrations. On-going liability and requires site management	On-going liability and requires site management and maintenance Leaves legacy for future owners. This may be less of an issue if FRNSW intend to renew their lease into the future.	Risk of PFAS impacted surface water flows contaminating the new, clean fill over a long period of time. Engineered water design and/or cap recommended to reduce this risk. Stormwater design assessment should be conducted/implemented to address surface water flows from the hard stand area.	Long term risk of PFAS migration to groundwater and via surface water flows to sensitive receptors (human and ecological). Potential for legal and reputational risk for FRNSW.
Capital Costs	Moderate	Moderate	Moderate	None
Ability to meet site improvement goal	Moderate to high. Long timeframe after implementation	Moderate to high	Moderate to high	Low

Issues	Retain as pond	Retain as soil containment cell	Decommission pond and fill with clean soil	Do nothing
On-going Liability *Any system that does not involve the full remediation of all contamination may necessitate some form of ongoing maintenance and/or monitoring to ensure the longer-term integrity of the remediation system adopted*	Moderate – high potential to capture PFAS impacted surface water runoff that would require re-treatment in the future. May require ongoing monitoring of groundwater and surface water to confirm improvement of water quality with time.	Moderate to low – maintaining integrity of the cell. May require ongoing monitoring of groundwater to confirm improvement of water quality with time.	Low – primary PFAS mass in the area removed, with cap to prevent further leaching to groundwater.	High – Primary mass of PFAS remains on-site. Ongoing monitoring of groundwater and surface water required.
Human Health Risk *Works that involve the disturbance of contaminated soils can potentially create health risk concerns to site workers*	Low – Minimal human health risk from PFAS via dermal contact, which is likely to be the primary pathway for construction workers. Accidental ingestion via splashes or residue on skin may present a risk over long term projects. Workers should therefore wear appropriate PPE and ensure washing of hands prior to eating.	Low – Minimal human health risk from PFAS via dermal contact, which is likely to be the primary pathway for construction workers. Accidental ingestion via splashes or residue on skin may present a risk over long term projects. Workers should therefore wear appropriate PPE and ensure washing of hands prior to eating.	Low – Minimal human health risk from PFAS via dermal contact, which is likely to be the primary pathway for construction workers. Accidental ingestion via splashes or residue on skin may present a risk over long term projects. Workers should therefore wear appropriate PPE and ensure washing of hands prior to eating.	Low – No disturbance

Issues	Retain as pond	Retain as soil containment cell	Decommission pond and fill with clean soil	Do nothing
Regulatory Approvals *Any remediation system needs to be endorsed by the relevant regulatory authorities. The difficulty in obtaining regulatory approvals will be largely dependent upon the nature of the remediation system proposed*	Planning approvals likely to be needed for construction works.	Planning approvals likely to be needed for cell construction works.	Planning approvals likely to be needed for construction works. Regulatory approvals needed for importation of fill.	May require justification to the EPA in future for this approach given the monitoring results. Additionally, may require EPA endorsement of a long term monitoring plan.
Site Disruption *Remediation of the site will invariably involve some disturbance to site occupiers/ users*	Low to moderate – construction works required, however foot print is expected to be confined to the retention basin area.	Low to moderate – construction works required, however foot print is expected to be confined to the retention basin area.	Low to moderate – construction works required, however foot print is expected to be confined to the retention basin area.	None
Waste streams	Liquid and solids – require treatment/management as described in Section 7.	Liquid and solids. Treated solids can be placed in cell.	Liquid and solids – require treatment/management as described in Section 7.	None
Timeframe	3 to 6 months to implement	3 to 6 months to implement	3 to 6 months to implement	NA

7. Waste stream options assessment

7.1 High level options assessment

Apart from the “do nothing” option, for the decommissioning of the pond, two waste streams will be produced that require management:

- Liquid – water currently in the pond and water produced from dewatering of the sediment
- Solids – dry product after dewatering sediment and possibly hardstand and other soils.

Management options for PFAS-impacted media have not been well established in terms of successful project completion to a specified endpoint in Australia at the time of preparing this document. Despite this, a high level remedial options assessment was undertaken to assess potential remediation technologies and their applicability to the site. This report is provided in Appendix B. The assessment first considered a large number of remedial options and reviewed them in terms of their likely or proven efficacy for addressing PFAS. This resulted in a short list of methods for further consideration.

The options retained for further consideration which were discussed with FRNSW are listed in Table 2 and 3 of the Options Assessment Report (GHD, 2017c) and are summarised in Table 7-2 with respect to their applicability to the proposed pond improvement works and the identified project goals (refer to Section 6.2). Options were assessed in reference to the parameters described in Remediation Technologies Screening Matrix and Reference Guide, 4th Edition (FRTR, 2002) summarised in Table 7-1.

Table 7-1 Parameters used in Table 7-2 options assessment

Table 7-2 Consideration	Colour	Description
PFAS impacted media	Yes	Directly applicable to target PFAS impact
	Yes	Incidental target of technology
	NA	Not applicable
Reliability – the demonstrated reliability of the treatment	High	High reliability and low maintenance
	Moderate	Moderate reliability and moderate maintenance
	Low	Low reliability and high maintenance
Time – the time typically required to complete site works and/or validate remediation for the selected technology	Short	<1 year for solids or < 3 years for liquids
	Mid-length	1 – 3 years for solids or 3 – 10 years liquids
	Long	>3 years for solids or >10 years for liquids
Cost – relative capital investment, design, construction, and operation and maintenance (to be confirmed in cost benefit analysis)	Low	Low capital investment and/or low operational costs
	Moderate	Average capital investment and/or average operational costs
	High	High capital investment and/or high operational costs

Table 7-2 High level review of waste stream treatment options generated from pond improvement works

Remedial technology	Process options	PFAS impacted media		Reliability	Time	Relative costs	Notable limitations
		Solid	Liquid				
On-site encapsulation	Engineered facility	Yes	NA	High - Depending on design	Short	Low	Regulatory approvals, legacy issue retained
Capping	Clay cap	Yes	NA	Moderate	Short	Low	Susceptible to cracking
	Asphalt or concrete cap	Yes	NA	High	Short	Low	
Biological	Phytoremediation	Yes	Yes	Moderate - theoretically viable, however not yet proven in Australia	Long term	Low	Treatment area required for soils, plants require disposal, may bioaccumulate in food chain although depuration rates are highly variable
Physical- chemical treatment	Soil washing	Yes	NA	Moderate – few trials in Australia. Site specific geology would need to be considered.	Mid-length	High due to limitations	Treated material and water waste stream requires management. High energy demand. Effectiveness would require trials.
	Solidification, stabilisation, sorption, cement, modified clay (CRC Care)	Yes	NA	High – determined by bench scale testing	Short	Moderate	Treated material solid requires management
	Incineration / thermal destruction	Yes	NA	High	Short	High	Treated material requires management, mobile option on-site not likely to be available.

Remedial technology	Process options	PFAS impacted media		Reliability	Time	Relative costs	Notable limitations
		Solid	Liquid				
	Filtration - e.g. activated carbon (granulated or powder), ion exchange resin (IXR)	NA	Yes	High	Short	Moderate to low	Pre-filtering of water may be required. Off-site destruction of GAC or IXR would be required.
	Chemical oxidation	NA	Yes	Theoretically moderate, however not yet proven in Australia	Short	Unknown	OH&S issues associated with oxidant chemicals. Other proven cheaper, effective options available
	Reverse osmosis	NA	Yes	High – based on Queensland water treatment facility	Short	High	Site specific design required, waste stream requires management
Disposal	Truck to a licenced, off-site facility	Yes	NA	High	Short	Moderate depending on licenced facility fees and trucking distance	Least preferable option under remediation hierarchy (Section 2.2)

Refer to Table 7-1 for description of parameters and colour classification.

Technology options based on those identified by the site Options Assessment Report (GHD, 2017c).

GHD recommends that advice for on-site treatment options for water be sought from specialised remediation contractors. Additionally, GHD recommends that a cost benefit analysis be conducted to assess financial implications and value associated with each recommended approach, as well as the overall FRNSW objectives for the site, as outlined in Table 8-2.

7.2 Indicative cost estimates

Indicative costs of various treatment methods are provided in Section 6 of the Options Assessment Report provided in Appendix B. However, GHD recommends that up to date and site specific quotes from remediation and waste contractors are obtained noting that the prices listed in the Options Assessment Report are based on quotes from 2017.

8. Strategy

8.1 Strategy choice

Based on the proposed end use of the site (intended long term use of the site as a training facility, refer to Section 5.3) and overall project goals, GHD believe the most effective strategy to reduce PFAS mass on the site and thereby reduce the risk to local receptors, is to decommission the pond and remove existing PFAS-impacted material. Improvements in the quality of groundwater and surface water are likely to subsequently occur over time.

The preferred approach is to remove the water and treat it followed by excavation of sediment and soil, thence dewatering of sediment and soil to create a dry, solid waste stream. The destination of the solids would be either:

- Encapsulation on-site in an engineered cell (utilising the pond excavation) or
- Off-site disposal to landfill or waste treatment facility licenced to accept PFAS-impacted soils.

A cost benefit analysis would be required to determine if a containment cell or disposal offsite is the more preferable endpoint for excavated solids although the waste hierarchy (outlined in Section 2.2) would suggest off-site disposal to be the least favourable option.

8.2 Role and responsibilities

The main roles and responsibilities of the main stakeholders in this process are summarised in Table 8-1.

Table 8-1 Stakeholder roles and responsibilities

Title	Company/ Organisation	Roles and responsibilities
Proponent	FRNSW	Responsible for engaging the Contractor and Environmental Consultant to complete the works. Review and approving the Construction Environmental Management Plan (CEMP) and other planning pertinent to the improvement works. Providing relevant inductions and access to the site for stakeholders.
Contractor	To be advised	Develop site CEMP. Implement improvement works. Obtain approval from regulators. Responsible for required civil works, including all measures required to protect worker and public health and the environment during the works.
Environmental Consultant	To be advised	Responsible for collection and analysis of validation and characterisation samples, advising FRNSW of appropriate actions on the basis of observations, sampling and analysis and preparing a report at the completion of works.

Title	Company/ Organisation	Roles and responsibilities
Regulator	NSW EPA	Providing planning approvals for the works where required.
Council	Armidale Regional Council	Providing planning approvals for the works where required.
Water Authority	Armidale Regional Council	Providing trade waste agreement and water discharge approvals.
Landowner	NSW State Government	Provide approval for works at the site.

8.3 Implementation plan

Based on the need to decommission the pond and remove PFAS mass, the approach outlined in Table 8-2 is recommended.

Table 8-2 Decommissioning approach

Step	Task / Action	Comments
1 Preliminary tasks	Approvals – NSW EPA, Armidale Regional Council, NSW State Government.	Refer to Section 8.3.2 for further information.
	Stormwater assessment and design	New stormwater design required to address surface flows from site. Refer to Section 8.3.3 for further information.
	Cost benefit analysis	This should be conducted to assess cost and benefits associated with each recommended approach, as well as the overall FRNSW objectives for the site.
	Design of the pond as a soil encapsulation cell (if the preferred option)	Only if chosen as the treatment method for excavated soils. Refer to Section 8.3.6 for further discussion.
	Additional site characterisation sampling	Discussed in Section 8.4.
	Establish Health, Safety and the Environment (HSE) protocols	To be completed upon finalisation of site works being undertaken. Should include developing a CEMP and OH&S Plan.
2 Decommissioning site works	Site establishment	Refer to Section 8.3.4 for further information.

Step	Task / Action	Comments
	Water removal from pond and treatment	Design and method dependent on remediation contractor input. To be confirmed by FRNSW and Remediation Contractor. Refer to Section 8.3.8 for discussion.
	Sediment excavation and dewatering	Design and method dependent on remediation contractor input. To be confirmed by FRNSW and Remediation Contractor. Refer to Section 8.3.4 for further information.
	Soil/ hardstand excavation from pond floor and surrounding areas	Refer to Section 8.3.4 for further information.
	Validation sampling	Refer to section 8.3.7 for further discussion.
3 Filling of pond	Construction of encapsulation cell and stormwater controls as per design plans if preferred option	Refer to Section 8.3.6 for further discussion.
	Fill cell with dewatered sediment, soil and hardstand; or Imported clean fill	
	Import fill for the remainder of volume as required	
	Completion of cell/excavation with impermeable capping and re-instatement of hard stand area as required	
4 Ongoing maintenance and monitoring and	Maintenance of capping layer	Refer to Section 8.3.9 for further discussion.
	Monitoring of groundwater and surface water around this area to confirm improvement works have met the intended goal.	Refer to Section 8.3.9 for further discussion.
5. Further site considerations	Additional pond treatment works and close out of CSM linkages	Refer to Section 8.4 for further considerations.

8.3.1 Basis of future assessment

The assessment criteria for PFAS are noted to have changed since the DSI assessments were undertaken prior to the release of the PFAS NEMP in January 2018. Additionally, GHD notes that the *Australian Drinking Water Guidelines (ADWG) 6* (NHMRC, 2011) were updated to version 3.5 in August 2018, to amend screening criteria for some existing analytes and to include criteria for the sum of PFOS+PFHxS and PFOA. The screening values provided by NHMRC (2011, updated 2018) are the same as those provided in the PFAS NEMP. Therefore future assessment results will be assessed against a different set of guidelines than those used in the DSI reports.

Environmental assessment

A number of human and ecological receptors were identified in the CSM, as outlined in Section 4. If any further site assessment is conducted, the new environmental site assessment results should be compared to screening values provided by the PFAS NEMP for land uses/receptors applicable to the sample location and sample matrix being assessed.

Site improvement works

The ASC NEPM (Schedule B1) notes that investigation and screening levels are not clean-up or response levels, and the use of investigation and screening levels as default remediation criteria may result in unnecessary remediation and increased development costs, unnecessary disturbance to the site and local environment, and potential waste of valuable landfill space. The goal of the planned pond improvement works is not to 'clean-up' the area to a given assessment criterion, or to 'chase out' any identified PFAS impact in either the horizontal or lateral directions. Rather, it is to remove PFAS mass from the environment to prevent further impact.

Results from samples collected as part of the improvement/validation works (Section 8.3.7) are intended to provide an overview of the conditions around and beneath the cell for future reference. Therefore, no specific assessment criteria are recommended for the excavation works. However, trends in groundwater PFAS levels will be assessed over time to confirm the improvement of groundwater quality. They will also be recovered to assess whether the level of risk from PFAS changes over time.

If water is to be disposed of to sewer or stormwater post treatment by a Remediation Contractor, samples should be assessed against disposal criteria as outlined in the disposal agreement between Armidale Regional Council and FRNSW.

Waste classification (if required)

In the event that waste soils produced during remediation of the site are required to be disposed from the site, classification will be carried out in accordance with the requirements and screening criteria detailed in the PFAS NEMP (for PFAS compounds) and NSW EPA (2014) *Waste Classification Guidelines, Part 1: Classifying Waste* for other contaminants regulated by the NSW EPA.

8.3.2 Approvals and planning

The required approvals for this project should be confirmed prior to starting site works.

Landowner consent from NSW State Government will be required prior to lodgement of the development application, given that the site is leased from the NSW State Government. Additionally, a development approval will be required from Council for the improvement works before any works can commence on-site.

Following award of the waste treatment contract, prior to commencement of works and once the development application is granted, all other relevant licences and consent for works shall be obtained by a Contractor engaged to conduct the improvement works from the relevant authorities. This may include:

- Armidale Regional Council if it is proposed to dispose of the treated waste water to sewer or stormwater.
- EPA and NSW State Government if a containment cell is to be built on-site.
- NSW EPA if PFAS impacted soils are to be disposed of to landfill (as per NEMP, 2018).

Other than the development approval and land access agreement, the Contractor should be responsible for identifying all other permitting requirements and arrange for the necessary issue of permits for the relevant site personnel, as well as ensure that all site personnel adhere to the relevant permitting requirements.

A CEMP should be developed by the contractor for the works, which should generally include the following:

- An un-expected finds protocol, including the potential discovery of asbestos;
- Uncovering unidentified underground services/structures;
- Assignment of responsibilities to nominated key personnel;
- Hazard assessment of potential off-site impacts;
- Reporting to regulatory authorities; and
- Unexpected situations such as:
  – Generation of unacceptable dust or vapours;
  – Generation of unacceptable noise;
  – Uncovering significant quantities of friable asbestos contaminating material; and
  – Remedial works taking longer than planned.

8.3.3 Stormwater assessment

A preliminary stormwater assessment would be required in advance of any mobilisation and improvement works to confirm that there will not be any potential issues with decommissioning the pond from a stormwater control perspective.

If certain stormwater volume or stormwater quality issues are identified by the preliminary assessment, an adequate stormwater design for the area may be required.

