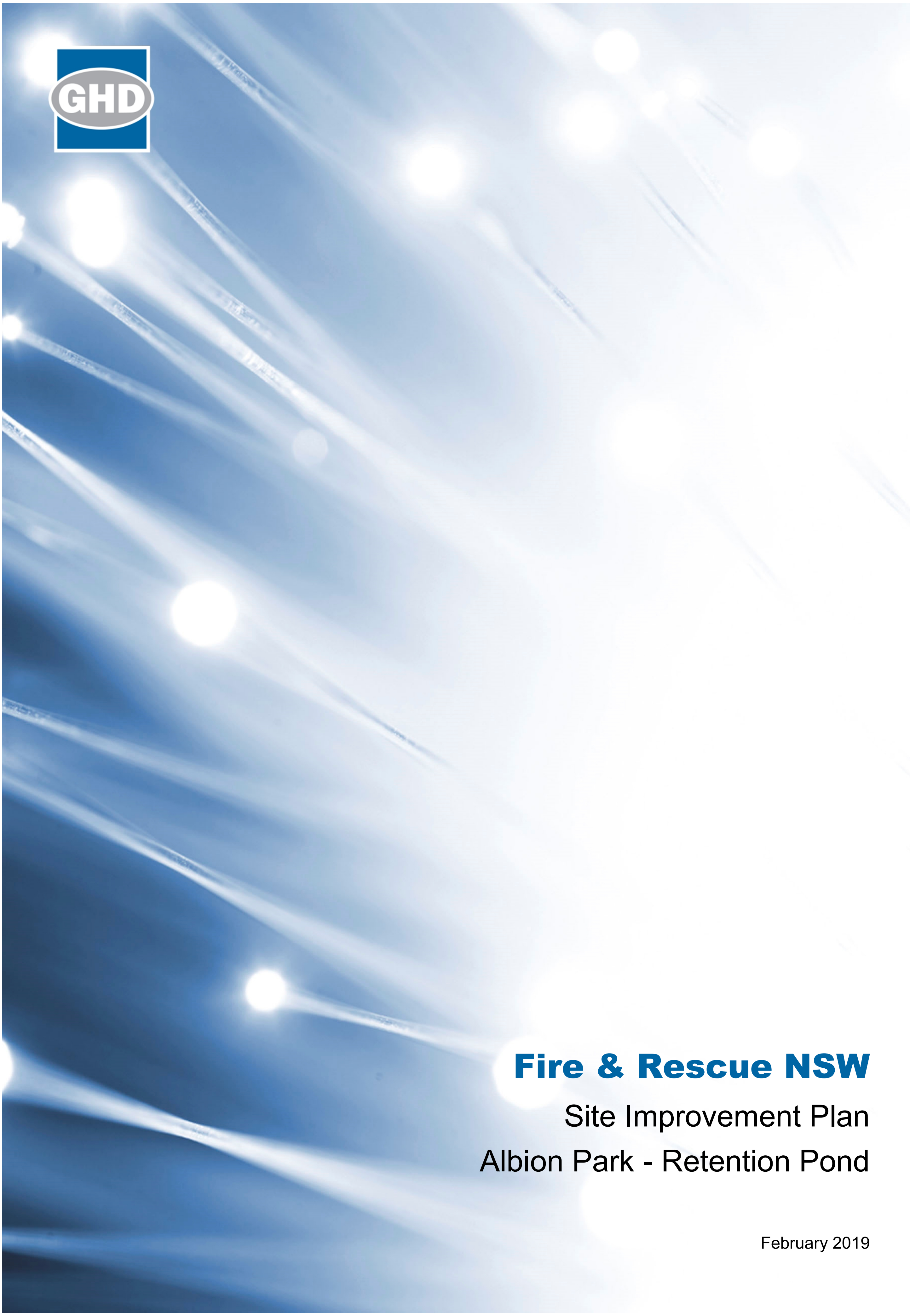

Fire & Rescue NSW

Site Improvement Plan

Albion Park - 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 Albion Park FRNSW training facility, located within Lot 10 DP 1157377 at Airport Road, Albion Park Rail NSW 2527 (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) Albion Park PFAS Investigation, Preliminary Site Investigation and Sampling and Analysis Quality Plan, August 2016 (the PSI).
- GHD (2017a) Fire & Rescue NSW, Albion Park Training Facility, Environmental Site Assessment. April 2017.
- GHD (2017b) Fire & Rescue NSW, Albion Park Training Facility, Phase 2 Environmental Site Assessment. October 2017.
- GHD (2018) Fire and Rescue NSW, Albion Park, Lake Illawarra Biota Sampling, August 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) Albion Park 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 risks posed by the presence of PFAS contamination remaining within the sediments and water in the on-site retention basin adjacent to the former fire training area.
- Provide recommendations to manage potential long term risk 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 DSI (GHD, 2017b) was 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 DSI. 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.

A targeted biota sampling program was completed in 2018 to assess potential risks to human health associated with the consumption of seafood caught in the Lake. Further discussion on the potential source – pathways – receptor linkages, including off-site aquatic environments is provided in Section 4.1.

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.

Analytical results from previous investigations for PFAS have been provided in Appendix C, with updated relevant guidelines based on those used in the DSI reports (GHD, 2017a; GHD, 2017b). GHD notes that results from all areas of the site have been screened against all criteria considered applicable to the investigation, and caution should therefore be applied in interpreting noted exceedances. In particular, sediment samples have been included with soil results, however there are no approved guidelines for the assessment of PFAS in sediments.

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, such as recommending placing a notation or covenant on the property title or a notation on an 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

Key features of the area occupied by FRNSW include the administration buildings and site offices and the main fire training area located to the south of the main driveway to the site. The fire training area was primarily covered with asphalt and GHD understands that the area has not been re-surfaced for at least five years.

One of the main features on-site is a pond, of dimensions 13 m by 37 m (based on aerial photographs). This pond has been referred to as a "surface water retention basin" which receives water draining from the fire training area. However, there is some doubt over whether it was constructed specifically to act as a stormwater retention pond. A review of the historical aerial photos suggest it was built in conjunction with the training facility and therefore more likely to be a specific part of the facility. This is discussed further in Section 6.1.

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

3.1 Site setting

The main features of the Albion Park site setting 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	Airport Road, Albion Park Rail, NSW 2527 (Part of Lot 10, DP 1157377) In close proximity to Lake Illawarra.	Located near a significant recreational area and ecosystem. Humans consume edible biota from the Lake.
Geology and hydrogeology	Quaternary porous sediment aquifer over deeper fractured rock aquifer. Groundwater is likely to flow towards the Lake to the east. No extractive use of groundwater down gradient of the site. Groundwater is generally brackish to saline. Salinity likely to increase towards the Lake.	Shallow aquifer may be more transmissive than the deeper one and is likely to discharge into the Lake. Salinity is a significant controller of PFAS solubility and, therefore, fate and transport.
Hydrology	The site has a surface water retention pond located in the north-eastern corner of the site, receiving onsite surface water drained through a variety of constructed drains. Onsite drains take water off-site to an unnamed tributary of Albion Creek, located approximately 420 m north of the investigation area. Albion Creek discharges in Lake Illawarra approximately 650 m east of site.	Surface water drains may be a significant migration pathway off-site and into Albion Creek and thence to the Lake.

Aspect	Summary	Potential management issues
Contaminants of concern	PFAS – notably PFOS, PFHxS, PFOA. Identified in soil, sediment, groundwater and surface water onsite and off-site. PFAS can sorb to soil and sediments; is water soluble, leachable and resistant to degradation; is possibly toxic to animals and humans; bioaccumulates in the food chain; have long half-lives in humans and a 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 have 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 pond and site soils/sediments. The highest PFAS in groundwater was found in a well adjacent to the pond. The retention pond contains elevated PFAS and PFAS is widespread in soils and drains.	The site, therefore, remains a potential source of PFAS contamination to off-site receptors.

3.2 Previous analytical results

As discussed in Section 2.1, the DSI was conducted prior to the release of the NEMP (2018). A summary of previous analytical results, with reference to current guidelines is therefore provided in Appendix C for completeness, however interpretation of the results was beyond the scope of this site improvement plan. Investigation locations are shown on Figure 3, Appendix A.

General findings from the DSI (GHD, 2017b) are summarised in the following subsections.

3.2.1 Soils and sediment

- The concentration of PFAS was greater than the laboratory limit of reporting (LOR) in soil samples across the site.
- Sediment sample SS05 had the highest PFAS concentrations in sediment across the site. This was taken from the retention pond.
- All off-site sediment samples reported detects of PFAS with the exception of SS02 and SS06. This indicated that PFAS is likely to be migrating off-site via the surface water drainage pathways.
- Leachability testing confirmed that PFAS impacted soils and sediments have the potential to release PFAS to the environment at concentrations exceeding the nominated screening levels.

3.2.2 Groundwater and surface water

- Standing water levels in on-site wells were recorded to be between 2.61 m below the top of well casing (mTOC) in GW04 and 3.35 mTOC in GW02. The general groundwater flow direction was inferred to be towards Lake Illawarra in the north-east.
- The highest concentration of PFAS contamination in groundwater was GW03 located adjacent to the retention pond.
- The highest value of PFAS on-site was from the surface water retention pond in the north-eastern corner of the fire training ground.
- PFAS was detected in all the surface water drainage lines downstream of the retention pond.
- PFAS was detected down gradient in Albion Creek and its unnamed tributary adjacent to Poplar Avenue.
- Levels of PFAS in surface water decreased with increasing distance from site.
- PFOS was detected close to the laboratory LOR in sediment from SS07. This location is a tributary to the north of Albion Creek suggesting potentially another unconfirmed source of PFAS.

3.2.3 Off-site biota sampling

Biological sampling of aquatic biota was conducted within the southern portion of Lake Illawarra, following the detection of PFAS in sediments and surface water along Albion Creek and in the southern reach of Koona Bay (GHD, 2017b). The focus of the sampling program was to assess potential risks to human health associated with the consumption of aquatic biota from Lake Illawarra. The assessment did not consider potential risks to ecological receptors.

The scope of works was developed in consultation with NSW Department of Primary Industries – Fisheries (NSW DPI) and the NSW Environment Protection Authority (EPA) and included the collection of aquatic organisms which were of high commercial and recreational value including mud ark, yellowfin bream, dusky flathead, luderick, sea mullet and blue swimmer crabs. In addition to biota samples, surface water and sediment samples were collected from the southern half of Lake Illawarra in May 2018.

The results are summarised as follows:

- PFAS were not reported in surface water or sediment samples collected as part of the biota sampling program of works
- PFOS was the only PFAS compound detected in biota samples, with concentrations ranging from <0.5 μg/kg to 2.1 μg/kg. The results were below the FSANZ (2017) trigger points derived for fish (5.2 μg/kg) and crustaceans (65 μg/kg)

Based on the outcomes of the works, it was concluded that the potential risk to human consumers of the species considered as part of the works was low and acceptable.

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) and updated based on the additional biota data collected in May 2018. This has been provided as Table 4-1 in this report, and as a pictorial CSM 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	Dermal contact	FRNSW and wider training facility commercial workers and intrusive maintenance workers.	Unlikely – PFAS impact detected in all shallow soil samples from this area (all onsite locations) however impact was below the adopted assessment criteria.
	Vertical/horizontal migration of leachate through unsaturated zone	Groundwater – subsequent migration in groundwater (secondary).	Yes – PFAS impact in GW03 and GW04, down-gradient of training facility (noting groundwater flow was inferred to be in a north-easterly direction, and noting data gaps outlined in Section 4.3).
	Surface runoff and sediment transport	Surface waters (including drainage systems – secondary pathway).	Yes – PFAS detected in sediment and surface water samples from drainage lines associated with this area.
		Off-site ecological.	Yes – off-site surface water indicate PFAS impact above ecological screening criteria, which is likely to be associated with the FRNSW site (noting data gaps outlined in Section 4.3).
Surface water retention pond	Dermal contact and ingestion	FRNSW and wider training facility commercial workers.	Unlikely – PFAS impact present exceeding drinking water and recreational criterion at SW05. However, the retention pond is enclosed by a fence and locked, therefore access is limited.
	Vertical/horizontal migration of water through unsaturated zone	Groundwater – subsequent migration in groundwater (secondary).	Yes - PFAS impact in GW03, GW04 and GW05, down-gradient of training facility (noting groundwater flow was inferred to be in a north-easterly direction, and noting data gaps outlined in Section 4.3).
		Down gradient surface waters.	Yes – PFAS impact reported at Albion Creek and at the outlet to Koona Bay down-gradient of the site (noting data gaps outlined in Section 4.3).

Potential Source	Primary pathway	Receptor	Pathway present?
Surface Water off-site – Albion Creek and Lake Illawarra	Dermal contact and ingestion	Down gradient surface waters.	Yes – PFAS impact reported at Albion Creek and at the outlet to Koona Bay down gradient of the site. Based on the results of biota sampling, GHD concluded that the potential risk to human consumers of the species was considered to be low and acceptable.
	Down gradient ecological receptors	Down gradient surface waters.	Yes – PFAS impact reported at Albion Creek and at the outlet to Koona Bay down gradient of the site.in sediments, surface water and leachate. PFAS detected in biota samples.
Contaminated groundwater	Vertical/horizontal migration	Down gradient surface waters recharged by groundwater.	Yes – GW03 and GW04 have PFAS impact above adopted assessment criteria off-site.
		Abstraction bores (stock and/or domestic use).	Unlikely – There are no known user of groundwater down gradient of the site.

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 via surface water and groundwater. However, risks to human health associated with the consumption of aquatic species from Lake Illawarra are considered to be low and acceptable based on the outcomes of the targeted biota sampling program (GHD, 2018).

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

4.3 Site investigation data gaps

Based on a review of the S-P-R linkages in Table 4-1, actions that could be further undertaken to aid development of the site CSM include:

- Delineation of groundwater impact up-gradient and down-gradient of the site. Installation of additional groundwater monitoring points will also aid in understanding the hydrogeological conditions at the site.
- Assessment of other potential sources of PFAS in the local area, noting that PFAS was detected in the most up-gradient groundwater monitoring locations, including consideration of additional information for the airport (up gradient of the site) and the Rural Fire Service property (cross gradient of the site).
- Installation of groundwater data loggers in selected wells to determine tidal/seasonal influences on groundwater movement at the site.

- Further understanding local community water use to adequately characterise risk from groundwater impact. In particular, the poultry farm in close proximity to the site should be assessed to close out possible risk to this receptor.

4.4 Drivers for site management

Based on the analytical results and site CSM, there appears to be a potential risk to off-site ecological receptors of Albion Creek and Lake Illawarra. However, biota sampling indicated that the potential risk to human consumers of the species considered as part of the works, was low.

Additionally, discussions with FRNSW indicated that the site lease may be terminated in the future (before 2027). The site will then be handed back to Shellharbour City Council ('Council' [the site owner]) under the lease condition that the site will be "made good".