8.3.4 Site establishment

Site establishment will require, but is not limited to, the following:

- Establishing access to, from and within the site;
- Setup of site compound, welfare facilities for site workers, and a vehicle wash-down area;
- Security fencing around work area (where applicable);
- Appropriate warning signs related to construction and hazardous waste;
- Identification and clearance of buried or overhead services;
- Management of stormwater and sediment runoff from the construction areas;
- Setup of suitable waste management areas including dewatering area and stockpile area;

- Establishment of dust control measures (if required); and
- Any other items identified in the CEMP, permits or management plans for the planned work.

8.3.5 Earthworks

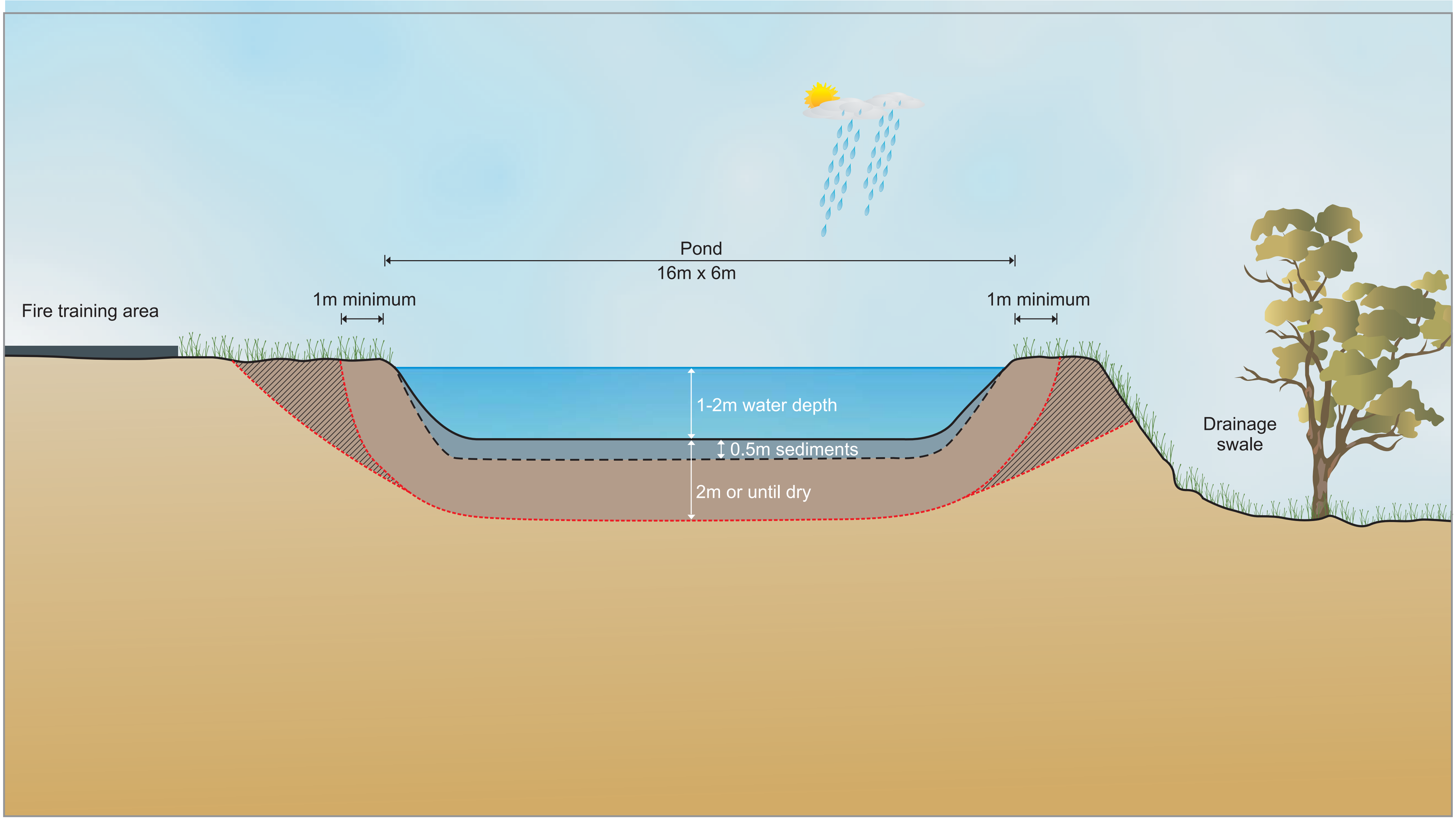
Earthworks should be staged to consider the following:

- Subsurface and above-ground services – conduct 'Dial Before You Dig' online search, and have services in the planned excavation area located using a professional service locator;
- Excavation shoring and/or battering – required on all excavations greater than 1.5 m below ground surface by Safe Work Australia (2012) unless professional geotechnical advice states otherwise;
- Excavation of material – refer to subsections below;
- Ex situ stockpiling of contaminated soils – refer to subsections below; and
- Site reinstatement– refer to Section 8.3.6.

Excavation footprint

The surface area of the pond is approximately 96 m^2. Sediments are assumed to extend approximately 0.5 m below the base of the pond (as outlined in the Options Assessment Report, Appendix B) with approximately 1 to 2 m of water above. A rough schematic diagram is shown in Figure 8-1.

GHD proposes that soils are excavated at least 1 m laterally from the edge of the pond, and at least 2 m from the base of the pond (including the assumed sediment layer) or until soils become dry in both the horizontal and lateral directions (whichever occurs first), as shown in Figure 8-1. These distances are based on the goal of removing the mass of PFAS associated with this pond (assumed to be the water component and shallow soils) and minimising waste volumes generated. However, consideration will be given to slope stability when finalising the final extent of excavation and it shall be the contractors responsibility to ensure that the excavation remains stable at all times.



Conceptual diagram only - not to scale

LEGEND

Excavation

Area may need to be excavated depending on slope stability / final depth

Fire & Rescue NSW
Armidale Training Centre

Conceptual Site Model

Job Number	21-27877
Revision	A
Date	5 Feb 2019

Figure 8-1

GHD\Launceston\Projects\21\27877\2127877_LTN_02.cdr

Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com

Based on the excavation dimensions and pond volume range outlined above, the following has been calculated:

- The volume of soil and sediment in-situ to be excavated is approximately 336 m^3 to 384 m^3.
- Based on the sandy clay/gravelly clay profile encountered in this area during the DSI, bulking factors between 20% and 60% are possible (Engineering ToolBox, 2009), which results in an ex-situ volume range of approximately 460 m^3 to 615 m^3 based on the maximum in-situ volume calculated above.

The closest groundwater monitoring location is MW01, located approximately 10 m to the west of the pond. In June 2017, the groundwater at this location was measured to be 13.9 m below top of casing (m bTOC). It is therefore assumed that groundwater is unlikely to impact excavation works at this site given the proposed depth of excavation outlined above.

Any water entering the excavation via seepage or as rainfall would require treatment as for the main volume of pond water. Considering the depth of groundwater, the total volume of seepage water is unlikely to be large. Water entering the excavation could be pumped out and stored on-site for treatment by the remediation contractor if it is not viable for the water treatment plant to remain on-site for the duration of the excavation works.

Material stockpiling and tracking

The edge of the hardstand area may be encountered as part of the excavation works depending on final depth and slope stability. This material will require either different disposal compared to the soils beneath or encapsulation in a containment cell. The hard stand material should therefore be broken up and stockpiled separately to the soils.

Soils and hardstand stockpiles should be assumed to contain PFAS, which is leachable from the soils in water. Stockpiles therefore need to be placed on a sealed surface such as high density plastic sheeting (HDPE). HDPE sheets should be used to cover the stockpiles overnight and during periods of rainfall. The covering HDPE can be secured using sand-bags. The Contractor should also ensure that the stockpiles are not left on-site for any significant length of time.

Other considerations for stockpiling of material includes:

- If necessary, stockpiles should be bunded with sediment control barriers to mitigate runoff from the stockpile to surrounding areas.
- Stockpiles should not be placed within or immediately adjacent to drainage lines, easements, footpaths, roadways, existing stormwater drains or steep slopes.
- Stockpiles should be positioned and formed to minimise potential for stockpile erosion where possible.

Stockpiles shall be designated and clearly labelled to ensure that the soil materials are properly tracked and classified as excavation progresses to avoid mixing of different classes of waste or materials for re-use on-site.

If required, any transport of material off-site for disposal requires waste classification as per the guidelines outlined in Section 8.3.1. This is likely to involve sampling and analysis of the material to be disposed of. Additionally, adequate waste transfer dockets should be obtained as a record of transport and receipt of the waste at an appropriately licenced facility.

8.3.6 Cell design and site reinstatement

If the cost benefit analysis indicates a containment cell is a viable option, then once excavations have been completed to the required depths, and following validation of the excavations, a containment cell should be constructed within the excavation. The design of this should be done by an experienced waste management consultant to meet the following criteria (at a minimum):

- The volume of the cell should be large enough to hold all excavated solid material. Further assessment on compaction of the material within the cell will be required to determine the final re-instated volume of material.
- The cell must be impermeable and include an impermeable capping layer.
- A marker layer should be included as part of the cap design to prevent any future site works from disturbing or accidentally damaging the cell.
- Consider 'best practice' notes outlined in the NEMP for on-site containment.

It is noted there are currently no NSW approved regulations detailing the requirements for on-site containment of PFAS waste. However, it is envisaged that an approval process will be needed on a site-specific basis.

The construction of the cell should be 'construction quality assessed (CQA)'.

Following completion of cell construction, the cell can be filled with the stockpiled material.

If the compacted volume of excavated material is less than the overall excavation, additional clean fill can be imported to the site to raise the cell to ground surface.

8.3.7 Validation

Validation sampling and assessment will be undertaken by an environmental consultant to demonstrate that the improvement goals have been achieved, and the site is returned to a standard that is suitable for the proposed commercial/industrial land use.

As a minimum, this should include:

- Sampling of the following:
  - Soils from the base of the excavation to assess the soil concentrations remaining in situ beneath the cell;
  - Treated wastewater from the remediation contractor's treatment plant to confirm that the treated wastewater has met the disposal criteria;
  - Soils imported onto the site for fill;
  - Soils requiring off-site disposal to landfill or reinstatement in an engineered cell.
- A validation report, including;
  - Information on the extent of excavation works undertaken;
  - The condition of soils at the extent (sides and base) of the excavation;
  - The classification of any excess soils that require off-site disposal at landfill;
  - The condition of any imported soil used as backfill at the site.

It should be noted that the proposed validation sampling programme is based on our current understanding of the site and that it may be modified during the detailed design stage or during the works as site conditions require. Validation testing of the treated soils may also be required depending on the treatment technology selected for the site by FRNSW and the Remediation Contractor.

The Remediation Contractor will need to select appropriate treatment technology(s) that will achieve any specific performance criteria (eg. Disposal to sewer criteria) and meet the site improvement goals presented in this site improvement plan.

A validation sampling plan should be developed by the environmental consultant once site improvement plans have been finalised, to confirm the number and frequency of samples required.

8.3.8 Waste streams

As shown in Figure 6-3, two waste streams will be generated as part of the pond improvement works:

- A liquid waste stream from dewatering the pond and sediments;
- A solid waste stream from the excavated sediments and soils.

Based on the review of available PFAS impacted waste treatment options outlined in Section 7, it is likely that waste water will be treated on-site by a Remediation Contractor using an appropriate filter (most likely granulated activated carbon filters- GAC), however this is to be confirmed by the chosen remediation contractor.

Discussion for on-site encapsulation in a containment cell has been provided in Section 8.3.6 as a method of managing the solid waste stream. However, GHD recommends that the preferred management approach be confirmed by a cost benefit analysis, as outlined in Table 8-2.

8.3.9 Monitoring and long term management

The capping layer of the containment cell should be maintained to ensure that it remains impermeable.

Additionally, signage should be installed around the cell area to ensure that future earthworks are not conducted that could compromise the integrity of the cell. Consideration should be given in regards to the need for inclusion of any containment cell on the property title to ensure that it remains intact with new site owners/tenants, should the land be sold or re-leased in the future.

Post completion of the pond improvement works, surface water down gradient of the pond should be assessed following rainfall periods to determine if there is decrease in PFAS concentrations. Additionally, groundwater wells adjacent and down gradient of the pond should be monitored on an annual basis to confirm if a decreasing trend is also apparent in groundwater.

Post-improvement monitoring would be detailed in a site monitoring plan. The plan would contain appropriate assessment criteria to assess changes in risks to various media and contingencies to address any changes in risk.

8.4 Further considerations

A number of additional opportunities have been identified for FRNSW that could be done in conjunction with the pond improvement works:

1. **Additional surface water treatment**

While a mobile water treatment plant is on-site, FRNSW could make use of the facility to de-water the other surface water ponds and dams identified both on and off site which also contain PFAS (refer to Figure 2, Appendix A). This would save FRNSW additional mobilisation costs should they want to treat all potential sources of PFAS impacted water. Such an approach would provide further means of improving surface water quality for neighbouring properties downgradient of the site. However a detailed cost benefit analysis is recommended, including consideration of the volume of PFAS mass which would be removed from the other surface water bodies. It is recommended that additional sampling data is obtained from the surface water bodies to provide current data to feed into this cost benefit analysis.

It is noted that dewatering will not solve the issue entirely, as the sediments/soils in the ponds can act as an ongoing sources of PFAS to water (hence the proposed excavation works for the primary retention pond).

2. **Close out identified data gaps**

A number of complete and possibly complete S-P-R linkages were identified for the site, as shown in Table 4-1. The DSI works indicated that PFAS contamination exists both on-site and off site, with the primary mode of transport identified to be via surface water. Improving the primary retention pond will address some of the pathways by removing a key source of PFAS at the site, however there is some evidence to suggest groundwater migration is also occurring with possible receptors down gradient.

Whilst the focus of this site improvement plan is on the management of PFAS associated with the primary on-site water body, data gaps associated with the broader site investigation works are outlined in Table 4-2, with associated discussion on further actions that could be conducted to address the identified data gap.

3. **Potential option to reduce intergenerational issues**

The use of on-site encapsulation will lead to long term storage of PFAS-impacted soil on-site. This creates a potential long-term intergenerational issue as the PFAS will not be remediated and may become a concern for future generations. However, the cell design could be modified or retro-fitted to act as a remediation cell. In this scenario, water is infiltrated into the cell to enhance desorption of PFAS from the soil into a leachate that could be gradually recovered and treated at the surface. This would eventually reduce PFAS levels in soil to less than laboratory LOR thereby allowing the soil or the area to be re-used in the future. Such a design might include:

- Sloping the floor of the cell to allow capture of any liquids at a designated collection point.
- Installation of recovery wells to recover leachate for surface treatment.
- Installation of an infiltration array to inject water (the system might also be able to rely somewhat on natural infiltration of rainwater).
- Installation of an above-ground leachate treatment system (potentially solar powered).
- Validation of the soil could occur when leachate PFAS levels have declined in the recovered water to below laboratory LOR or appropriate clean up level.

9. References

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GHD (2018) Armidale tourist Park – Private bore sampling results. Letter dated 09 May 2018.

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NSW EPA 2017 Contaminated Land Management – Guidelines for the NSW Site Auditor Scheme (3rd Edition).

NSW OEH. (2011). Guidelines for consultants reporting on contaminated sites. Sydney: NSW Office of Environment and Heritage.

Safe Work Australia 2012. Excavation Work Code of Practice, July 2012.

10. Limitations

This report: has been prepared by GHD for Fire & Rescue NSW and *may only be used and relied on by Fire & Rescue NSW for the purpose agreed between GHD and the Fire & Rescue NSW as set out in section 1 of this report.*

GHD otherwise disclaims responsibility to any person other than Fire & Rescue NSW arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Fire & Rescue NSW and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared preliminary cost estimate/prices using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD.