Overall, the main driver for site management and to support future site lease termination therefore include:

- The prevention of any further migration of PFAS from onsite sources to the off-site environment.

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 remediation strategy for the site, GHD has undertaken an assessment of the various available remediation 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 onsite 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 water and sediment and site soils. The extent of soil contamination may be relatively limited. Groundwater contamination appears limited in extent and largely retained onsite. Off-site groundwater maybe impacted through infiltration of PFAS from drains rather than large scale migration.
- Soil and groundwater contamination remediation is not required to be addressed at this stage as their impacts to off-site receptors is considered negligible. However, a more systematic soil assessment across the site is recommended.

The main driver for management is the prevention of any further migration of PFAS from onsite sources to the off-site environment, focussing on surface water migration. Addressing the main source of PFAS contamination onsite (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 pond.

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. Based on the data collected in previous investigations, the mass in the retention pond has the most likely potential to provide PFAS mass to migrate off-site and impact onsite drainage lines and groundwater as well as off-site drains and surface water bodies. These are readily accessible at the surface onsite 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. Although there are some exceedances of the NEMP 2018 human health criteria for public open space (as shown in Table 1, Appendix C), this landuse is not currently realised onsite. 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 management has not been considered further in this report, as it does not contribute to the mass of PFAS in the retention pond and does not appear to be a major contributor to the risk to ecosystems. 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. 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.	PFAS can migrate considerable distances and discharge into Lake Illawarra. There it may partition into sediments near the mouth and potentially expose benthic organisms to PFAS, which in turn can be predated by more migratory species. Concentration of PFAS in the lake water are likely to be highly diluted and may not be detectable. A gum tree plantation adjacent to the site, may extract groundwater and compounds dissolved in the groundwater, notably PFAS.
Regulatory constraints	Screening criteria for ecological receptors tend to be very low. The criteria protective of human consumption of impacted biota and ecosystem protection is generally below laboratory LORs. Based on the EnRisk1 (2016) decision tree process for prioritisation, the site is classified as a priority 1 site. Waste disposal criteria for PFAS were not available at the time of DSI reporting.	Achieving concentration below some criteria is impractical. 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.

[1] EnRisk (2016) Proposed decision tree for prioritising sites potentially contaminated with PFAS. 25 February 2016

	Summary	Discussion
Management constraints	PFAS can be destroyed thermally but at very high temperatures i.e. >1400 ^{o}C. Many other technologies have been tested at bench scale but not full scale. There are methods 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) and are considered in Section 7 of this report.
Land ownership	Land parcel is owned by Shellharbour City Council. The site leased by FRNSW for use as a training facility. The site has been occupied by FRNSW since 1997. In an email from Council to FRNSW (dated 4 December 2018) Shellharbour Council noted that “the drainage line linking overflow from the retention basin to ‘the pit’ is on a Council reserve which contains significant biodiversity, for which there is a management plan. Any impact on the drainage line will require further ecological assessment and/or conditions”.	Land works will require the permission of Council and additional biodiversity management for any off-site works on the reserve area.

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;

- FRNSW confirmed that Council are happy for the pond to be decommissioned, as long as there is adequate drainage.
- FRNSW installed the pond 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 2027, however FRNSW do not plan to remain on-site for the full rental term. It is assumed that the site would need to be returned to its original condition, however the extent of this phrase has not been confirmed in regards to addressing the identified site contamination.
- Considering the above, FRNSW do not want to have to do multiple rounds of remediation on the retention pond. FRNSW are seeking a long term solution.
- Timeframe goals of possible remediation strategies depends on liability for FRNSW. However, FRNSW also need to address the retention pond close to the end of the 2018/2019 financial year to meet commitments made to the Council.
- 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 options based on long term site needs.

6. Retention pond strategy options

6.1 Retention pond profile

6.1.1 Pond and retention basin features

Based on review of aerial photographs and local topography noted during site visits, the retention basin area is considered to extend beyond the foot print of the pond. The assumed retention basin foot print is shown in Figure 6-1. The improvement works outlined in this document focusses on addressing surface water associated with the pond within the retention basin area.

Figure 6-1 Retention basin outline

The surface area of the pond is approximately 481 m^2 (based on dimensions of 13 m by 37 m). For the purpose of this document, an average depth of 1 m to 2 m has been assumed. The volume of the pond would therefore range from 481 m^3 to 962 m^3 (480,000 L to 962,000 L). A photograph of the pond is shown in Figure 6-2.

Figure 6-2 Pond (July 2016), showing the fire training area on the left.

6.1.2 Current functionality

The basin currently receives onsite surface water runoff, drained through a variety of constructed above ground drains, as shown in Figure 6-2. The pond then drains off-site to a tributary of Albion Creek via surface overflow and then via an underground drainage network.

A preliminary assessment of the basin indicates that it has not been adequately designed to perform the functions of a detention or retention basin, as indicated by limited overflow capacity/design and its permanent retention of water as shown in Figure 6-2 (i.e. no capacity to hold additional stormwater).

FRNSW has advised that the retention basin (or a similar feature) is not required on-site for training facility operations (refer to Section 5.3). Shellharbour Council have also advised that they do not have any specific need to preserve the retention basin, and that “the pond offers limited stormwater benefit” (email from Council forwarded to GHD via FRNSW, 4 December 2018). There are no current plans from Council to modify any of the stormwater infrastructure within the property.

There is a possibility that the pond 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 significant PFAS source is likely to outweigh the advantages of possible general water quality improvement.

6.2 Pond improvement goals

PFAS target

The overarching aim of these works is to reduce the mass of PFAS associated with the retention pond 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 be made suitable for its intended end of lease.

Costs

FRNSW is seeking a cost-efficient solution to meet the overall project objectives, especially considering the potential need for further site improvement works to meet conditions of the site lease.

Time frame

Based on the outcomes from a teleconference between FRNSW and GHD, any works being conducted on-site need to be completed prior to 2027 (end of lease agreement). However, to meet FRNSW commitments to Council, works on the retention pond need to be started prior to the end of the 2018/2019 financial year.

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 pond are shown in Figure 6-3. Each option would require a staged approach with further options in the final form of the retention pond 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 capture 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.