The Cost Estimate has been prepared for the purpose of providing a basis for FRNSW to decided on possible future actions *and must not be used for any other purpose.*

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the pond improvement works *can or will be undertaken at a cost which is the same or less than the Cost Estimate.*

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

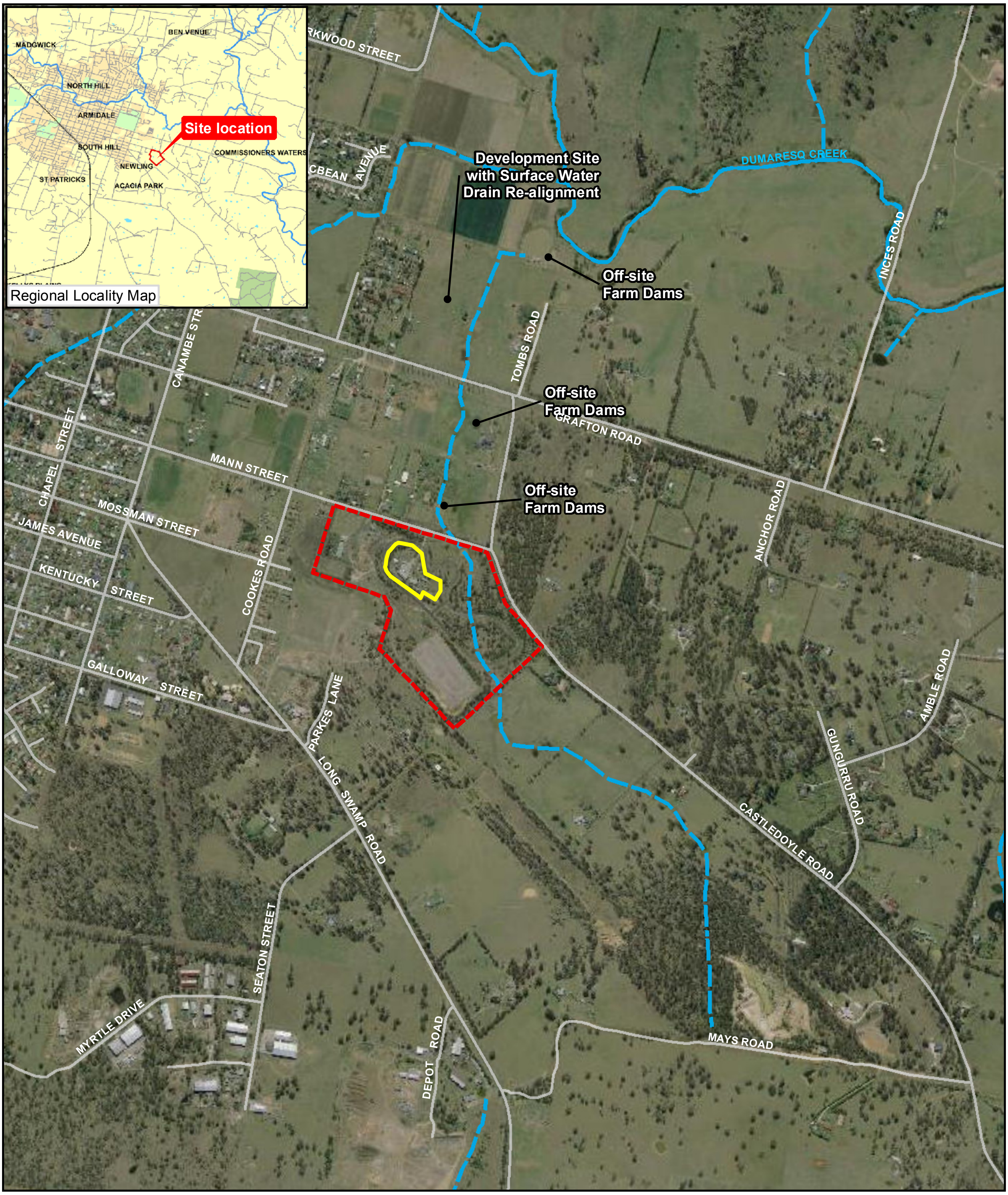
The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Appendices

Appendix A – Figures



LEGEND

- FR NSW Site
- Wider Training Facility
- Streets
- Major Waterways
- Minor Waterways

Paper Size A4

0 50 100 200 300 400 500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Fire & Rescue NSW
Armidale Site Investigation

Job Number | 21-25583
Revision | A
Date | 15 Feb 2017

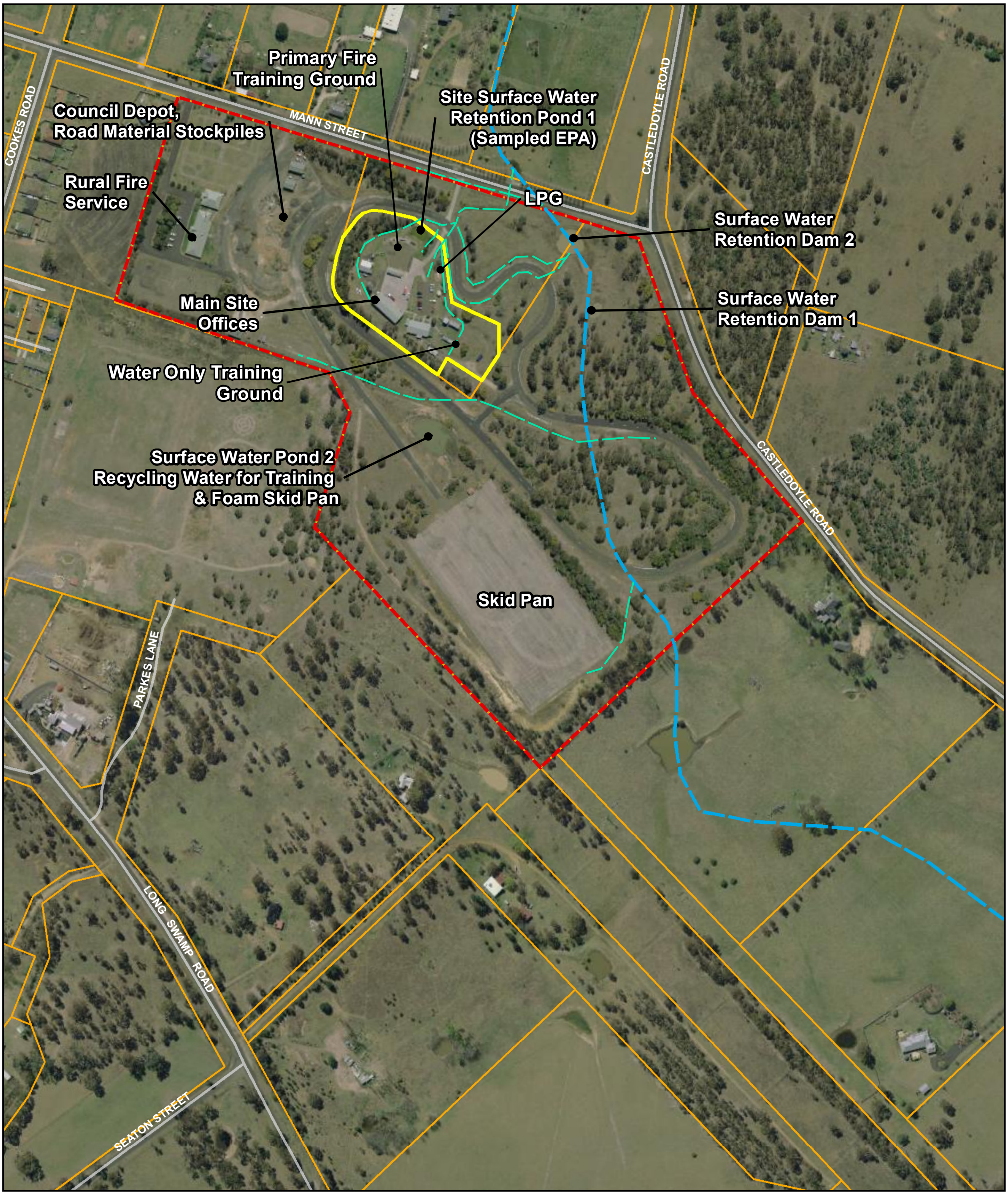
Site Location and Key Off-site Receptors

Figure 1

G:\21\25583\GIS\Maps\Deliverables\Armidale\21_25583_Z001_Armidale_SiteLocation.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Imagery - ©Land and Property Information (Extracted: 15/02/17); Streets, Waterways - NSW LPI 2015 DTDB. Created by:mweber



LEGEND

- FR NSW Site
- Wider Training Facility
- Cadastre
- Streets
- Major Waterways
- Minor Waterways
- Inferred Surface Drainage

Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Fire & Rescue NSW
Armidale Site Investigation

Job Number 21-25583
Revision A
Date 15 Feb 2019

Site Layout

Figure 2

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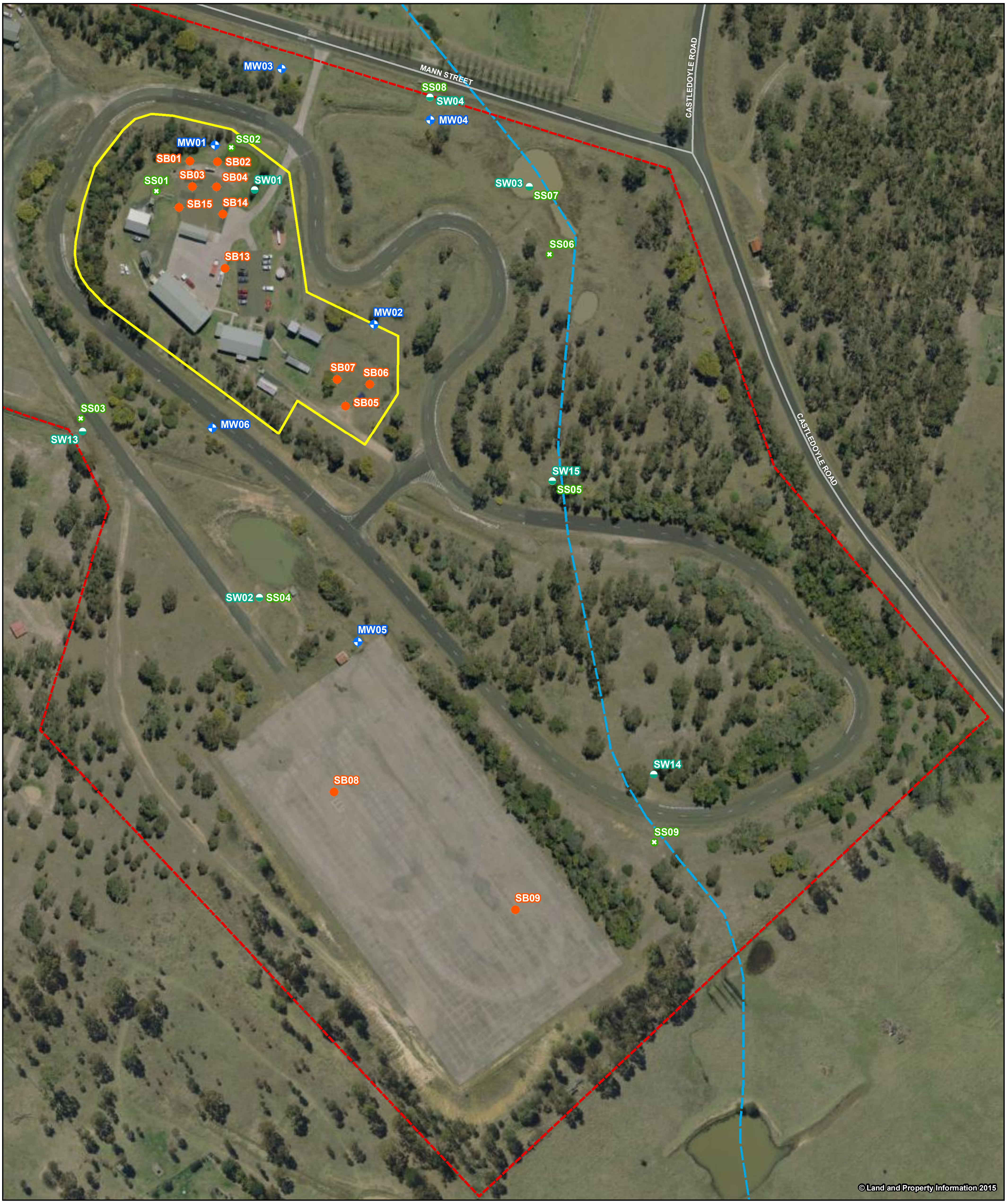
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Imagery - ©Land and Property Information (Extracted: 15/02/19); Streets, Waterways - NSW LPI 2015 DTDB. Created by:kqvelasco



LEGEND

- FR NSW Site
- Wider Training Facility
- Streets
- Major Waterways
- Minor Waterways
- Groundwater Monitoring Well (GHD, 2016)
- Existing Private Groundwater Well
- Soil Borehole (GHD, 2016)
- Sediment Sample Location (GHD, 2016)
- Surface Water Sample Location (GHD, 2016)

0 10 20 30 40 50
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Fire & Rescue NSW
Armidale Site Investigation

Job Number 21-25583
Revision A
Date 17 Oct 2017

Investigation Locations (Within the Wider Training Facility)

Figure 3A

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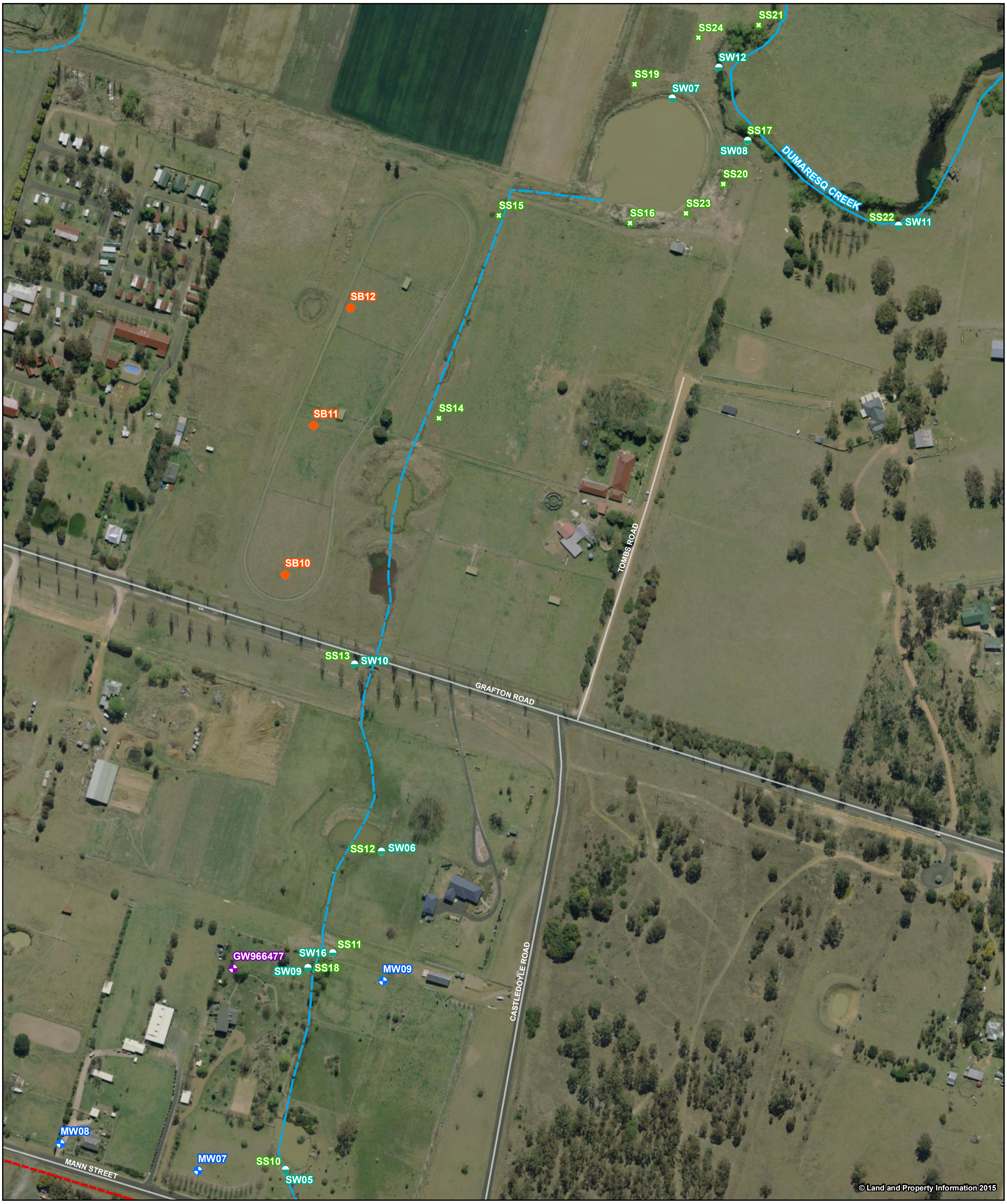
Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Data source: Imagery - Google Earth Pro; Streets, Waterways - NSW LPI 2012 DTDB. Created by:fcheong



LEGEND

- FR NSW Site
- Wider Training Facility
- Streets
- Major Waterways
- Minor Waterways
- Inferred Surface Drainage
- Groundwater Monitoring Well (GHD, 2016)
- Existing Private Groundwater Well
- Soil Borehole (GHD, 2016)
- Sediment Sample Location (GHD, 2016)
- Surface Water Sample Location (GHD, 2016)