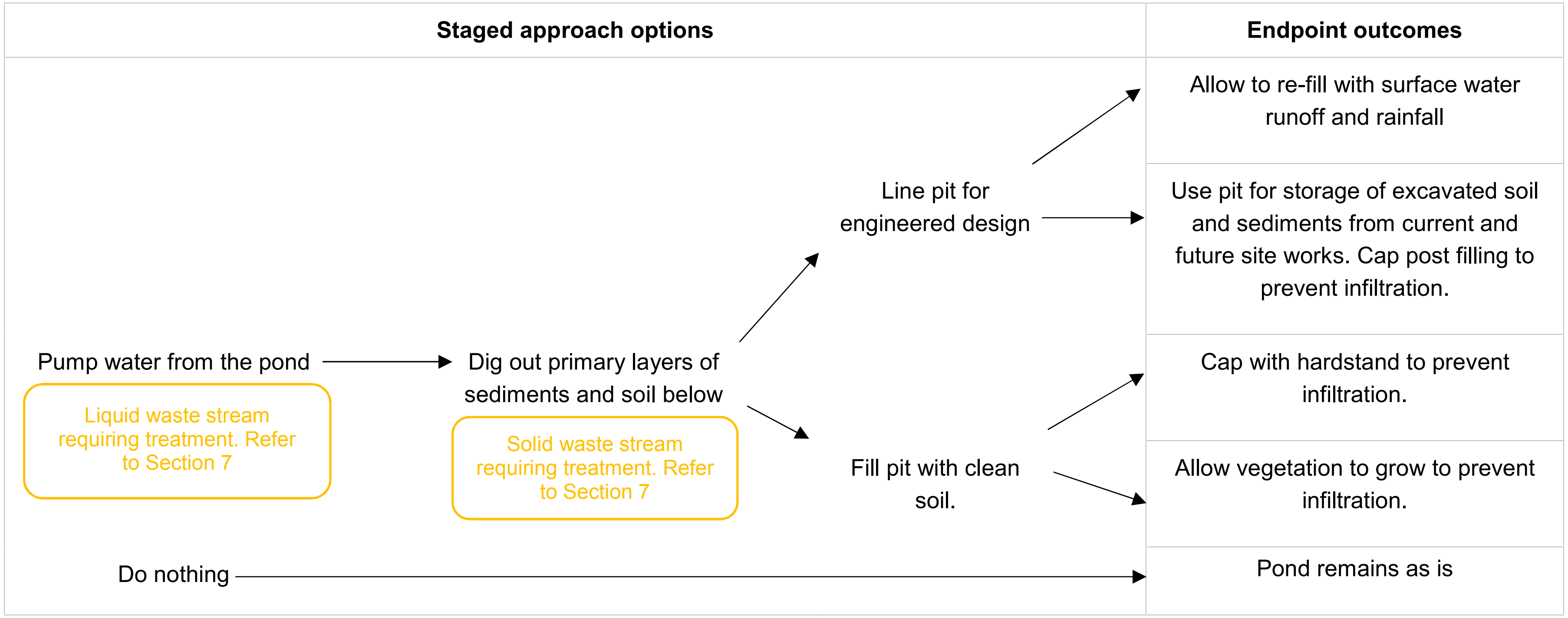


Figure 6-3 Flow chart showing pond option approaches

Table 6-1 Evaluation of end point improvement options for the retention pond

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
Implementation 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 management options assessment was undertaken to assess potential technologies and their applicability to the site. This report is provided in Appendix B. The assessment first considered a large number of 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.

7.1 Indicative cost estimates

Indicative costs of various treatment methods are provided in *Section 6* of the Options Assessment Report (GHD, 2018) 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 (end of lease, 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 off-site 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 Roles and responsibilities

The main roles and responsibilities of the main stakeholders in this process are summarise in

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

Title	Company/Organisation	Roles and responsibilities
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
Regulator	NSW EPA	Providing planning approvals for the works where required
Council	Shellharbour City Council	Providing planning approvals for the works where required
Water Authority	Sydney Water	Providing trade waste agreement and water discharge approvals

8.3 Implementation plan

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

Table 8-2 Decommissioning approach

Step	Task/Action	Comments
1 Preliminary tasks	Approvals – EPA and Council, Sydney water	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.

Step	Task/Action	Comments
	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.
	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 ponds	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	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.

Step	Task/Action	Comments
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) have been 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 Sydney Water 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 Council will be required prior to lodgement of the development application, given that the site is leased from Council. Subsequently, 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:

- Sydney Water if it is proposed to dispose of the treated waste water to sewer or stormwater.
- NSW EPA and Council if a containment cell is to be built onsite.
- 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

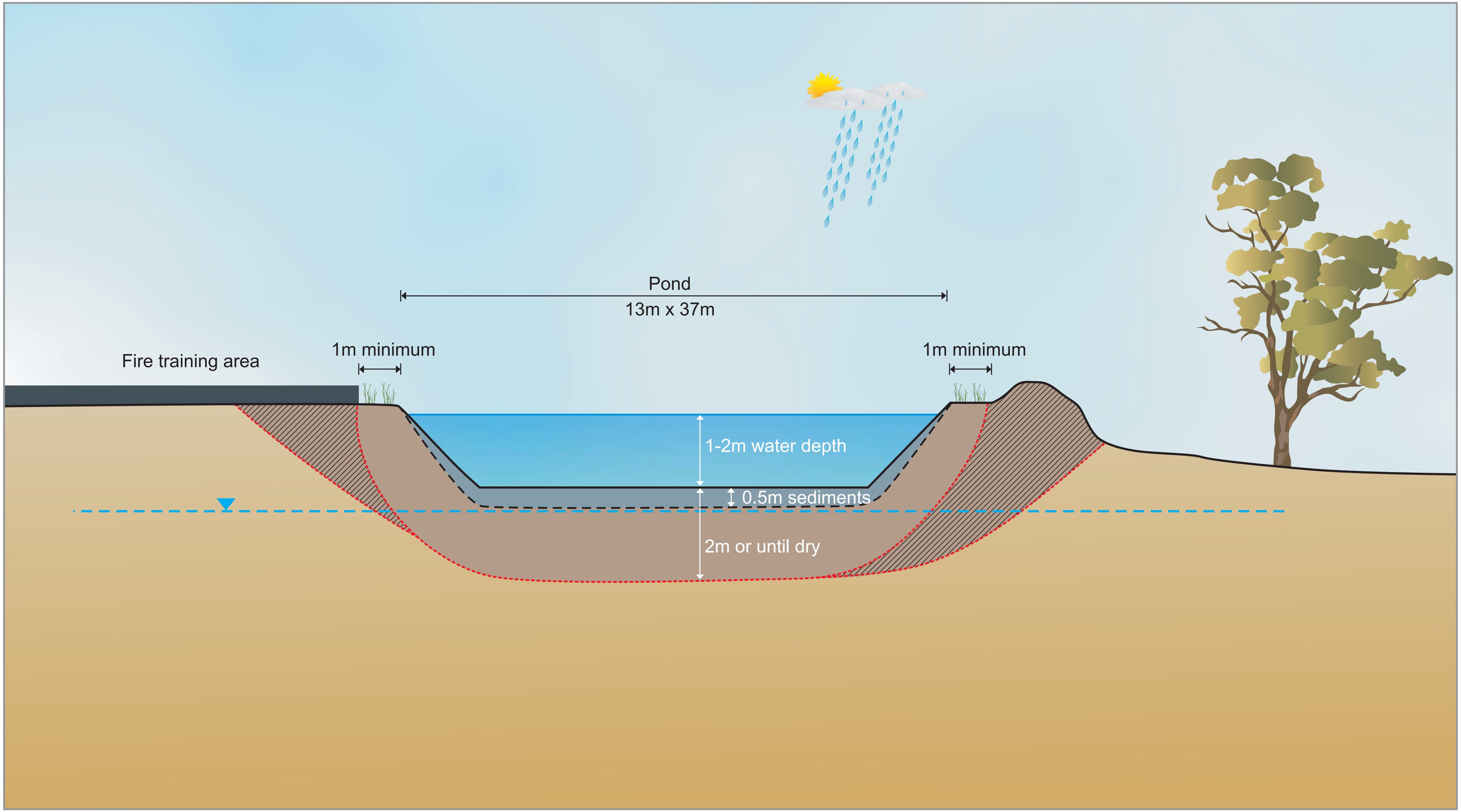
Earthworks should be staged to consider the following:

- 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;
- Site reinstatement– refer to Section 8.3.6.

Excavation Footprint

The surface area of the pond is approximately 481 m^2 (based on dimensions of 13 m by 37 m). Although not directly measured, for the purpose of this report, 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 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

2016 groundwater level in GW03

Fire & Rescue NSW
Albion Park Site Improvement Plan

Conceptual Site Model

Job Number	21-27877
Revision	A
Date	13 Feb 2019

Figure 8-1

GHD\Launceston\Projects\21\27877\2127877_LTN_03.cdr

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

- The volume of the soil and sediment in situ to be excavated is approximately 1274 m^3 to 1378 m^3
- Based on the silty sand, sandy clay and clay encountered in GW03 during the DSI (GHD, 2017b) bulking factors between 20% and 40% are possible (Engineering ToolBox, 2009), which results in an ex-situ volume range of approximately 1654 m^3 to 1929 m^3 based on the maximum in-situ volume calculated above.

The closest groundwater monitoring location is GW03, located approximately 5 m to the east of the pond. In December 2016, the groundwater at this location was measured to be 2.7 m below top of casing (m bTOC). It is therefore possible that groundwater may be encountered during the excavation.

Any water entering the excavation via seepage or as rainfall would require treatment as for the main volume of pond water. 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 along with the excavated and dried sediment and soil. 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 (e.g. 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 Section 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.

The location and dimensions of the cell must be surveyed to Map Grid Australia (MGA) coordinates and the coordinates stored on site in a document that is readily available for inspection.

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 undertaken in conjunction with the pond improvement works:

1. **Additional site improvement works – cost/benefit opportunity**

If it is determined that the site requires additional remediation (such as soil and hard stand treatment) to end the property lease, it may be best to action the pond improvement works as part of the entire site decommissioning.

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 primary source of PFAS at the site, however there is some evidence to suggest groundwater migration is also occurring with possible receptors down gradient. Additionally, there are other potential PFAS source up-gradient and cross gradient of the site which could be assessed, as discussed in Section 4.3.

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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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

- Site Boundary
- Streets
- Major Waterways
- Minor Waterways

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
Albion Park Site Investigation

Job Number 21-25583
Revision A
Date 21 Feb 2017

Site Location and Key Off-site Receptors

Figure 1

G:\21\25583\GIS\Maps\Deliverables\Albion Park\21_25583_Z001_AlbionPark_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 - Google Earth Pro; Streets, Waterways - NSW LPI 2012 DTDB. Created by:mweber

LEGEND

- Site Boundary
- Cadastre
- Environmentally Sensitive Land
- Streets
- Major Waterways
- Minor Waterways
- Inferred Surface Drainage (Aboveground)
- Inferred Surface Drainage (Underground)

Paper Size A4

0 20 40 80 120

Metres

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

N

GHD

Fire & Rescue NSW
Albion Park Site Investigation

Job Number 21-25583
Revision A
Date 17 Feb 2017

Site Layout

Figure 2

G:\21\25583\GIS\Maps\Deliverables\Albion Park\21_25583_Z002_AlbionPark_SiteLayout.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: 17/02/17); Streets, Waterways - NSW LPI 2012 DTDB. Created by:mweber

LEGEND

Site Boundary	Inferred Surface Drainage (Underground)
Streets	Groundwater Monitoring Well (GHD, 2016) (5)
Major Waterways	Soil Borehole (GHD, 2016) (10)
Minor Waterways	Sediment Sample Location (GHD, 2016) (5)
Inferred Surface Drainage (Aboveground)	Surface Water Sample Location (GHD, 2016) (5)

0 10 20 40 60 80 100
Metres

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

N

Fire & Rescue NSW
Albion Park Site Investigation

Job Number	21-25583
Revision	A
Date	17 Feb 2017

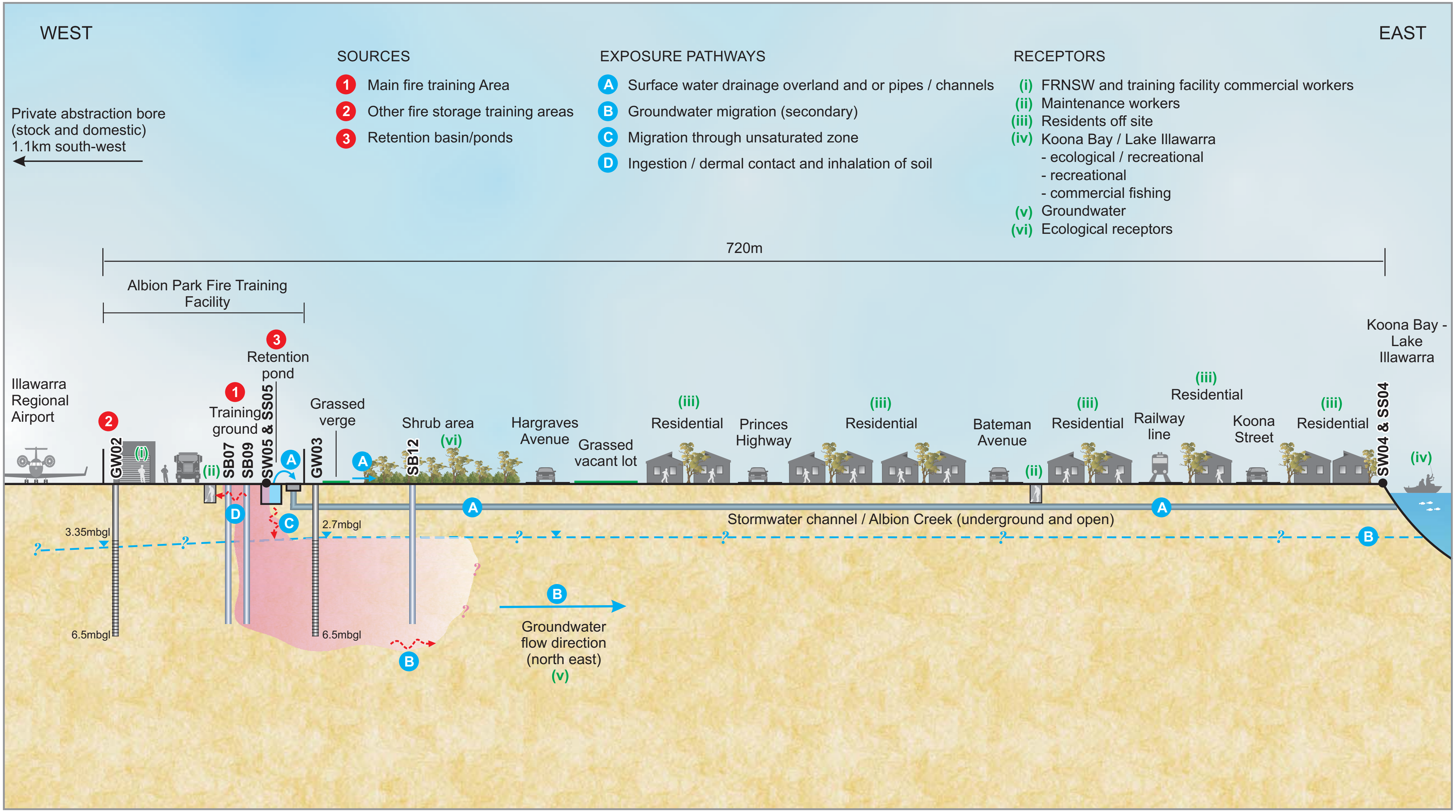
Investigation Locations

Figure 3

G:\21\25583\GIS\Maps\Deliverables\Albion Park\21_25583_Z004_AlbionPark_InvestigationLocations.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 2017; Streets, Waterways - NSW LPI 2012 DTDB. Created by:mweber



Conceptual diagram only - not to scale

LEGEND

- Sandy CLAY
- Groundwater table
- Surface water flows
- PFAS impact
- Sample location
- Migration
- Soil bore
- Piezometer (groundwater well)
- Screen

Fire & Rescue NSW
Albion Park Fire Training Centre

Conceptual Site Model

Job Number	21-25583
Revision	A
Date	20 Feb 2017

Figure 4

GHD\Launceston\Projects\21\25583\2125583_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

Appendix B – GHD Options assessment report

20 December 2017

Melanie Stutchbury
Fire & Rescue NSW
1 Amarina Ave
Greenacre NSW 2190

Our ref: 21/25583 221170
Your ref:

Dear Sir/Madam

Albion Park 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 Albion site, located at Airport Road, Albion Park, NSW 2527 (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) *Albion Park 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, Albion Park 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, Albion Park Training Facility, Phase 2 Environmental Site Assessment*. October 2017.