0 20 40 60 80 100
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Fire & Rescue NSW
Armidale Site Investigation

Job Number	21-25583
Revision	A
Date	17 Oct 2017

Investigation Locations (Outside the Wider Training Facility)

Figure 3B

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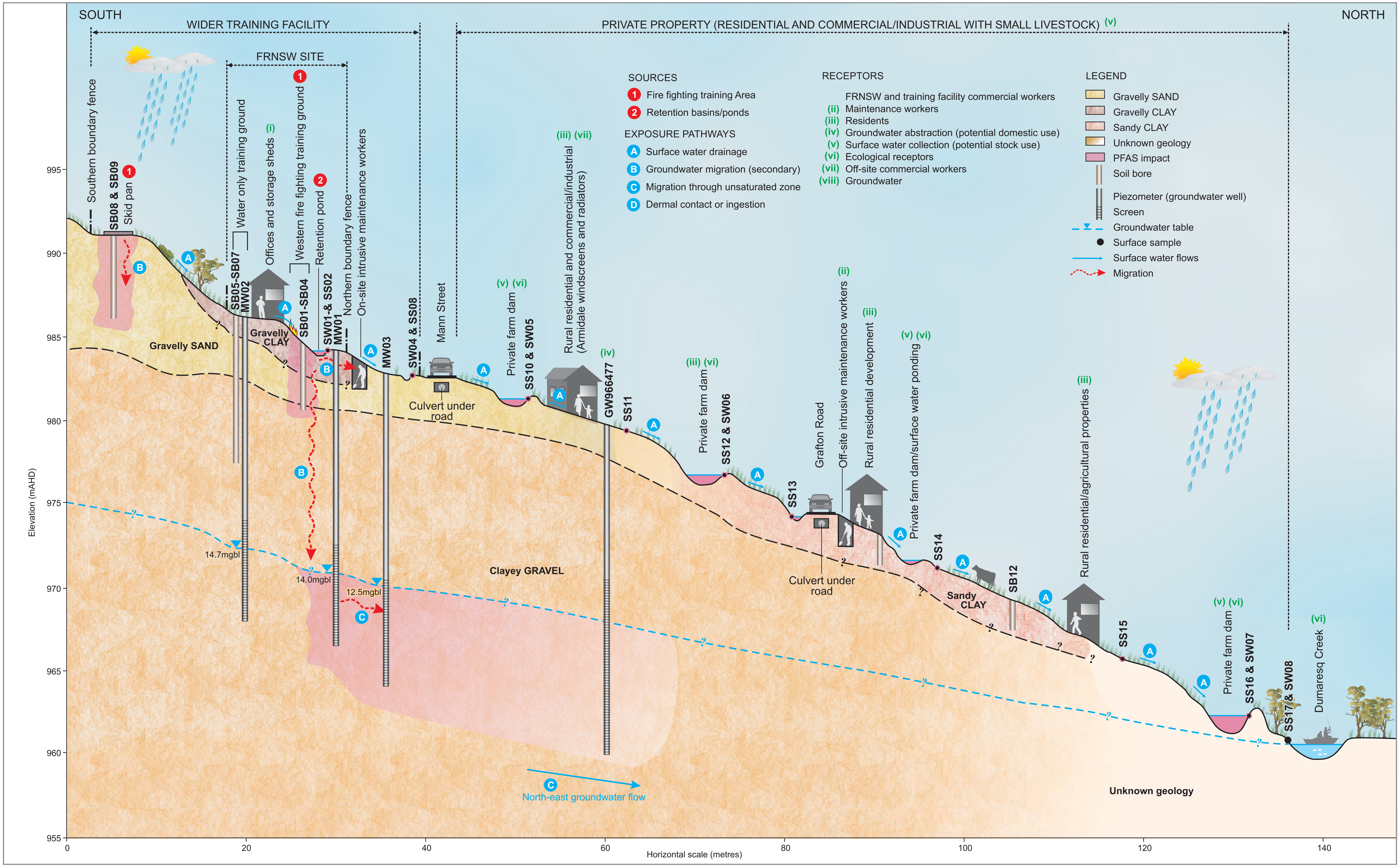
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Imagery - Google Earth Pro; Streets, Waterways - NSW LPI 2012 DTDB. Created by:fcheong



LEGEND

Gravelly SAND
Gravelly CLAY
Sandy CLAY
Unknown geology
PFAS impact
Soil bore
Piezometer (groundwater well)
Screen
Groundwater table
Surface sample
Surface water flows
Migration

Conceptual diagram only - not to scale

Fire & Rescue NSW
Armidale Training Centre

Revised Conceptual Site Model

Job Number	21-25583
Revision	A
Date	31 Mar 2017

Figure 4

GHD\Launceston\Projects\21\25583\2125583_LTN_07.cdr

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com W www.ghd.com

Appendix B – GHD Options Assessment Report

20 December 2017

Melanie Stutchbury
Senior Project Officer
Fire & Rescue NSW
1 Amarina Ave
Greenacre NSW 2190

Our ref: 21/25583 221171
Your ref:

Dear Melanie

Armidale Training Facility
PFAS Management Options Assessment

1 Introduction

Fire and Rescue NSW (FRNSW) engaged GHD Pty Ltd (GHD) to undertake a management options assessment (MOA) for the FRNSW Armidale site, located at 2-16 Mann Street Armidale, NSW 2350 (the 'site'). The MOA was required to provide a discussion document for a remediation workshop to be held in Sydney in 2018.

The MOA was in response to identified contamination from per- and poly-fluorinated alkyl substances (PFAS) which were derived from the former use of specific aqueous film forming foams (AFFF) at the site.

2 Purpose

The purpose of this report is to provide FRNSW with an understanding of the potential management options to address onsite and offsite contamination of soil, groundwater and surface water.

The document first summarises the site setting and constraints, potential remedial/management options and then some suggested management scenarios for discussion. Approximate, ball park costs for aspects of the remediation are included for the purpose of preliminary budget planning. Owing to the nature of this emerging issue, management options and remedial technologies are continually under review and the costs provided in this report should be treated as provisional items for the purpose of budget estimates only.

3 Approach

The approach used to develop the MOA comprised:

- Assessment of the results of previous investigations at the site;
- A data gap analysis to identify where further data might be needed;
- A qualitative risk assessment to inform the level of remediation required;
- Assessment of the volumes and extents of contamination;

- A remediation options assessment to select the most suitable remedial and/or management technology to address the contamination issues;
- Selection of remediation and or management options for discussion.

3.1 Previous analytical results

A preliminary site investigation (PSI) was undertaken by GHD in 2016 to identify potential sources of contamination and areas of potential concern and develop a sampling and analytical plan for further intrusive investigations on the site. The findings of the PSI are reported in:

- GHD (2016) *Fire & Rescue NSW, Armidale PFAS Investigation, Preliminary Site Investigation and Sampling and Analysis Quality Plan*. August 2016 (the PSI).

Following the PSI, an environmental site assessment (ESA) was undertaken by GHD in 2016. The aim of the investigation was to characterised impacts from PFAS on the site and the surrounding environment. The findings of the ESA are reported in:

- GHD (2017a) *Fire & Rescue NSW, Armidale Fire Training Facility, Environmental Site Assessment*. April 2017.

A further ESA was undertaken in May 2017. The findings of the May 2017 ESA are reported in:

- GHD (2017b) *Fire & Rescue NSW, Armidale Fire Training Facility, Phase 2 Environmental Site Assessment - PFAS.* October 2017.

The results of the two ESAs included:

- The inferred groundwater flow was in a northerly direction. Groundwater depths range from approximately 9 m to 27 mTOC.
- Groundwater was fresh to slightly brackish
- All soil PFAS results were low and below the nominated screening criteria. The highest PFAS concentration in soil was reported in shallow soils at onsite location SB15_0.0-0.1 (total PFAS concentration of 0.0749 mg/kg).
- Soil samples recovered from offsite monitoring well locations MW07 to MW09 reported PFAS below the laboratory limit of reporting (LOR).
- The highest concentration of PFAS was in the concrete sample collected from SB09 on the skid pan in the wider training area (0.406 mg/kg – WA DER sum of total). However, the concentration of PFAS in soil 0.9 m below this point, was at least an order of magnitude lower for all PFAS analytes (total PFAS 0.0025 mg/kg).
- Concentrations of PFAS in sediments were low and generally below or close to the laboratory LOR. Offsite sediment samples exceeded the OEH / NSW Health 2017 Residential off-site criteria at five locations and the Soil Indirect – Agricultural Land, residential and parkland offsite criteria at four locations. The highest concentrations of PFAS (sum of total) was located at off-site sampling location SS11 (0.119 mg/kg). The sample was collected off-site and within a dam on a private property.

- There are no applicable screening criteria for samples classified as ‘sediments’ (SS17, SS21 and SS22) which were collected from Dumaresq Creek. However, each of these locations reported concentrations of PFAS (sum of total) above the laboratory LOR, potentially representing an on-going source of PFAS to nearby surface water receptors.
- Groundwater PFAS exceeded the adopted drinking water, recreational water and freshwater ecological guidelines in three well onsite and the drinking water guideline in two wells immediately north of the site. Surface water samples also exceeded the same guidelines both onsite and offsite.
- PFAS was detected above the laboratory LOR and drinking water guideline in a private bore to the north of the site. The extent of the groundwater plume down gradient of the site is not fully delineated.
- The western training area on the Armidale site (including the soils and associated retention basin) is considered the likely primary source of PFAS impact, which is migrating off-site to residential/commercial properties as well as to the local groundwater.

3.2 Site setting and constraints

The main features of the Armidale site setting and their relevance to determining appropriate management options are provided in Table 1

Table 1 Site setting and contaminant issues

Aspect	Summary	Issues
Site location	Located in a largely semi-rural setting surrounded by agricultural and residential land. The property is owned by Armidale Dumaresq Council and used for a number of purposed including the Armidale traffic education centre’ and the NSW Rural Fire Service. A portion of the property is currently leased by FRNSW for use as a firefighting training facility, but it is understood that FRNSW also uses other portions of the wider training facility.	Located in an area of multiple land uses. Land ownership obligations may be impacted by PFAS contamination
Geology and hydrogeology	The site is underlain by Carboniferous Sandon Beds consisting of greywacke, argillite, chert, jasper and basic volcanics. Groundwater is likely to flow northwards towards Dumaresq Creek. Groundwater salinity is fresh to slightly brackish. There is one registered groundwater bore within 500 m of the site and it is considered potentially downgradient of the site. This bore is registered for stock watering.	Groundwater flow will be controlled by fractures in the underlying geology and yields may be limited. Salinity is a significant controller of PFAS solubility and therefore, fate and transport. Groundwater is used downgradient of the site and has been shown to be impacted by PFAS.

Aspect	Summary	Issues
Hydrology	The closest surface water body is Dumaresq Creek, located approximately 1 km away to the north of the site. There are several drainage lines through the wider training facility. Surface water flows off the site to the north via a surface drain. The drain has three retention dams along its course. The dam located near the skid pad uses captured water for training purposes and is recycled back into the dam. The drainage line eventually drains to a large offsite dam adjacent to Dumaresq Creek. When overflowing, the dam would likely drain into Dumaresq Creek, approximately 900 metres north of the site	Surface drains may be a significant migration pathway offsite
Contaminants of concern	PFAS – notably PFOS, PFHxS, PFOA. Identified in soil, sediment, groundwater and surface water onsite and offsite. Water soluble, can sorb to soil and sediments, leachable, resistant to degradation, possibly toxic to animals and humans, bioaccumulate in the food chain, long half-lives in humans and high adverse profile in the media.	The physico-chemical characteristics of PFAS make these chemicals very hard to remove from the environment and to destroy. PFAS has been released to the environment and therefore plants, animals and human have the potential to become exposed to PFAS. PFOS_PFHXS exceed screening criteria in surface water and groundwater. PFAS have received very negative reporting in the media and have a high perception of risk to the community.
Contaminant sources	AFFF products containing PFAS are no longer used on the site so no primary sources exist. Significant secondary sources of PFAS contamination include the retention ponds and surface water/sediments in drains onsite and offsite. The highest PFAS in groundwater was found in onsite well MW03 which is adjacent to the northern boundary of the site. PFAS is generally higher in the retention ponds onsite and dams offsite than in groundwater. The highest PFAs was reported in a surface water retention pond adjacent to the fire training ground.	The site remains a potential source of PFAS contamination to offsite receptors. A significant mas of PFAS has migrated from the site via surface drains and possibly via groundwater flow.

Aspect	Summary	Issues
Contaminant fate and transport	PFAS can leach from soil into groundwater and migrate offsite. PFAS can migrate offsite in drains. PFAS may partition to sediments upon contact with more saline surface water. Dissolved PFAS can be taken up by plants. Smaller PFAS molecules are more soluble and less able to sorb to organic material than larger molecules. Potential receptors include extractive use, terrestrial biotas and aquatic biota in Dumaresq Creek.	PFAS can migrate considerable distances in groundwater although this is restricted by hydraulic gradients and permeability. Permeability in the fractured rock aquifer may be low. Groundwater will discharge into Dumaresq Creek where concentrations of PFAS will be diluted. Migration via drains may be more significant that in groundwater.
Regulatory constraints	Currently no accepted waste disposal criteria for PFAS Screening criteria for ecological receptors tend to be very low. The criteria protective of human consumption of impacted biota is generally below laboratory LORs.	Offsite disposal to a landfill is not a currently available option. Offsite disposal to a treatment facility is a potential option
Remedial constraints	PFAS can be destroyed thermally but at very high temperatures i.e. >1400ºC. Many other technologies have been tested at bench scale but not full scale. There are method that can remove PFAS from water including filtration methods and reverse osmosis.	Remedial methods are not well established and may be cost-prohibitive if volumes of water and/or soil are large. Options are discussed further in Section 5.

3.3 Summary

The information presented above indicated that the site is a likely source of offsite PFAS contamination. PFAS contamination in surface water ponds onsite and dams offsite are higher than in groundwater.

4 Management drivers

Based on the data set, there appears to be a risk to offsite ecological receptors and potentially human recreational users of Dumaresq Creek and from extractive use of groundwater. The presence of PFAS in offsite media also poses a potential reputational risk for FRNSW.

GHD concludes that:

- Impacted PFAS sources include the retention dams and sediment onsite. Surface water and sediment are also impacted in drains offsite. The extent of soil contamination has not been systematically assessed. PFAS is also present in sediment and water from Dumaresq Creek.
- Groundwater contamination appears to have extended offsite and has impacted an extractive bore to the north of the site.

- PFAS in surface water, including Dumaresq Creek, is available to terrestrial biota and aquatic biota and to humans consuming tainted biota.
- The main driver for management is the immediate prevention of any further migration of PFAS from onsite sources to the offsite environment.
- Addressing the main source of PFAS contamination onsite (the retention ponds) should be a priority to achieve this outcome.

5 Management options approach

The options discussed below do not necessarily address all contamination but rather provide a means of mitigating further impact through a combination of source reduction and isolation of the contamination.

Management options discussed below are subject to further site investigations.

The main approaches are:

- PFAS mass reduction through destruction, isolation or removal; or
- Control of migration through interception or isolation; or
- A combination of the two.

5.1 Soil

It is likely that PFAS contamination is present over most of the site, albeit a low concentrations. The PFAS onsite does not represent a significant risk to human health based on a commercial/industrial setting. Therefore, physical removal of all this soil is not considered a practicable immediate response or commensurate with the risks posed by the soil.

Potential management options for the site's soils include:

- Further assessment of the extent of soil contamination
- Maintenance of any hardstand area to restrict rainwater access to the subsoil and to prevent runoff from impacted hardstand. This might involve resealing or further capping with concrete of asphalt. This would reduce the impact risk of mass migration to the groundwater.
- Targeted excavation of the soils with the highest PFAS concentrations followed by either:
  - Offsite disposal to an appropriately licenced facility for destruction
  - Onsite encapsulation in an engineered facility
  - Onsite treatment with a stabilising agent.

In case the regulatory authority require more active remediation of soil, a contingency approach has been included in Section 5.4.

5.2 Groundwater

The extent of PFAS in groundwater offsite is not fully delineated and therefore the magnitude of this issue is not yet fully understood. Further assessment of the extent of groundwater impact it recommended before any further management options are considered.

5.3 Surface water and sediments

The surface water and associated sediments in the retention ponds and drains appear to represent the main potential sources of offsite PFAS impact. Concentrations of PFAS in these ponds was generally higher than in groundwater.

The mass of PFAS in the retention ponds has probably the most potential to migrate offsite and impact onsite drainage lines and groundwater and offsite drains and surface water bodies. These are readily accessible at the surface onsite and therefore, are amenable to removal or treatment.