The results of the two ESAs included:

- Standing water levels in on-site wells were recorded to be between 2.61 mTOC (GW04) and 3.35 mTOC (GW02). The general groundwater flow direction was inferred to be towards the north-east.
- Analysis of the soil and sediment samples **<u>on</u>-site** indicated the following:
  - Only one onsite soil sample (SB09_0.0_0.1) reported PFAS above the residential human health screening criteria. It was, however, below the industrial/commercial criteria.
  - Sediment sample SS05 had the highest PFAS concentrations in sediment across the site. This was taken from the retention pond.
- Analysis of the soil and sediment samples **off-site** indicated the following:
  - Four soil samples had concentrations of PFHxS and PFOS (sum of total) above the nominated human health screening criteria at GW03, SB12, SB14 and SB15 collected during the December 2016 ESA. The screening criteria is highly conservative for residential when the area is open space. These samples were taken from the adjacent commercial property and the gum tree plantation east of the site indicating soil access by the public may be limited.
  - Two samples report concentrations of PFOS above the nominated ecological screening criteria at GW03 and SB15 collected during the December 2016 ESA.
  - All off-site sediment samples reported detects of PFAS with the exception of SS02 and SS06. This indicates that PFAS is likely to be migrating off-site via the surface water drainage pathways.

- Leachability testing confirmed that PFAS impacted soils and sediments have the potential to release PFAS to the environment at concentrations exceeding the nominated screening levels.
- Analysis of the groundwater and surface water samples indicated the following:
  - The highest concentration of PFAS contamination in groundwater was GW03 located adjacent to the retention pond.
  - GW01 to GW05 exceed drinking water criteria with GW01, GW02 and GW03 exceeding the recreation criteria and GW01, GW02. GW03 and GW04 exceeded the ecological screening criteria.
  - The highest value of PFAS contamination on-site is from the surface water retention pond in the north-eastern corner of the fire training ground.
  - PFAS was detected in all the surface water drainage lines leading from the retention pond.
  - PFAS is detected down gradient in Albion Creek and its unnamed tributary adjacent Poplar Avenue.
  - Levels of PFAS in surface water decrease with increasing distance from site.
  - Concentrations of PFAS in a surface water sample near the discharge point of Albion Creek to Lake Illawarra exceeded ecological guidelines.
  - PFAS was detected in surface water in all the surface water drainage lines leading from the retention pond.
  - Levels of PFAS in surface water decrease with increasing distance from site.
  - Concentrations of PFAS in a surface water sample near the discharge point of Albion Creek to Lake Illawarra exceeded ecological guidelines in December 2016. However, was below the laboratory LOR in May 2017.
  - SW08 and SW09 surface water samples collected in Koona Bay, Lake Illawarra were below the nominated ecological guidelines.
  - PFOS was detected close to the laboratory LOR in sediment from SS07. This location is a tributary to the north of Albion Creek suggesting potentially another unconfirmed source of PFAS.

3.2 Site setting and constraints

The main features of the Albion 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	In close proximity to Lake Illawarra.	Located near a significant recreational area and ecosystem. Humans consume edible biota from the Lake.

Aspect	Summary	Issues
Geology and hydrogeology	Quaternary porous sediment aquifer over deeper fractured rock aquifer. Groundwater is likely to flow towards the Lake to the east. No extractive use of groundwater downgradient of the site. Groundwater is generally brackish to saline. Salinity likely to increase towards the Lake.	Shallow aquifer may be more transmissive than the deeper one and is likely to discharge into the Lake. Salinity is a significant controller of PFAS solubility and therefore, fate and transport.
Hydrology	The site has a surface water retention pond located in the north-eastern corner of the site, receiving onsite surface water drained through a variety of constructed drains. Onsite drains take water offsite to Albion Creek which flows into Lake Illawarra.	Surface drains may be a significant migration pathway offsite and into Albion Creek and thence to the Lake.
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 pond and site soils/sediments. The highest PFAS in groundwater was found in a well adjacent to the pond. The retention pond contains elevated PFAS and PFAS is widespread in soils and drains.	The site, therefore, remains a potential source of PFAS contamination to offsite receptors.

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.	PFAS can migrate considerable distances and discharge into Lake Illawarra. There it may partition into sediments near the mouth and potentially expose benthic organisms to PFAS, which in turn can be predated by more migratory species. Concentration of PFAS in the lake water are likely to be highly diluted and may not be detectable. A gum tree plantation adjacent to the site, may extract PFAS from 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. Based on the EnRisk[1] (2016) decision tree process for prioritisation, the site is currently classified as a priority 1 site	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 methods 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 **Error! Reference source not found.**.

3.3 Summary

The information presented above indicated that the site is a likely source of offsite PFAS contamination.

4 Management drivers

Based on the limited data set, there appears to be a risk to offsite ecological receptors and potentially human recreational users of Albion Creek and Lake Illawarra. The presence of PFAS in offsite media also poses a potential reputational risk for FRNSW.

[1] EnRisk (2016) Proposed decision tree for prioritising sites potentially contaminated with PFAS. 25 February 2016

GHD concludes that:

- Impacted PFAS sources include the retention pond water and sediment and site soils. The extent of soil contamination may be relatively limited. Groundwater contamination appears limited in extent and largely retained onsite. Offsite groundwater maybe impacted through infiltration of PFAS from drains rather than large scale migration.
- 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 pond) should be a priority to achieve this outcome.
- Soil and groundwater contamination remediation need not be addressed at this stage as their impacts to offsite receptors is considered negligible. However, a more systematic soil assessment across the site is recommended. In case the regulatory authority require more active remediation of these media, a contingency approach has been included in Section 5.4.

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:

- 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 facility for destruction
  - Onsite encapsulation in an engineered facility
  - Onsite treatment with a stabilising agent.

5.2 Groundwater

Groundwater PFAS extent is largely confined to the site and immediate surrounds. GW05 contains low concentrations of PFAS but this may have infiltrated from the nearby drain. Wells downgradient from the site and between the site and receptor (Lake Illawarra) do not contain detectable levels of PFAS.

Remediation of groundwater impacted by PFAS is considered impractical due to the lack of proven, economically viable methods, the relatively limited extent of the PFAS plume, the lack of groundwater use in the area and the relatively low risk posed by groundwater to the ecosystem of Lake Illawarra. The risks posed by the groundwater PFAS concentrations are considered lower than that from the surface water. Consequently, an immediate management response to groundwater contamination is considered a lower priority than the management of surface waters.