Consideration should be given to decommissioning of existing onsite drains and replacement with lined drains and sediment traps in conjunction with hardstand maintenance discussed in Section 5.1.

5.3.1 Surface water

Options for management of onsite surface water include:

- Construction of alternative storage e.g. ponds or tanks. This would allow for the site to become operational in a shorter timeframe and allow for the concurrent decommissioning of the existing retention pond and its contaminated media. The remediation of the existing retention pond could be achieved in a controlled manner and in a timeframe more suitable to budgetary constraints.
- Treatment of the water by a remediation contractor.
- Tanking of water to an offsite waste treatment facility.

Options for management of offsite surface water include:

- Removal and treatment of contaminated water from impacted dams or
- Removal and transport of water to a treatment facility.

GHD has obtained quoted from a remediation contractor for the onsite treatment of surface water. These are discussed in Section 6.1.

5.3.2 Sediment

Addressing of the sediments in the onsite retention dams require the initial removal and treatment of the surface water (see above).

The main options for onsite sediment include:

- Offsite disposal to landfill. The NSW EPA waste guidelines provide classification criteria for PFAS-impacted soils. However, this option would require agreement from the receiving landfill.
- Onsite retention of the sediment, either by:
  - encapsulation in an engineered facility. The facility would be designed to resist erosion, direct rainwater away and prevent leaching of water through the sediment; or

- treatment and reuse. The sediment would need to be assessed for acid sulphate potential and its engineering properties if it is to be reused on site.

The main options for offsite sediment in dams include:

- Offsite disposal to landfill. The NSW EPA waste guidelines provide classification criteria for PFAS-impacted soils. However, this option would require agreement from the receiving landfill.
- Retention of the sediment at the Armidale site, either by:
  - encapsulation in an engineered facility or
  - treatment and reuse.

The facility would be designed to accept sediment from onsite and offsite sources and would require regulatory approval and appropriate licencing in order to receive off-site materials.

An indicative cost estimate is provided for offsite disposal and onsite encapsulation. Treatment and reuse would be subject to approval by the EPA, the engineering characteristics of the soil and suitable reuse areas being available. However, this does not remove the mass from the site and would not remove the potential for leaching of PFAS from the reused soils. Therefore a cost estimate is not provided.

5.4 Contingencies

While GHD recommends the remediation of the surface water and sediments, it is possible that the regulatory authority may require more intrusive approach to other contaminated media. For this reason, GHD has conducted a remediation options assessment (ROA) for soil and groundwater.

The ROA considers broad general response actions which are categories of actions for accomplishing remedial objectives and can be combined to form remedial alternatives. These are:

- No Action (rejected).
- Institutional controls.
- Containment.
- Removal.
- In-situ treatment.
- Ex-situ Treatment.

The assessment first considered a large number of remedial options and reviewed them in terms of their likely or proven efficacy for addressing PFAS. This results in a short list of methods for further consideration. The options retained for further consideration and discussion in the workshop are listed in Tables 2 and 3.

Table 2 Soil management options

General Response Actions	Remedial Technology	Process Options	Descriptions	Treated compounds	Limitations	Effectiveness	Implementability
Containment	Capping	Clay Cap	Compacted clay placed over the impacted area. Clay should be covered by at least 0.5m of silty sand or sandy soil to maintain the integrity of the clay cap (i.e., to protect it from root penetration).	Prevents mobilisation of PFAS compounds by infiltration of surface waters	May require a large volume of imported soil in excess of the volume of contaminated soil. This may be sourced from on-site. Would require an Environmental Management Plan (EMP) to ensure ongoing effectiveness. Legacy issue retained.	The compacted clay liners are effective if they retain a certain moisture content but are susceptible to cracking if the clay material is desiccated. They do not prevent rising groundwater levels from contacting the impacted soils and dissolving contaminants.	Good
		Asphalt or Concrete Cap	Paving grade asphalt or concrete placed over the prepared impacted area. Fill settlement must be evaluated in considering a concrete cap design. Sprayed asphalt needs to be covered with soil or opaque reflective paint to protect the asphalt from ultraviolet light and retard oxidation.	Prevents mobilization of PFAS compounds by infiltration of surface waters	May require a large area of asphalt or concrete. Would not prevent rising groundwater levels from contacting the impacted soils. Would require an EMP to ensure ongoing effectiveness. Legacy issue retained.	Effective if maintained well. Susceptible to deformation in constant wetting and drying conditions. They do not prevent rising groundwater levels from contacting the impacted soils. Would require an EMP to ensure ongoing effectiveness.	Good
Removal	Excavation (to the extent practicable)	Excavation with on-site treatment	Excavation of impacted solids using standard construction equipment (i.e. backhoes, bulldozers, and front-end loaders). Soils are treated to reduce contaminant concentrations or to stabilise compounds against future leaching. Soil are analysed for suitability for re-use on site.	Excavation is applicable to the PFAS compounds. Treatment methods require further assessment	Treatment methods may be expensive and many are unproven. Disposal of treatment end products may be problematic.	Dependent on the technology used. Mixing with binding agents has been shown to be effective in full scale operations. Refer to insitu and Ex situ treatment methods below.	Could be implemented assuming there is sufficient suitable area for treatment and an effective method for treatment is provided. Treatment can be conducted over a timeframe suitable to F&RNSW
		Excavation with on-site encapsulation	Excavated soils are placed in a purpose-built engineered retention facility to prevent access to the soils from human activity and the elements, notably infiltration, leaching and run-off.	Excavation is applicable to the PFAS compounds	Potential significant regulatory and technical problems with implementation. The regulatory process could be lengthy and involved. Legacy issue retained.	Effectiveness is dependent on the design and maintenance of the facility. It does not remove the liability from the site but should break the source-receptor pathway.	Could be implemented assuming there is sufficient suitable area for treatment and there is regulatory acceptance. Volumes of soil cannot be predicted at this stage.
		Excavation with temporary on-site stockpiling	Excavated soils are placed in purpose-built stockpiles to prevent access to the soils from human activity and the elements, notably infiltration, leaching and run-off. Storage would be temporary to allow for removal of source and planning for treatment at a later date.	Excavation is applicable to the PFAS compounds	Fugitive emissions such as dust and particulates are often a problem during operations. Stockpile facility would need to be weather-proof and allow no leaching to soils and groundwater.	Effective in removing PFAS mass from the environment and from potentially contributing more PFAS to groundwater and surface water. Effectiveness is dependent on the design and maintenance of the stockpiles. It does not remove the liability from the site but allows F&RNSW more time to consider budgetary requirements in their remediation planning i.e. spreading the cost of remediation over a longer time period.	Could be implemented assuming there is sufficient suitable area for stockpiling.

General Response Actions	Remedial Technology	Process Options	Descriptions	Treated compounds	Limitations	Effectiveness	Implementability
Ex Situ Treatment (assumes excavation)	Biological	Phytoremediation	Use of plants and their associated rhizospheric microorganisms to remove, transfer, stabilise, and/or destroy contaminants in soil or groundwater.	There is currently no literature on the effectiveness of Phytoremediation on PFAS compounds however uptake by plants in dissolved form is feasible and this may be effective in removing PFAS from excavated soils.	A treatment area would be required for this process which might impinge on site activities. Plant material would then have to be harvested and require disposal.	Unknown but theoretically possible based on PFAS solubility. With excavated soils, the access by plant roots could potentially be achieved. The presence of a gum plantation next to the site and the lack of PFAS in groundwater downgradient from this plantation may mean the trees have taken PFAS up from the groundwater. This needs further assessment and research to confirm this observation and assess its effectiveness.	While there is insufficient information to prove its effectiveness, theoretically it may be a viable option to address soils on site.
	Physical-Chemical Treatment	Soil Washing	Water-based process for washing soils to remove contaminants. The process involves either dissolving or suspending the contaminants in solution. The contaminated water from the washing is then treated and treated soil replaced in the excavation	PFAS compounds likely to be amenable to flushing/washing	May require several washing events. Water treatment system would be required.	Effectiveness would need to be assessed by pilot testing to assess the concentration of treated soil against remediation criteria.	Requires a custom-built plant unless a suitable hire plant is available. May be costly and would depend on the volume of soil requiring treatment. Likely to be more economical with larger soil volumes.
		Solidification/Stabilisation/Sorption	Contaminants are immobilised by sorption, precipitation or incorporation into crystal lattices or physically encapsulation by the addition of suitable reagent or concrete. The process is designed to reduce leaching potential and to improve soil condition.	Sorption of PFAS compounds on to various substrates have been assessed in the literature and been shown to have some benefit. Some proprietary products have been tested in the lab and at full scale. Soils may be encapsulated in cement.	Mixtures of contaminants may make formulation of a single process difficult. Doesn't destroy or remove contaminants. Long term effects are difficult to predict and long-term management may be required.	Full scale stabilisation projects has been documented in Australia. Site-specific testing of the material would be required to assess effectiveness.	Requires some bench testing or pilot trials to optimise mixtures and pre-treatments requirements. Relatively short remedial timeframe.
		Effluent treatment (assumes soil washing)	The process may be modified to treat effluent from soil washing to more effectively remove PFAS from the soil rather than simply immobilising it.	PFAS compounds specifically.	Would depend on the ability of the soil washing process to remove PFAS from the soil. This might be limited by the soil properties i.e. grain size, pH. There is little information of throughputs of large scale processes required.	CRC-Care literature indicated two successful waste water treatment projects involving treatment of 200,000L of waste water.	Likely to be implementable. Commercial organisations and CRC Care have developed treatment systems. Would likely require removal of colloidal material from the waste water stream to be effective.

General Response Actions	Remedial Technology	Process Options	Descriptions	Treated compounds	Limitations	Effectiveness	Implementability
		Incineration	High temperatures, 1,200 °C+, are used to combust (in the presence of oxygen) organic constituents in hazardous wastes. Plasma arc technology can also create sufficient heat to destroy PFAS	Literature indicates high temperature incineration is beneficial for PFAS destruction.	Significant energy requirements and potential to generate GHGs. Incomplete combustion may create additional contaminants of concern e.g fluorine. Disposal of solid residues may be problematic as they may concentrate other inorganic compounds. Probably not a mobile option and soil would need to be delivered to a licenced facility.	Effective. Literature indicated PFAS compounds can be incinerated at temperatures of 1200ºC. ToxFree facility in Queensland has conducted such work and achieve over 99% destruction.	Good - Would require off site disposal of soils to a licenced facility but these do exist.

Table 3 Groundwater management options

General Response Actions	Remedial Technology	Process Options	Descriptions	Treated compounds	Limitations	Effectiveness	Implementability
Containment	Hydraulic Barriers	Vertical Wells	Conventional groundwater extraction is pumping in vertical wells. Other extraction device include vacuum enhanced recovery, jet-pumping systems, etc.	Well technology is applicable to the PFAS	Limited by the effective capture zone of each well. Careful hydrogeological assessment and pilot trials would be needed to assess effective radius of influence and pumping rates. Volumes of water produced requiring treatment might be excessive and need treatment - the rate of treatment would need to match or exceed the rate of extraction.	Widely used and demonstrated effectiveness. Generally effective for hydraulic containment (i.e. horizontal migration) and ineffective for groundwater restoration.	Good. Common technology; often combined with other treatment technologies applied to the extracted groundwater in an integrated system.
		Interception Trenching	Trenches backfilled with granular material provide preferred flow path for collection in pipe or sump. Groundwater collection technique to increase production rate from low permeability areas.	Method allows for capture of impacted groundwater rather than actual treatment. The treatment would occur ex-situ. (However, should the technology exists, reactive material could be included in the trench to treat the groundwater in situ).	Depth of PFAS impact not well known. Large volumes of water likely to be produced which requires treatment.	Widely used and demonstrated effectiveness.	Good. Groundwater is shallow.
In Situ Treatment	Chemical	Chemical Oxidation	Aqueous injection of oxidizing agents (activated persulphate, Fentons) to promote abiotic in situ oxidation of PFAS	Some literature suggests this might be an effective method of PFAS destruction assuming site-specific trials are conducted.	Unproductive oxidant consumption by natural media. Application involves injection of aqueous phase reagents will be significantly constrained in low permeability media. OH&S issues associated with handling oxidants.	Theoretically effective, but requires good contact between contaminant and reagent. Aquifer heterogeneity not clearly understood but could make uniform distribution difficult and would limit effectiveness.	Relatively easy to implement. Deployment could be through wells, trenches or infiltration basins.
	Biological	Phytoremediation	Phytoremediation is a set of processes that uses plants to remove, transfer, stabilise and destroy organic/inorganic contamination in ground water, surface water, and leachate. These mechanisms include enhanced rhizosphere biodegradation, hydraulic control, phyto-degradation and phyto-volatilization.	No literature on this process and its effectiveness on treating AFFF.	Toxicity and bioavailability of biodegradation products is not always known. Degradation by-products may be mobilised in groundwater or bio-accumulated in animals. More research is needed to determine the fate of various compounds in the plant metabolic cycle. Disposal of harvested plants can be a problem if they contain high levels of heavy metals. Climatic or seasonal conditions may interfere or inhibit plant growth, slow remediation efforts, or increase the length of the treatment period. It can transfer contamination across media, e.g., from soil to air. Phytoremediation will likely require a large surface area of land for remediation. Phytoremediation for extraction or degradation is generally limited to relatively shallow depths of root penetration.	PFAS has been shown to be present in plants and therefore, uptake of dissolved PFAS by plants may be effective as long as the root systems are deep enough. This might require larger plant species (e.g. eucalypts)	Most applicable for control of shallow groundwater plumes. High concentrations of hazardous materials can be toxic to plants but this may not be the case with PFAS. It is still in the demonstration stage. Pumping the water out of the ground and using it to irrigate plantations of trees may treat contaminated groundwater that is too deep to be reached by plant roots however this may only serve to increase the area of impact. High rainfall may flush the contaminants back into groundwater.

General Response Actions	Remedial Technology	Process Options	Descriptions	Treated compounds	Limitations	Effectiveness	Implementability
Ex Situ Treatment (assumes extraction)	Chemical	Chemical Oxidation	Oxidizing agents are used to destroy organic contaminants in an ex situ storage area Potential oxidizing agents are activated persulphate and Fentons Reagent.	Some literature information on the potential effectiveness of this method on PFAS.	Lack of full scale examples. Would require site-specific trials. Heterogeneity of the aquifer is not understood.	Lack of full scale examples. Would require site-specific trials.	Lack of full scale examples. Would require site-specific trials.
		Precipitation	This process transforms dissolved compounds into an insoluble solid, facilitating the compound's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant and flocculation. It is used as a pre-treatment process with other technologies (such as chemical oxidation or air stripping), where the presence of metals would interfere with treatment.	No literature on this method applied to PFAS. However PFOS has a tendency to partition to sediments in waters with high salinity. Increasing the salinity of the water may remove it from the water stream allowing for marine disposal of the effluent water. Impacted sediments would then need treatment and disposal.	Untested method.	Unproven effectiveness but theoretically could be an effective method of removing PFOS from a waste water stream.	Unproven
	Physical Treatment	Granular activated Carbon (GAC) Adsorption	GAC adsorption is a full-scale technology in which ground water is pumped through one or more vessels containing activated carbon to which dissolved organic contaminants adsorb. GAC is incinerated at the end of its life.	Applicable to PFAS	Streams with high suspended solids (> 50 mg/L) and oil and grease (> 10 mg/L) may cause fouling of the carbon and may require frequent treatment. Unknown sorption capacity or site-specific data. GAC becomes a waste source that needs destruction.	The technology has some efficacy for addressing PFAS according to literature although not every one agrees. Work conducted by GHD has shown it to be effective in achieving guideline criteria for drinking water and trade waste disposal for low turbidity waters. Contaminant removal efficiencies need to be further assessed.	Carbon adsorption systems can be deployed rapidly. Would need a site-specific design
		CRC Care Method	Uses modified clay as an adsorption media for PFAS. Water is initially stripped of colloidal content and then passed through a number of chambers to remove the PFAS from the water. Clay media is collected by CRC for disposal.	PFAS specifically	May be limited by required throughput. CRC quote 4L per hour which may not be adequate for groundwater remediation. However this rate may be increased if water is colloid free.	Apparently successful in treating waste water according to CRC literature	Apparently implementable according to CRC literature
		Reverse osmosis	Impacted water is forced through a membrane or series of membranes to remove water from dissolved phases	Has been demonstrated in Queensland to be effective on removing PFAS from waste	Expensive technology and high energy consumer.	Experience from Queensland water treatment facility showed it removed 100% of PFAS from impacted water.	RO systems can be deployed rapidly. Would need a site-specific design
Disposal	Extraction	Reinjection	Reinjection of groundwater to the aquifer upgradient or side-gradient to the impacted area.	PFAS	Limited by the capacity of the aquifer to receive the groundwater.	Could create enhanced gradients which would mobilise contamination	Relatively easy to implement

6 Indicative cost estimates

The available contamination data provided a certain level of understanding of the site, however, there are a number of uncertainties or data gaps remaining. The uncertainty can only be further reduced by further assessment work. Consequently, a number of assumptions have to be made which utilise information gained from comparable sites where some data is available and based on our experience with similar sites. In addition, some inputs for developing the indicative cost estimates are from Rawlinsons, *Australian Construction Handbook, Edition 35, 2017.*

Recognising that there is risk of cost exceedance, suitably robust contingencies have been to be applied to these costs for any budgeting or other financial purposes. The costs, contingencies and sundries should be ratified by a suitably qualified cost estimator and preferably market tested, should greater certainty be required.