Other options for dealing with the risks of groundwater contamination include:

- Institutional restrictions of groundwater extraction e.g. groundwater extraction prohibitions. Such approaches would require approval and implementation by the relevant authorities and may not be greeted favourably by local community. However, these approaches have been successfully implemented in other areas subject to groundwater contamination from a range of sources and would require community consultation and active stakeholder engagement
- Source migration reduction through capping of soils and isolation/removal of surface water and sediment sources.
- Groundwater monitoring plan to include triggers that indicate when the risk profile changes and contingencies should triggers be exceeded.

5.3 Surface water and sediments

The surface water and associated sediments in the retention pond and site drains appear to represent the main potential sources of offsite PFAS impact. A significant mass of PFAS was identified in the surface retention pond water and sediment and PFAS was identified in offsite sediment and surface water.

The mass in the retention pond 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 surface water include:

- Removal and replacement of the existing retention pond. The replacement pond should be engineered to prevent infiltration into the groundwater e.g. concrete or other impermeable lining. This would require the initial removal and treatment of the existing water and sediment and associated contaminated soils. This might impinge on the operational capacity of the site temporarily whilst the works are completed.

- 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.

Of these, only water treatment and disposal was considered for costing as the other options are not considered practical or necessarily available. GHD has obtained quotes from a remediation contractor for the onsite treatment of surface water for the purpose of budget estimates. These are discussed in Section 6.1.

5.3.2 Sediment

Addressing of the sediments in the dams and onsite retention basin require the initial removal and treatment of the surface water (see above). The main options for sediment include:

- Offsite disposal. 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.

An indicative cost estimate is provided for offsite disposal and onsite encapsulation. Treatment and reuse wold 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 site 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 is a short list of methods for further consideration. The options retained for further consideration and discussion in the workshop are listed in Table 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 soils 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 indicative surface water and sediment volumes based on the surface area of the dams.

- The estimated surface water volume for the onsite retention pond is approximately **570,000 L**.
- Sediment within the retention pond is estimated to be in the order of 290 m^3 based on pond surface area of 570 m^2 and an assumed thickness of 0.5 m.

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 retention pond is in the order of **$200,000.** 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.

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.

The indicative cost estimate to dispose of **290 m^3** of dry sediment offsite is in the order of **$75,000**.

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 have 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 for 290 m^3 of sediment is in the order of **$30,000**.

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 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 **Error! Reference source not found.**

Table 4 Indicative management cost estimates

Media	Method	Indicative cost estimate
Onsite Water	Treatment and discharge	$200,000
Onsite Sediment	Offsite disposal	$75,000
	Onsite encapsulation	$40,000

8 Limitations

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

GHD otherwise disclaims responsibility to any person other than FRNSW 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 FRNSW 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 FRNSW with estimates for internal FRNSW 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

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Appendix C – Previous analytical results

Appendix C
Table 1
Previous analytical results - soil and sediment

						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)
						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	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	0.0005	0.0005	0.0002	0.0002	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]																				
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential										**0.01[#2]**																				
Site_ID	**Field_ID**	**Location_Code**	**Sample_Depth_Range**	**Sampled_Date**	**Lab_Report_Number**																									
Albion Park FRNSW	BD3_071216	SB12	0-0.1	07/12/2016	527586	<0.005	-	0.007[#1]	-	0.009[#1]	<0.005	0.006	<0.005	0.008[#1]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	-	-	-	-	<0.005
Albion Park FRNSW	DR1 0.0-0.05	SS10	0-0.05	09/10/2018	621846	<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	<0.005	<0.005	<0.01	<0.01	<0.005
Albion Park FRNSW	DR2 0.0-0.1	SS11	0-0.1	09/10/2018	621846	<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	<0.005	<0.005	<0.01	<0.01	<0.005
Albion Park FRNSW	DR3 0.0-0.1	SS12	0-0.1	09/10/2018	621846	<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	<0.005	<0.005	<0.01	<0.01	<0.005
Albion Park FRNSW	DR4 0.1-0.2	SS13	0.1-0.2	09/10/2018	621846	<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	<0.005	<0.005	<0.01	<0.01	<0.005
Albion Park FRNSW	GW01_0.0_0.2	GW01	0-0.2	06/12/2016	ES1628401	0.0015	0.001	0.0154	0.0015	**0.0193**	<0.0002	<0.001	0.003	0.0042	0.0014	0.0018	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW01_4.0_4.1	GW01	4-4.1	06/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW02_0.5_0.6	GW02	0.5-0.6	06/12/2016	ES1628401	0.0024	0.0014	0.034	0.0007	**0.0263**	<0.0002	<0.001	0.0006	0.0028	0.0002	0.0004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW02_5.0_5.1	GW02	5-5.1	06/12/2016	ES1628401	<0.0002	<0.0002	0.0008	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW03_0.0_0.1	GW03	0-0.1	07/12/2016	ES1628401	0.0147	0.0099	0.14	0.0185	**0.676**	0.0008	0.001	0.0081	0.0323	0.0105	0.0243	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW03_5.0_5.1	GW03	5-5.1	07/12/2016	ES1628401	0.0002	<0.0002	0.0005	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW04_0.5_0.6	GW04	0.5-0.6	08/12/2016	ES1628401	<0.0002	<0.0002	0.0012	<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	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW04_6.0_6.1	GW04	6-6.1	08/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW05_1.6_1.7	GW05	1.6-1.7	08/12/2016	ES1628401	0.0005	0.0003	0.0021	<0.0002	0.0015	<0.0002	<0.001	<0.0002	0.0006	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW05_3.4_3.5	GW05	3.4-3.5	08/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW06_3.0-3.1	GW06	3-3.1	18/05/2017	ES1712281	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW06_6.0-6.1	GW06	6-6.1	18/05/2017	ES1712281	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW07_3.0-3.1	GW07	3-3.1	18/05/2017	ES1712281	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW07_5.0-5.1	GW07	5-5.1	18/05/2017	ES1712281	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW08_2.0-2.1	GW08	2-2.1	18/05/2017	ES1712281	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	GW08_5.0-5.1	GW08	5-5.1	18/05/2017	ES1712281	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	QC1 0.3-0.4	STP1	0.3-0.4	09/10/2018	621846	<0.005	<0.005	<0.005	<0.005	0.009[#1]	<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	<0.01	<0.01	<0.005
Albion Park FRNSW	QC2 0.0-0.1	SS11	0-0.1	09/10/2018	621846	<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	<0.005	<0.005	<0.01	<0.01	<0.005
Albion Park FRNSW	SB06_0.5_0.6	SB06	0.5-0.6	06/12/2016	ES1628401	0.0055	0.007	0.164	0.0506	**3.57**	0.0036	<0.001	0.0036	0.0163	0.0086	0.0599	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0012	0.0018	<0.0012	<0.0012	<0.0012	<0.0012	<0.0005	<0.0005	<0.0005
Albion Park FRNSW	SB06_5.0_5.1	SB06	5-5.1	06/12/2016	ES1628401	0.0153	0.0102	0.0733	0.0032	**0.0226**	<0.0002	<0.001	0.0038	0.0193	0.0043	0.0054	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB07_0.5_0.6	SB07	0.5-0.6	05/12/2016	ES1628401	<0.0002	<0.0002	<0.0002	<0.0002	0.0035	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB07_3.0_3.1	SB07	3-3.1	05/12/2016	ES1628401	<0.0002	<0.0002	0.0005	<0.0002	0.0032	<0.0002	<0.001	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB07_ASHPALT_0.0_0.3	SB07	0-0.3	05/12/2016	ES1628401	<0.0002	<0.0002	0.0002	0.0003	**0.0144**	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB08_0.5_0.6	SB08	0.5-0.6	05/12/2016	ES1628401	0.0005	0.0013	0.0137	0.0046	**0.124**	<0.0002	<0.001	0.001	0.004	0.0005	0.0019	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB08_5.0_5.1	SB08	5-5.1	05/12/2016	ES1628401	0.002	0.0027	0.0103	0.0003	<0.0002	<0.0002	<0.001	0.0012	0.0063	0.0005	0.0008	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB09_0.0_0.1	SB09	0-0.1	05/12/2016	ES1628401	0.0172	0.0431	0.143	0.104	**4.07**	0.0218	0.012	0.0231	0.127	0.0136	0.0671	<0.0002	0.0015	0.0004	<0.0002	<0.0002	<0.0005	0.0068	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	0.0004	<0.0005
Albion Park FRNSW	SB09_4.0_4.1	SB09	4-4.1	06/12/2016	ES1628401	0.0056	0.0091	0.0444	0.0033	**0.0459**	<0.0002	<0.001	0.0044	0.0299	0.0028	0.0049	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB10_0.0_0.1	SB10	0-0.1	06/12/2016	ES1628401	0.0004	0.0027	0.0496	0.0079	**0.0967**	<0.0002	<0.001	0.0075	0.0169	0.0039	0.0097	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB10_2.3_2.5	SB10	2.3-2.5	06/12/2016	ES1628401	<0.0002	<0.0002	0.0006	<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	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB11_1.0_1.1	SB11	1-1.1	07/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB11_5.4-5.5	SB11	5.4-5.5	06/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB12_0.0_0.1	SB12	0-0.1	07/12/2016	ES1628401	0.0032	0.0036	0.0111	0.0005	0.0052	<0.0002	<0.001	0.0021	0.0071	0.0006	0.0004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB12_5.6_5.7	SB12	5.6-5.7	07/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB13_0.5_0.6	SB13	0.5-0.6	07/12/2016	ES1628401	<0.0002	<0.0002	0.0002	<0.0002	0.0066	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB13_2.0_2.1	SB13	2-2.1	07/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB14_0.5_0.6	SB14	0.5-0.6	08/12/2016	ES1628401	0.0005	0.0016	0.0103	<0.0002	0.002	<0.0002	<0.001	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB14_3.0_3.1	SB14	3-3.1	08/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB15_1.0_1.1	SB15	1-1.1	08/12/2016	ES1628401	<0.0002	0.0006	0.0116	0.0006	**0.0174**	<0.0002	<0.001	0.0006	0.0047	0.0004	0.001	0.0008	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SB15_5.0_5.1	SB15	5-5.1	08/12/2016	ES1628401	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SS01	SS01		16/12/2016	ES1629123	<0.0002	-	0.0002	-	0.0047	-	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005
Albion Park FRNSW	SS01	SS01		25/05/2017	ES1712870	<0.0002	0.0002	0.0016	0.0002	**0.0393**	0.0014	<0.001	<0.0002	0.0005	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	0.0007	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SS02	SS02		16/12/2016	ES1629123	<0.0002	-	<0.0002	-	<0.0002	-	<0.001	<0.0002	<0.0002	<0.0002	<0.0002	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005
Albion Park FRNSW	SS02	SS02		25/05/2017	ES1712870	<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	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
Albion Park FRNSW	SS03	SS03		16/12/2016	ES1629123	<0.0002	-	0.0027	-	**0.112**	-	<0.001	0.0004	<0.0002	<0.0002	0.0006	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005