GHD has provided separate indicative surface water and sediment volumes for onsite and offsite sources based on the surface area of the dams.

- Onsite:
  - The estimated surface water volume for the four onsite dams is approximately **910,000 L.**
  - Estimated sediment volume, assuming 1 m thickness, for onsite dams is **910 m^3**.
- Offsite
  - The estimated surface water volume for the three offsite dams is approximately **7,860,000 L**.
  - Estimated sediment volume, assuming 1 m thickness, for onsite dams is **7860 m^3**.

6.1 Water

GHD has obtained quotes from a remedial contractor for the treatment of the surface water based on rate per litre basis. Based on the assumed volume, the indicative cost estimate to treat the water in the onsite retention ponds is in the order of **$250,000. T**he indicative cost estimate to treat the water in the offsite dams is in the order of **$2,000,000.**

This figure excludes discharge and sediment management.

The price included:

- Removal of waters from the primary dam
- Process the waters through the mobile PFAS treatment system
- Discharge treated water into temporary storage tanks
- Sampled, analyse, and validated the waters to satisfy the discharge criteria (at present the discharge criteria has not been established)

According to the contractor, the end result of the treatment would be discharge of the treated water or use for irrigation. It is not clear from the contractor's quote what criteria this is based on or whether this is a valid assumption. GHD makes no assertion that their methodology will achieve regulatory approval for discharge or irrigation, but provide the quote for indicative costing purposes. This would need to be further assessed prior to implementation.

6.2 Sediment

6.2.1 Offsite disposal

This option is subject to landfill acceptance of the sediment. It is likely that they would not receive sludge and the sediment is therefore likely to require dewatering.

Onsite sediments – The indicative cost estimate to dispose of 910 m^3 of dry sediment to landfill is in the order of **$230,000**.

Offsite sediments – The indicative cost estimate to dispose of 7860 m^3 of dry sediment to landfill is in the order of **$1,950,000**.

This estimate includes allowances for excavation, transport, plant hire and landfill waste levy.

The benefits of this method (assuming landfill acceptance) is that it permanently removes PFAS mass from the site.

6.2.2 Onsite encapsulation

GHD has used a proprietary spreadsheet to calculate the cost for construction of an engineered soil repository to contain the sediments, indefinitely. The indicative cost estimate to construct the facility are:

- ***Onsite sediments*** – based on 910 m^3 of dry sediment is in the order of **$30,000**.
- ***Onsite sediments*** – based on 7860 m^3 of dry sediment is in the order of **$120,000**.

Additional costs would be incurred for excavation and haulage of the sediment to the facility and compaction. Such costs may be in the order of **$10,000**.

This indicative cost estimate is based on:

- Design
- Cell construction with geosynthetic lining, clay capping, leachate collection and sump, set out, stormwater management.
- 20% contingency.

Such a facility would require prior approval from EPA to licence the facility to accept the material, ongoing maintenance and monitoring and the PFAS mass will remain on site indefinitely. This would incur additional costs. However, if the landfill will not receive the sediment, this may be the only response to PFAS mass isolation.

6.2.3 Exclusions

The indicative cost estimates provided above excludes a number of items including:

- Planning approval
- Auditing

- Validation sampling
- Quality control or verification inspections
- Gas venting systems
- Dewatering of sediments

7 Summary

Indicative cost estimates for the water and sediment management are summarised in Table 4

Table 4 Indicative management cost estimates

Media	Method	Indicative cost estimate
Onsite Water	Treatment and discharge	$250,000
Onsite Sediment	Offsite disposal	$230,000
	Onsite encapsulation	$40,000
Offsite Water	Treatment and discharge	$2,000,000
Offsite Sediment	Offsite disposal	1,950,000
	Onsite encapsulation	$130,000

8 Limitations

This report has been prepared by GHD for Fire & Rescue NSW and may only be used and relied on by Fire & Rescue NSW for the purpose agreed between GHD and the Fire & Rescue NSW as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Fire & Rescue NSW arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described throughout this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Fire & Rescue NSW and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the indicative management cost estimates set out in Section 6 of this report ("Indicative Cost Estimate") using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD.

The Indicative Cost Estimate has been prepared for the purpose of providing Fire & Rescue NSW with estimates for internal Fire & Rescue NSW use only and must not be used for any other purpose.

The Indicative Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Indicative Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Indicative Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Sincerely

Jacqui Hallchurch
Principal Environmental Scientist
02 9239 7046

Mark Clough
Principal Environmental Scientist
03 8687 8585

Appendix C – Previous analytical results

Appendix C
Table 1
Previous soil and sediment analytical results
Off-site

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	PFAS															
							Perfluorobutane sulfonic acid (PFBS)	Perfluoropentane sulfonic acid (PFPeS)	Perfluorohexane sulfonic acid (PFHxS)	Perfluoroheptane sulfonic acid (PFHpS)	Perfluorooctane sulfonic acid (PFOS)	Perfluorodecanesulfonic acid (PFDS)	Perfluorobutanoic acid (PFBA)	Perfluoropentanoic acid (PFPeA)	Perfluorohexanoic acid (PFHxA)	Perfluoroheptanoic acid (PFHpA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorodecanoic acid (PFDA)	Perfluoroundecanoic acid (PFUnDA)	Perfluorododecanoic acid (PFDoDA)	Perfluorotridecanoic acid (PFTrDA)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
PFAS NEMP 2018 Health Public Open Space																	**10**					
PFAS NEMP 2018 Health Residential Accessible Soil																	0.1					
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space											1#1						10#1					
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential											0.01#2											
Armidale FRNSW	Off-site	SS10	SS10		01/12/2016	ES1627706	<0.0002	<0.0002	0.0003	<0.0002	0.0046	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW07	MW07_12.0-12.7	12-12.7	31/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW07	MW07_2.5-2.7	2.5-2.7	31/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW07	MW07_6.0-6.7	6-6.7	31/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	FD10	18.2-18.7	01/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	MW08_0.9-1.0	0.9-1	01/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	MW08_18.2-18.7	18.2-18.7	01/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	MW08_4.7-5.2	4.7-5.2	01/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW09	MW09_0.2-0.3	0.2-0.3	02/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW09	MW09_10.7-11.2	10.7-11.2	02/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW09	MW09_16.7-17.2	16.7-17.2	02/06/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB10	SB10_0.3-0.4	0.3-0.4	08/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB10	SB10_0.6-0.7	0.6-0.7	08/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB10	SB10_1.2-1.3	1.2-1.3	08/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB11	SB11_0.2-0.3	0.2-0.3	09/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB11	SB11_0.5-0.6	0.5-0.6	09/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB11	SB11_1.2-1.3	1.2-1.3	09/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB12	SB12_0.8-0.9	0.8-0.9	09/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB12	SB12_0-0.1	0-0.1	09/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	0.0005	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS11	SS11		08/12/2016	ES1628450	<0.0002	<0.0002	0.0011	0.0002	0.0199	0.0004	<0.001	0.0005	0.0003	0.0003	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS12	SS12		08/12/2016	ES1628450	<0.0002	<0.0002	0.0002	<0.0002	0.0048	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS13	SS13		08/12/2016	ES1628450	<0.0002	<0.0002	0.0005	<0.0002	0.0112	<0.0002	<0.001	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS14	SS14		08/12/2016	ES1628450	<0.0002	<0.0002	0.0004	<0.0002	0.0114	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS15	SS15		08/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	0.0014	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS16	SS16		08/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	0.0034	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS17	SS17		08/12/2016	ES1628450	<0.0002	<0.0002	<0.0002	<0.0002	0.0026	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS10	SS10		15/06/2017	ES1715278	<0.0002	<0.0002	0.0008	<0.0002	0.0167	<0.0002	<0.001	<0.0002	0.0003	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002

Appendix C
Table 1
Previous soil and sediment analytical results
Off-site

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	PFAS: Perfluorobutane sulfonic acid (PFBS)	Perfluoropentane sulfonic acid (PFPeS)	Perfluorohexane sulfonic acid (PFHxS)	Perfluoroheptane sulfonic acid (PFHpS)	Perfluorooctane sulfonic acid (PFOS)	Perfluorodecanesulfonic acid (PFDS)	Perfluorobutanoic acid (PFBA)	Perfluoropentanoic acid (PFPeA)	Perfluorohexanoic acid (PFHxA)	Perfluoroheptanoic acid (PFHpA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorodecanoic acid (PFDA)	Perfluoroundecanoic acid (PFUnDA)	Perfluorododecanoic acid (PFDoDA)	Perfluorotridecanoic acid (PFTrDA)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
PFAS NEMP 2018 Health Public Open Space																	**10**					
PFAS NEMP 2018 Health Residential Accessible Soil																	0.1					
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space											1[#1]						10[#1]					
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential											0.01[#2]											
Armidale FRNSW	Off-site	SS11	SS11		16/06/2017	ES1715278	<0.0002	0.0003	0.0025	0.0007	0.112	0.0007	<0.001	<0.0002	0.0008	0.0006	0.001	0.0003	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS12	SS12		16/06/2017	ES1715278	<0.0002	<0.0002	0.0008	0.0002	0.0599	0.0008	<0.001	<0.0002	0.0003	0.0003	0.0004	0.0003	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS13	SS13		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0028	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS14	SS14		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0093	<0.0002	<0.001	<0.0002	<0.0002	0.0004	0.0005	0.0004	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS15	SS15		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0015	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS16	SS16		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS17	SS17		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0044	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	0.0005	0.0005	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS18	SS18		16/06/2017	ES1715278	<0.0002	<0.0002	0.001	0.0003	0.0495	0.0004	<0.001	<0.0002	0.0004	0.0004	0.0006	0.0005	0.0003	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS19	SS19		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0021	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS20	SS20		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0007	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS21	SS21		16/06/2017	ES1715278	<0.0002	<0.0002	0.0017	0.0003	0.0223	<0.0002	<0.001	<0.0002	0.0003	0.0002	0.0011	0.0009	0.001	0.0002	0.0004	<0.0002
Armidale FRNSW	Off-site	SS22	SS22		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0035	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	0.0003	<0.0002	0.0003	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS23	SS23		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0076	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS24	SS24		16/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002

Env Stds Comments
#1:Ecological Direct Exposure
#2:Ecological Indirect Exposure

Appendix C
Table 1
Previous soil and sediment analytical results
Off-site

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	Perfluorotetradecanoic acid (PFTeDA)	Perfluorooctane sulfonamide (FOSA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)	N-Methyl perfluorooctane sulfonamidoethanol (MEFOSE)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	6:2 Fluorotelomer Sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	PFAS (Sum of Total)	Sum of PFHxS and PFOS	PFAS (Sum of Total)(WA DER List)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0005	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0002
PFAS NEMP 2018 Health Public Open Space																				1	
PFAS NEMP 2018 Health Residential Accessible Soil																				0.009	
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space																					
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential																					
Armidale FRNSW	Off-site	SS10	SS10		01/12/2016	ES1627706	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0051	0.0049	0.0051
Armidale FRNSW	Off-site	MW07	MW07_12.0-12.7	12-12.7	31/05/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW07	MW07_2.5-2.7	2.5-2.7	31/05/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW07	MW07_6.0-6.7	6-6.7	31/05/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	FD10	18.2-18.7	01/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	MW08_0.9-1.0	0.9-1	01/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	MW08_18.2-18.7	18.2-18.7	01/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW08	MW08_4.7-5.2	4.7-5.2	01/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW09	MW09_0.2-0.3	0.2-0.3	02/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW09	MW09_10.7-11.2	10.7-11.2	02/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	MW09	MW09_16.7-17.2	16.7-17.2	02/06/2017	ES1714150	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB10	SB10_0.3-0.4	0.3-0.4	08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB10	SB10_0.6-0.7	0.6-0.7	08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB10	SB10_1.2-1.3	1.2-1.3	08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB11	SB11_0.2-0.3	0.2-0.3	09/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB11	SB11_0.5-0.6	0.5-0.6	09/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB11	SB11_1.2-1.3	1.2-1.3	09/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB12	SB12_0.8-0.9	0.8-0.9	09/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SB12	SB12_0-0.1	0-0.1	09/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	0.0005	0.0005
Armidale FRNSW	Off-site	SS11	SS11		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.023	0.021	0.0224
Armidale FRNSW	Off-site	SS12	SS12		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.005	0.005	0.005
Armidale FRNSW	Off-site	SS13	SS13		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.012	0.0117	0.012
Armidale FRNSW	Off-site	SS14	SS14		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0118	0.0118	0.0118
Armidale FRNSW	Off-site	SS15	SS15		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0014	0.0014	0.0014
Armidale FRNSW	Off-site	SS16	SS16		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0034	0.0034	0.0034
Armidale FRNSW	Off-site	SS17	SS17		08/12/2016	ES1628450	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0026	0.0026	0.0026
Armidale FRNSW	Off-site	SS10	SS10		15/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.018	0.0175	0.018

Appendix C
Table 1
Previous soil and sediment analytical results
Off-site

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	Perfluorotetradecanoic acid (PFTeDA)	Perfluorooctane sulfonamide (FOSA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)	N-Methyl perfluorooctane sulfonamidoethanol (MEFOSE)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	6:2 Fluorotelomer Sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	PFAS (Sum of Total)	Sum of PFHxS and PFOS	PFAS (Sum of Total)(WA DER List)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0005	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0002
PFAS NEMP 2018 Health Public Open Space																				**1**	
PFAS NEMP 2018 Health Residential Accessible Soil																				0.009	
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space																					
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential																					
Armidale FRNSW	Off-site	SS11	SS11		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.119	0.114	0.117
Armidale FRNSW	Off-site	SS12	SS12		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.063	0.0607	0.0617
Armidale FRNSW	Off-site	SS13	SS13		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0028	0.0028	0.0028
Armidale FRNSW	Off-site	SS14	SS14		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0106	0.0093	0.0102
Armidale FRNSW	Off-site	SS15	SS15		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0015	0.0015	0.0015
Armidale FRNSW	Off-site	SS16	SS16		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	Off-site	SS17	SS17		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0054	0.0044	0.0049
Armidale FRNSW	Off-site	SS18	SS18		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0534	0.0505	0.0519
Armidale FRNSW	Off-site	SS19	SS19		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0021	0.0021	0.0021
Armidale FRNSW	Off-site	SS20	SS20		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0007	0.0007	0.0007
Armidale FRNSW	Off-site	SS21	SS21		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0284	0.024	0.0256
Armidale FRNSW	Off-site	SS22	SS22		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0041	0.0035	0.0038
Armidale FRNSW	Off-site	SS23	SS23		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0076	0.0076	0.0076
Armidale FRNSW	Off-site	SS24	SS24		16/06/2017	ES1715278	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002

Env Stds Comments
#1:Ecological Direct Exposure
#2:Ecological Indirect Exposure

Appendix C
Table 2
Previous soil and sediment analytical results
On-site

PFAS

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	Perfluorobutane sulfonic acid (PFBS)	Perfluoropentane sulfonic acid (PFPeS)	Perfluorohexane sulfonic acid (PFHxS)	Perfluoroheptane sulfonic acid (PFHpS)	Perfluorooctane sulfonic acid (PFOS)	Perfluorodecanesulfonic acid (PFDS)	Perfluorobutanoic acid (PFBA)	Perfluoropentanoic acid (PFPeA)	Perfluorohexanoic acid (PFHxA)	Perfluoroheptanoic acid (PFHpA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorodecanoic acid (PFDA)	Perfluoroundecanoic acid (PFUnDA)	Perfluorododecanoic acid (PFDoDA)	Perfluorotridecanoic acid (PFTrDA)	Perfluorotetradecanoic acid (PFTeDA)	Perfluorooctane sulfonamide (FOSA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0005	0.0002	0.0005	0.0005
PFAS NEMP 2018 Health Industrial/Commercial																	50									
PFAS NEMP 2018 Health Public Open Space																	**10**									
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space											1[#1]						10[#1]									
PFAS NEMP 2018 Interim Ecological Indirect Exposure Commercial/Industrial											0.14[#2]															
Armidale FRNSW	On-site	SB03	QA03	0.9-1	30/11/2016	526327	-	-	-	-	<0.005	-	-	-	-	-	<0.005	-	-	-	-	-	-	-	-	-
Armidale FRNSW	On-site	SB06	QA04	0.4-0.5	01/12/2016	526327	-	-	-	-	<0.005	-	-	-	-	-	<0.005	-	-	-	-	-	-	-	-	-
Armidale FRNSW	On-site	SB14	FD02	0.4-0.5	29/05/2017	549869	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Armidale FRNSW	On-site	MW01	MW1_0.5-0.6	0.5-0.6	29/11/2016	ES1627710	0.0003	0.0004	0.0048	<0.0002	0.0054	<0.0002	<0.001	0.0003	0.0014	0.0004	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW01	MW1_3.0-3.1	3-3.1	29/11/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW02	MW02_0.9-1.0	0.9-1	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW02	MW02_17.0-18.0	17-18	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW03	MW03_0.9-1.0	0.9-1	30/11/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW03	MW03_17.0-18.0	17-18	30/11/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW04	MW04_1.9-2.0	1.9-2	01/12/2016	ES1627710	<0.0002	<0.0002	0.001	<0.0002	0.0045	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW04	MW04_17.0-18.0	17-18	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB01	QA02	0.5-0.6	30/11/2016	ES1627710	0.001	0.0016	0.0164	0.004	0.082	<0.0002	<0.001	0.0024	0.0048	0.001	0.003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB01	SB01_0.5-0.6	0.5-0.6	30/11/2016	ES1627710	0.0011	0.0019	0.0169	0.0034	0.0647	<0.0002	<0.001	0.0014	0.0049	0.001	0.0026	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB01	SB01_2.9-3.0	2.9-3	30/11/2016	ES1627710	0.0002	0.0003	0.0012	<0.0002	0.006	<0.0002	<0.001	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB02	SB02_0.9-1.0	0.9-1	30/11/2016	ES1627710	0.0027	0.004	0.047	0.0037	0.228	<0.0002	<0.001	0.0166	0.0244	0.0035	0.0057	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB02	SB02_3.9-4.0	3.9-4	30/11/2016	ES1627710	<0.0002	0.0002	0.0013	<0.0002	0.0125	<0.0002	<0.001	0.0005	0.0007	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB03	SB03_0.9-1.0	0.9-1	30/11/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	0.0003	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB03	SB03_Asphalt_0-0.08	0-0.08	30/11/2016	ES1627710	0.0008	0.0004	0.0025	0.0005	0.0325	<0.0002	<0.001	0.0005	0.0005	<0.0002	0.0004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB04	SB04_0.4-0.5	0.4-0.5	30/11/2016	ES1627710	0.004	0.004	0.0287	0.0027	0.0112	<0.0002	<0.001	0.0028	0.0075	0.0014	0.0041	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB04	SB04_4.4-4.5	4.4-4.5	30/11/2016	ES1627710	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB05	SB05_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB05	SB05_4.9-5.0	4.9-5	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB06	SB06_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB06	SB06_4.9-5.0	4.9-5	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB07	SB07_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB07	SB07_1.6-1.7	1.6-1.7	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB08	SB08_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	0.0016	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB08	SB08_3.9-4.0	3.9-4	01/12/2016	ES1627710	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB09	QA06	0.9-1	01/12/2016	ES1627710	<0.0002	<0.0002	0.001	<0.0002	0.0008	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB09	SB09_0.9-1.0	0.9-1	01/12/2016	ES1627710	<0.0002	<0.0002	0.0012	<0.0002	0.0013	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB09	SB09_4.9-5.0	4.9-5	01/12/2016	ES1627710	<0.0002	<0.0002	0.0006	<0.0002	0.0055	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB09	SB09_Concrete_0-0.2	0-0.2	01/12/2016	ES1627710	0.0372	0.0123	0.0758	0.006	0.106	<0.0002	0.021	0.0367	0.0898	0.0055	0.0124	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	0.0006	<0.0005	<0.0005
Armidale FRNSW	On-site	SS01	SS01		28/11/2016	ES1627710	0.0005	<0.0002	0.0022	0.0002	0.0248	0.0006	<0.001	0.0019	0.0018	0.0012	0.002	0.0006	0.0009	<0.0002	0.0006	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS02	SS02		28/11/2016	ES1627710	0.0004	<0.0002	0.0029	<0.0002	0.0356	0.0012	<0.001	0.0007	0.0018	0.0003	0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0005	0.0006	<0.0005	<0.0005
Armidale FRNSW	On-site	SS03	SS03		28/11/2016	ES1627710	<0.0002	<0.0002	0.0003	<0.0002	0.0022	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS04	SS04		28/11/2016	ES1627710	<0.0002	<0.0002	0.0004	<0.0002	0.0041	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS05	SS05		28/11/2016	ES1627710	<0.0002	<0.0002	0.0003	<0.0002	0.0027	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS06	SS06		28/11/2016	ES1627710	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS07	SS07		01/12/2016	ES1627710	<0.0002	<0.0002	0.0003	0.0008	0.0032	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS08	SS08		01/12/2016	ES1627710	0.0005	<0.0002	0.004	0.0005	0.0469	0.0003	<0.001	0.002	0.0021	0.0011	0.0019	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS09	QA01		28/11/2016	ES1627710	<0.0002	<0.0002	0.0002	<0.0002	0.0009	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS09	SS09		28/11/2016	ES1627710	<0.0002	<0.0002	0.0005	<0.0002	0.0028	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW05	MW05_0.2-0.3	0.2-0.3	30/05/2017	ES1714150	<0.0002	<0.0002	0.0004	<0.0002	0.0108	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005

Appendix C
Table 2
Previous soil and sediment analytical results
On-site

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	PFAS																			
							Perfluorobutane sulfonic acid (PFBS)	Perfluoropentane sulfonic acid (PFPeS)	Perfluorohexane sulfonic acid (PFHxS)	Perfluoroheptane sulfonic acid (PFHpS)	Perfluorooctane sulfonic acid (PFOS)	Perfluorodecanesulfonic acid (PFDS)	Perfluorobutanoic acid (PFBA)	Perfluoropentanoic acid (PFPeA)	Perfluorohexanoic acid (PFHxA)	Perfluoroheptanoic acid (PFHpA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorodecanoic acid (PFDA)	Perfluoroundecanoic acid (PFUnDA)	Perfluorododecanoic acid (PFDoDA)	Perfluorotridecanoic acid (PFTrDA)	Perfluorotetradecanoic acid (PFTeDA)	Perfluorooctane sulfonamide (FOSA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0005	0.0002	0.0005	0.0005
PFAS NEMP 2018 Health Industrial/Commercial																	50									
PFAS NEMP 2018 Health Public Open Space																	**10**									
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space											1[#1]						10[#1]									
PFAS NEMP 2018 Interim Ecological Indirect Exposure Commercial/Industrial											0.14[#2]															
Armidale FRNSW	On-site	MW05	MW05_20.2-21.7	20.2-21.7	31/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW06	MW06_13.2-14.2	13.2-14.2	30/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW06	MW06_2.0-2.2	2-2.2	29/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW06	MW06_2.9-3.1	2.9-3.1	30/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	MW06	MW06_4.0-4.2	4-4.2	29/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB13	SB13_0.0-0.1	0-0.1	29/05/2017	ES1714150	<0.0002	<0.0002	0.0014	<0.0002	0.016	<0.0002	<0.001	0.0014	0.0006	0.0005	0.0006	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB13	SB13_0.4-0.5	0.4-0.5	29/05/2017	ES1714150	0.0008	0.0003	0.0012	<0.0002	0.0018	<0.0002	<0.001	0.0003	0.0004	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB13	SB13_1.6-1.9	1.6-1.9	29/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB14	SB14_0.0-0.1	0-0.1	29/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB14	SB14_0.4-0.5	0.4-0.5	29/05/2017	ES1714150	0.0002	<0.0002	0.0012	<0.0002	0.0002	<0.0002	<0.001	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB14	SB14_2.5-2.7	2.5-2.7	29/05/2017	ES1714150	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB15	FD01	0-0.1	29/05/2017	ES1714150	<0.0002	<0.0002	0.0022	0.0005	0.0571	0.0018	<0.001	0.0002	0.0004	0.0004	0.0031	0.0009	0.0041	0.0006	0.0009	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB15	SB15_0.0-0.1	0-0.1	29/05/2017	ES1714150	<0.0002	<0.0002	0.0028	0.0005	0.0473	0.0014	<0.001	<0.0002	0.0004	0.0003	0.0024	0.0008	0.0033	0.0006	0.0008	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB15	SB15_1.8-2.0	1.8-2	29/05/2017	ES1714150	<0.0002	<0.0002	0.0011	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	0.0004	0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SB15	SB15_2.5-2.7	2.5-2.7	29/05/2017	ES1714150	<0.0002	<0.0002	0.0004	<0.0002	0.0012	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS01	SS01		13/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0071	0.0004	<0.001	<0.0002	<0.0002	0.0002	0.0004	0.0004	0.0014	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS02	SS02		13/06/2017	ES1715278	<0.0002	0.0002	0.0011	0.0002	0.0732	0.0021	<0.001	<0.0002	0.0009	0.0008	0.001	0.0016	0.0012	0.0004	<0.0002	<0.0002	<0.0005	0.0005	<0.0005	<0.0005
Armidale FRNSW	On-site	SS03	SS03		14/06/2017	ES1715278	<0.0002	<0.0002	<0.0002	<0.0002	0.0064	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS04	SS04		14/06/2017	ES1715278	<0.0002	<0.0002	0.0003	<0.0002	0.0238	<0.0002	<0.001	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS05	DUP03		14/06/2017	ES1715278	<0.0002	<0.0002	0.0007	<0.0002	0.0214	0.0002	<0.001	<0.0002	<0.0002	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS05	SS05		14/06/2017	ES1715278	<0.0002	<0.0002	0.0006	<0.0002	0.0216	0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS06	SS06		14/06/2017	ES1715278	<0.0002	<0.0002	0.0006	<0.0002	0.0174	<0.0002	<0.001	<0.0002	0.0002	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS07	SS07		14/06/2017	ES1715278	<0.0002	0.0003	0.0016	0.0003	0.0409	<0.0002	<0.001	<0.0002	0.0005	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS08	SS08		14/06/2017	ES1715278	<0.0002	0.0005	0.0027	0.0005	0.067	0.0004	<0.001	0.0026	0.0014	0.0019	0.0015	0.0016	0.0003	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005
Armidale FRNSW	On-site	SS09	SS09		14/06/2017	ES1715278	<0.0002	<0.0002	0.0003	<0.0002	0.0054	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005

Env Stds Comments
#1:Ecological Direct Exposure
#2:Ecological Indirect Exposure

Appendix C
Table 2
Previous soil and sediment analytical results
On-site

Site_ID	SampleComments	Location_Code	Field_ID	Sample_Depth_Range	Sampled_Date	Lab_Report_Number	N-Methyl perfluorooctane sulfonamidoethanol (MEFOSE)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	6:2 Fluorotelomer Sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	PFAS (Sum of Total)	Sum of PFHxS and PFOS	PFAS (Sum of Total)(WA DER List)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0005	0.0005	0.0002	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0002
PFAS NEMP 2018 Health Industrial/Commercial																20	
PFAS NEMP 2018 Health Public Open Space																**1**	
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space																	
PFAS NEMP 2018 Interim Ecological Indirect Exposure Commercial/Industrial																	
Site_ID	**SampleComments**	**Location_Code**	**Field_ID**	**Sample_Depth_Range**	**Sampled_Date**	**Lab_Report_Number**											
Armidale FRNSW	On-site	SB03	QA03	0.9-1	30/11/2016	526327	-	-	-	-	-	<0.01	-	-	-	-	-
Armidale FRNSW	On-site	SB06	QA04	0.4-0.5	01/12/2016	526327	-	-	-	-	-	<0.01	-	-	-	-	-
Armidale FRNSW	On-site	SB14	FD02	0.4-0.5	29/05/2017	549869	<0.005	<0.005	<0.01	<0.01	<0.005	<0.01	<0.005	<0.005	-	-	-
Armidale FRNSW	On-site	MW01	MW1_0.5-0.6	0.5-0.6	29/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0132	0.0102	0.0128
Armidale FRNSW	On-site	MW01	MW1_3.0-3.1	3-3.1	29/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0002	0.0002	0.0002
Armidale FRNSW	On-site	MW02	MW02_0.9-1.0	0.9-1	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW02	MW02_17.0-18.0	17-18	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW03	MW03_0.9-1.0	0.9-1	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW03	MW03_17.0-18.0	17-18	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW04	MW04_1.9-2.0	1.9-2	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0055	0.0055	0.0055
Armidale FRNSW	On-site	MW04	MW04_17.0-18.0	17-18	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB01	QA02	0.5-0.6	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.116	0.0984	0.111
Armidale FRNSW	On-site	SB01	SB01_0.5-0.6	0.5-0.6	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0979	0.0816	0.0926
Armidale FRNSW	On-site	SB01	SB01_2.9-3.0	2.9-3	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0082	0.0072	0.0079
Armidale FRNSW	On-site	SB02	SB02_0.9-1.0	0.9-1	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0128	<0.0005	<0.0005	0.348	0.275	0.341
Armidale FRNSW	On-site	SB02	SB02_3.9-4.0	3.9-4	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0152	0.0138	0.015
Armidale FRNSW	On-site	SB03	SB03_0.9-1.0	0.9-1	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0003	0.0003	0.0003
Armidale FRNSW	On-site	SB03	SB03_Asphalt_0-0.08	0-0.08	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0381	0.035	0.0372
Armidale FRNSW	On-site	SB04	SB04_0.4-0.5	0.4-0.5	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.002	<0.0005	<0.0005	0.0684	0.0399	0.0617
Armidale FRNSW	On-site	SB04	SB04_4.4-4.5	4.4-4.5	30/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0003	0.0003	0.0003
Armidale FRNSW	On-site	SB05	SB05_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB05	SB05_4.9-5.0	4.9-5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB06	SB06_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB06	SB06_4.9-5.0	4.9-5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB07	SB07_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB07	SB07_1.6-1.7	1.6-1.7	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB08	SB08_0.4-0.5	0.4-0.5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0016	0.0016	0.0016
Armidale FRNSW	On-site	SB08	SB08_3.9-4.0	3.9-4	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0003	0.0003	0.0003
Armidale FRNSW	On-site	SB09	QA06	0.9-1	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0018	0.0018	0.0018
Armidale FRNSW	On-site	SB09	SB09_0.9-1.0	0.9-1	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0025	0.0025	0.0025
Armidale FRNSW	On-site	SB09	SB09_4.9-5.0	4.9-5	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0061	0.0061	0.0061
Armidale FRNSW	On-site	SB09	SB09_Concrete_0-0.2	0-0.2	01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0028	<0.0005	<0.0005	0.406	0.182	0.387
Armidale FRNSW	On-site	SS01	SS01		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0373	0.027	0.0344
Armidale FRNSW	On-site	SS02	SS02		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0094	0.0014	0.003	0.0577	0.0385	0.0527
Armidale FRNSW	On-site	SS03	SS03		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0025	0.0025	0.0025
Armidale FRNSW	On-site	SS04	SS04		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0045	0.0045	0.0045
Armidale FRNSW	On-site	SS05	SS05		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.003	0.003	0.003
Armidale FRNSW	On-site	SS06	SS06		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0004	0.0004	0.0004
Armidale FRNSW	On-site	SS07	SS07		01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0043	0.0035	0.0035
Armidale FRNSW	On-site	SS08	SS08		01/12/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0014	0.0006	<0.0005	0.0613	0.0509	0.0605
Armidale FRNSW	On-site	SS09	QA01		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0011	0.0011	0.0011
Armidale FRNSW	On-site	SS09	SS09		28/11/2016	ES1627710	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0033	0.0033	0.0033
Armidale FRNSW	On-site	MW05	MW05_0.2-0.3	0.2-0.3	30/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0112	0.0112	0.0112

Appendix C
Table 2
Previous soil and sediment analytical results
On-site

							N-Methyl perfluorooctane sulfonamidoethanol (MEFOSE)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	6:2 Fluorotelomer Sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	PFAS (Sum of Total)	Sum of PFHxS and PFOS	PFAS (Sum of Total)(WA DER List)
							mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL							0.0005	0.0005	0.0002	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0002
PFAS NEMP 2018 Health Industrial/Commercial																20	
PFAS NEMP 2018 Health Public Open Space																**1**	
PFAS NEMP 2018 Interim Ecological Direct Exposure Public Open Space																	
PFAS NEMP 2018 Interim Ecological Indirect Exposure Commercial/Industrial																	
Site_ID	**SampleComments**	**Location_Code**	**Field_ID**	**Sample_Depth_Range**	**Sampled_Date**	**Lab_Report_Number**											
Armidale FRNSW	On-site	MW05	MW05_20.2-21.7	20.2-21.7	31/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW06	MW06_13.2-14.2	13.2-14.2	30/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW06	MW06_2.0-2.2	2-2.2	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW06	MW06_2.9-3.1	2.9-3.1	30/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	MW06	MW06_4.0-4.2	4-4.2	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB13	SB13_0.0-0.1	0-0.1	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0207	0.0174	0.0205
Armidale FRNSW	On-site	SB13	SB13_0.4-0.5	0.4-0.5	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.005	0.003	0.0047
Armidale FRNSW	On-site	SB13	SB13_1.6-1.9	1.6-1.9	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0002	0.0002	0.0002
Armidale FRNSW	On-site	SB14	SB14_0.0-0.1	0-0.1	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB14	SB14_0.4-0.5	0.4-0.5	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0018	0.0014	0.0018
Armidale FRNSW	On-site	SB14	SB14_2.5-2.7	2.5-2.7	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002
Armidale FRNSW	On-site	SB15	FD01	0-0.1	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0027	<0.0005	<0.0005	0.0749	0.0593	0.0661
Armidale FRNSW	On-site	SB15	SB15_0.0-0.1	0-0.1	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0024	<0.0005	<0.0005	0.063	0.0501	0.0556
Armidale FRNSW	On-site	SB15	SB15_1.8-2.0	1.8-2	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0019	0.0011	0.0019
Armidale FRNSW	On-site	SB15	SB15_2.5-2.7	2.5-2.7	29/05/2017	ES1714150	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0016	0.0016	0.0016
Armidale FRNSW	On-site	SS01	SS01		13/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0099	0.0071	0.0077
Armidale FRNSW	On-site	SS02	SS02		13/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	0.0042	0.0021	0.0048	0.0943	0.0743	0.0833
Armidale FRNSW	On-site	SS03	SS03		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0064	0.0064	0.0064
Armidale FRNSW	On-site	SS04	SS04		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0243	0.0241	0.0243
Armidale FRNSW	On-site	SS05	DUP03		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0226	0.0221	0.0224
Armidale FRNSW	On-site	SS05	SS05		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0224	0.0222	0.0222
Armidale FRNSW	On-site	SS06	SS06		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0187	0.018	0.0187
Armidale FRNSW	On-site	SS07	SS07		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0439	0.0425	0.0433
Armidale FRNSW	On-site	SS08	SS08		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	0.0006	<0.0005	0.081	0.0697	0.0777
Armidale FRNSW	On-site	SS09	SS09		14/06/2017	ES1715278	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	0.0057	0.0057	0.0057

Env Stds Comments
#1:Ecological Direct Exposure
#2:Ecological Indirect Exposure

Appendix C
Table 3
Previous analytical results
Groundwater and surface water

Site_ID	Location_Code	Field_ID	Sampled_Date_Time	Lab_Report_Number	Perfluorobutane sulfonic acid (PFBS)	Perfluoropentane sulfonic acid (PFPeS)	Perfluorohexane sulfonic acid (PFHxS)	Perfluoroheptane sulfonic acid (PFHpS)	Perfluorooctane sulfonic acid (PFOS)	Perfluorodecanesulfonic acid (PFDS)	Perfluorobutanoic acid (PFBA)	Perfluoropentanoic acid (PFPeA)	Perfluorohexanoic acid (PFHxA)	Perfluoroheptanoic acid (PFHpA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorodecanoic acid (PFDA)	Perfluoroundecanoic acid (PFUnDA)	Perfluorododecanoic acid (PFDoDA)	Perfluorotridecanoic acid (PFTrDA)	Perfluorotetradecanoic acid (PFTeDA)	Perfluorooctane sulfonamide (FOSA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)	N-Methyl perfluorooctane sulfonamidoethanol (MEFOSE)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	6:2 Fluorotelomer Sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	PFAS (Sum of Total)	Sum of PFHxS and PFOS	PFAS (Sum of Total)(WA DER List)
					PFAS																														
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL					0.02	0.02	0.02	0.02	0.01	0.02	0.1	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.05	0.02	0.05	0.05	0.05	0.05	0.02	0.02	0.05	0.05	0.05	0.05	0.01	0.01	0.01
PFAS NEMP 2018 Freshwater 95%									0.13[#1]						220[#1]																				
PFAS NEMP 2018 Health Drinking Water															0.56																			0.07	
PFAS NEMP 2018 Health Recreational Water															**5.6**																			**0.7**	
Armidale FRNSW	GW047498	GW047498	23/04/2018	ES1811607	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01
Armidale FRNSW	GW047498	QA101	23/04/2018	ES1811607	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01
Armidale FRNSW	GW966477	GW966477	15/06/2017	ES1715278	0.02	0.02	0.08	<0.02	0.2	<0.02	<0.1	<0.02	0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.34	0.28	0.32
Armidale FRNSW	GW966477	GW977466	1/12/2016	ES1627706	<0.02	<0.02	0.06	<0.02	0.14	<0.02	<0.1	<0.02	0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.24	0.2	0.24
Armidale FRNSW	MW01	DUP01	13/06/2017	551367	0.2	0.13[#1]	0.21[#1]	0.02[#1]	0.23[#1]	<0.01	0.12	0.41	0.38[#1]	0.05[#1]	0.03[#1]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.01	<0.05	<0.01	<0.01	-	-	-
Armidale FRNSW	MW01	MW01	8/12/2016	ES1628450	0.23	0.14	0.32	0.02	0.19	<0.02	<0.1	0.39	0.35	0.06	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	1.73	0.51	1.57
Armidale FRNSW	MW01	MW01	13/06/2017	ES1715278	0.46	0.37	0.59	0.04	0.48	<0.02	<0.1	0.55	0.59	0.14	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	3.27	**1.07**	2.86
Armidale FRNSW	MW01	QA102	8/12/2016	527617	0.17	-	0.21[#1]	-	0.25[#1]	<0.01	0.14	0.28[#1]	0.48[#1]	0.04[#1]	0.03[#1]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	-	-	-	-	<0.01	<0.05	<0.01	-	-	-	-
Armidale FRNSW	MW02	MW02	8/12/2016	ES1628450	0.03	<0.02	0.09	<0.02	0.1	<0.02	<0.1	<0.02	0.04	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.29	0.19	0.29
Armidale FRNSW	MW02	MW02	13/06/2017	ES1715278	0.04	0.04	0.18	<0.02	0.53	<0.02	<0.1	<0.02	0.05	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.07	<0.05	<0.05	0.93	**0.71**	0.89
Armidale FRNSW	MW03	MW03	8/12/2016	ES1628450	0.45	0.38	0.55	<0.02	0.66	<0.02	<0.1	0.12	0.39	0.05	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	2.63	**1.21**	2.25
Armidale FRNSW	MW03	MW03	15/06/2017	ES1715278	0.72	0.71	0.86	0.03	0.92	<0.02	<0.1	0.15	0.48	0.09	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.08	<0.05	<0.05	4.08	**1.78**	3.34
Armidale FRNSW	MW04	MW04	8/12/2016	ES1628450	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.03	0.03	0.03
Armidale FRNSW	MW04	MW04	14/06/2017	ES1715278	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01
Armidale FRNSW	MW05	DUP02	14/06/2017	ES1715278	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.02	0.02	0.02
Armidale FRNSW	MW05	MW05	14/06/2017	ES1715278	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.03	0.03	0.03
Armidale FRNSW	MW07	MW07	15/06/2017	ES1715278	0.14	0.12	0.32	<0.02	0.1	<0.02	<0.1	0.21	0.33	0.06	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	1.31	0.42	1.19
Armidale FRNSW	MW08	MW08	15/06/2017	ES1715278	0.12	0.08	0.16	<0.02	0.02	<0.02	<0.1	<0.02	0.1	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.48	0.18	0.4
Armidale FRNSW	MW09	MW09	15/06/2017	ES1715278	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01
Armidale FRNSW	SW01	SW01	28/11/2016	ES1627710	0.29	0.36	3.11	0.21	15	<0.02	<0.1	1.48	1.88	0.54	0.95	0.18	0.08	<0.02	<0.02	<0.02	<0.05	0.03	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	5.27	0.54	<0.05	29.9	**18.1**	29.1
Armidale FRNSW	SW01	SW01	13/06/2017	ES1715278	0.28	0.34	2.15	0.14	5.79	<0.02	<0.1	0.84	0.85	0.37	0.32	0.08	0.04	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.83	0.1	<0.05	12.1	**7.94**	11.5
Armidale FRNSW	SW02	QA101	28/11/2016	ES1627710	0.03	0.02	0.17	<0.02	0.65	<0.02	<0.1	<0.02	0.06	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.96	**0.82**	0.94
Armidale FRNSW	SW02	SW02	28/11/2016	ES1627710	0.03	0.02	0.18	<0.02	0.61	<0.02	<0.1	<0.02	0.05	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.92	**0.79**	0.9
Armidale FRNSW	SW02	SW02	14/06/2017	ES1715278	0.04	0.03	0.22	<0.02	0.5	<0.02	<0.1	<0.02	0.06	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.87	**0.72**	0.84
Armidale FRNSW	SW03	SW03	1/12/2016	ES1627710	0.05	0.04	0.25	<0.02	0.79	<0.02	<0.1	<0.02	0.07	<0.02	0.04	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	1.24	**1.04**	1.2
Armidale FRNSW	SW03	SW03	14/06/2017	ES1715278	0.06	0.04	0.27	<0.02	0.45	<0.02	<0.1	<0.02	0.06	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.9	**0.72**	0.86
Armidale FRNSW	SW04	SW04	8/12/2016	ES1628450	0.29	0.29	2.28	0.26	7.9	<0.02	<0.1	1.08	1.08	0.38	0.43	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.96	<0.05	<0.05	15	**10.2**	14.4
Armidale FRNSW	SW04	SW04	14/06/2017	ES1715278	0.64	0.6	2.93	0.22	6.78	<0.02	<0.1	1.17	1.47	0.55	0.42	0.04	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.35	<0.05	<0.05	15.2	**9.71**	14.3
Armidale FRNSW	SW05	SW05	1/12/2016	ES1627706	0.1	0.1	0.71	0.07	2.99	<0.02	<0.1	0.18	0.33	0.08	0.18	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	0.09	<0.05	<0.05	4.83	**3.7**	4.66
Armidale FRNSW	SW05	SW05	15/06/2017	ES1715278	0.19	0.18	0.9	0.06	1.9	<0.02	<0.1	0.21	0.33	0.11	0.09	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	3.97	**2.8**	3.73
Armidale FRNSW	SW06	SW06	8/12/2016	ES1628450	0.11	0.1	0.8	0.09	2.33	<0.02	<0.1	0.18	0.28	0.09	0.13	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	4.11	**3.13**	3.92
Armidale FRNSW	SW06	SW06	16/06/2017	ES1715278	0.11	0.1	0.5	0.05	2	<0.02	<0.1	0.12	0.18	0.07	0.07	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	3.2	**2.5**	3.05
Armidale FRNSW	SW07	DUP04	16/06/2017	ES1715278	0.05	0.04	0.24	0.02	0.72	<0.02	<0.1	<0.02	0.08	0.03	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	1.21	**0.96**	1.15
Armidale FRNSW	SW07	SW07	8/12/2016	ES1628450	0.04	0.04	0.26	<0.02	0.66	<0.02	<0.1	0.06	0.1	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	1.19	**0.92**	1.15
Armidale FRNSW	SW07	SW07	16/06/2017	ES1715278	0.05	0.04	0.24	0.02	0.68	<0.02	<0.1	<0.02	0.08	0.03	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	1.17	**0.92**	1.11
Armidale FRNSW	SW08	SW08	8/12/2016	ES1628450	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01
Armidale FRNSW	SW08	SW08	16/06/2017	ES1715278	<0.02	<0.02	0.02	<0.02	0.02	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.04	0.04	0.04
Armidale FRNSW	SW09	SW09	16/06/2017	ES1715278	0.14	0.13	0.7	0.05	1.88	<0.02	<0.1	0.12	0.21	0.08	0.08	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	3.39	**2.58**	3.21

Appendix C
Table 3
Previous analytical results
Groundwater and surface water

					PFAS																														
					Perfluorobutane sulfonic acid (PFBS)	Perfluoropentane sulfonic acid (PFPeS)	Perfluorohexane sulfonic acid (PFHxS)	Perfluoroheptane sulfonic acid (PFHpS)	Perfluorooctane sulfonic acid (PFOS)	Perfluorodecanesulfonic acid (PFDS)	Perfluorobutanoic acid (PFBA)	Perfluoropentanoic acid (PFPeA)	Perfluorohexanoic acid (PFHxA)	Perfluoroheptanoic acid (PFHpA)	Perfluorooctanoic acid (PFOA)	Perfluorononanoic acid (PFNA)	Perfluorodecanoic acid (PFDA)	Perfluoroundecanoic acid (PFUnDA)	Perfluorododecanoic acid (PFDoDA)	Perfluorotridecanoic acid (PFTrDA)	Perfluorotetradecanoic acid (PFTeDA)	Perfluorooctane sulfonamide (FOSA)	N-Methyl perfluorooctane sulfonamide (MeFOSA)	N-Ethyl perfluorooctane sulfonamide (EtFOSA)	N-Methyl perfluorooctane sulfonamidoethanol (MEFOSE)	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE)	N-Methyl perfluorooctane sulfonamidoacetic acid (MeFOSAA)	N-Ethyl perfluorooctane sulfonamidoacetic acid (EtFOSAA)	4:2 Fluorotelomer sulfonic acid (4:2 FTS)	6:2 Fluorotelomer Sulfonate (6:2 FTS)	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	10:2 Fluorotelomer sulfonic acid (10:2 FTS)	PFAS (Sum of Total)	Sum of PFHxS and PFOS	PFAS (Sum of Total)(WA DER List)
					µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL					0.02	0.02	0.02	0.02	0.01	0.02	0.1	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.05	0.02	0.05	0.05	0.05	0.05	0.02	0.02	0.05	0.05	0.05	0.05	0.01	0.01	0.01
PFAS NEMP 2018 Freshwater 95%									0.13[#1]						220[#1]																				
PFAS NEMP 2018 Health Drinking Water															0.56																			0.07	
PFAS NEMP 2018 Health Recreational Water															**5.6**																			**0.7**	
Site_ID	**Location_Code**	**Field_ID**	**Sampled_Date_Time**	**Lab_Report_Number**																															
Armidale FRNSW	SW10	SW10	16/06/2017	ES1715278	0.12	0.1	0.55	0.05	1.85	<0.02	<0.1	0.11	0.18	0.08	0.07	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	3.11	**2.4**	2.96
Armidale FRNSW	SW11	SW11	16/06/2017	ES1715278	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.02	0.02	0.02
Armidale FRNSW	SW12	SW12	16/06/2017	ES1715278	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.1	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.02	0.02	0.02
Armidale FRNSW	SW13	SW13	14/06/2017	ES1715278	0.61	0.68	3.55	0.35	4.67	<0.02	<0.1	0.21	1.14	0.32	0.36	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	11.9	**8.22**	10.9
Armidale FRNSW	SW14	SW14	14/06/2017	ES1715278	0.04	0.03	0.21	<0.02	0.25	<0.02	<0.1	<0.02	0.02	<0.02	0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.56	0.46	0.53
Armidale FRNSW	SW15	SW15	14/06/2017	ES1715278	0.04	0.03	0.18	<0.02	0.2	<0.02	<0.1	<0.02	0.03	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.48	0.38	0.45
Armidale FRNSW	SW16	SW16	16/06/2017	ES1715278	0.11	0.1	0.52	0.04	1.94	<0.02	<0.1	0.11	0.18	0.06	0.07	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05	<0.02	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	3.13	**2.46**	2.99

Env Stds Comments

#1:95% species protection - slightly to moderately disturbed systems

Data Comments

#1 Quantification of linear and branched isomers has been conducted as a single total response using the relative response factor for the corresponding linear/branched standard.

GHD

Level 3
22 Giffnock Avenue
T: 61 2 9239 7100   F: 61 2 9239 7199   E: sydmail@ghd.com

21-SO1-314015432-11/https://projects.ghd.com/oc/sydney2/frnswsiteimprovement/Delivery/Documents/2127877_REP site improvement plan - Armidale.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	A Walker	M Clough		J Hallchurch		22/02/2019

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