Appendix C
Table 1
Previous analytical results - soil and sediment

PFAS

Site_ID	Field_ID	Location_Code	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)
						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
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]						
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential										**0.01[#2]**						
Albion Park FRNSW	SS03	SS03		25/05/2017	ES1712870	0.0012	0.002	0.0142	0.0015	**0.0843**	<0.0002	<0.001	<0.0002	0.003	0.0008	0.0015
Albion Park FRNSW	SS04	SS04		16/12/2016	ES1629123	<0.0002	-	<0.0002	-	0.0015	-	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	SS04	SS04		25/05/2017	ES1712870	<0.0002	<0.0002	<0.0002	<0.0002	0.0007	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	SS05	SS05		16/12/2016	ES1629123	0.0005	-	0.0039	-	**0.0718**	-	<0.001	0.0014	0.0031	0.0007	0.0024
Albion Park FRNSW	SS05	SS05		25/05/2017	ES1712870	0.0003	0.0004	0.0039	0.0005	**0.263**	0.008	<0.001	<0.0002	0.0029	0.0003	0.0016
Albion Park FRNSW	SS06	SS06		25/05/2017	ES1712870	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	SS07	SS07		25/05/2017	ES1712870	<0.0002	<0.0002	<0.0002	<0.0002	0.001	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	SS08	SS08		25/05/2017	ES1712870	<0.0002	<0.0002	<0.0002	<0.0002	0.005	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	SS09	SS09		25/05/2017	ES1712870	<0.0002	<0.0002	<0.0002	<0.0002	**0.0202**	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	SSQA2	SS05		16/12/2016	ES1629123	0.0008	-	0.0108	-	**0.186**	-	<0.001	0.0019	0.0045	0.0012	0.0051
Albion Park FRNSW	TQA01	GW06	6-6.1	18/05/2017	ES1712281	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.001	<0.0002	<0.0002	<0.0002	<0.0002
Albion Park FRNSW	TQA06	SS05		25/05/2017	ES1712870	0.0002	0.0003	0.0022	0.0003	**0.101**	0.0044	<0.001	<0.0002	0.002	<0.0002	0.0009

Field_ID	Sampled_Date	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)
		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	0.0005	0.0002	0.0005	0.0005	0.0005	0.0005	0.0002	0.0002	0.0005
SS03	25/05/2017	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
SS04	16/12/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005
SS04	25/05/2017	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
SS05	16/12/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005
SS05	25/05/2017	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	0.0118	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	0.0003	<0.0005
SS06	25/05/2017	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
SS07	25/05/2017	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
SS08	25/05/2017	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
SS09	25/05/2017	<0.0002	0.0006	<0.0002	0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
SSQA2	16/12/2016	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.0005
TQA01	18/05/2017	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	<0.0002	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0005
TQA06	25/05/2017	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0005	0.0031	<0.0005	<0.0005	<0.0005	<0.0005	0.0004	<0.0002	<0.0005

Env Stds Comments

#1:Ecological Direct Exposure

#2:Ecological Indirect Exposure

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.

Appendix C
Table 1
Previous analytical results - soil and sediment

						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)	Sum of US EPA PFAS (PFOS + PFOA)*	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL						0.0005	0.0005	0.0005	0.0002	0.0002	0.0002	0.005	0.005
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													
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential													
Site_ID	**Field_ID**	**Location_Code**	**Sample_Depth_Range**	**Sampled_Date**	**Lab_Report_Number**								
Albion Park FRNSW	BD3_071216	SB12	0-0.1	07/12/2016	527586	<0.01	<0.005	-	-	-	-	-	-
Albion Park FRNSW	DR1 0.0-0.05	SS10	0-0.05	09/10/2018	621846	<0.01	<0.005	<0.005	<0.05	<0.005	<0.01	<0.005	<0.005
Albion Park FRNSW	DR2 0.0-0.1	SS11	0-0.1	09/10/2018	621846	<0.01	<0.005	<0.005	<0.05	<0.005	<0.01	<0.005	<0.005
Albion Park FRNSW	DR3 0.0-0.1	SS12	0-0.1	09/10/2018	621846	<0.01	<0.005	<0.005	<0.05	<0.005	<0.01	<0.005	<0.005
Albion Park FRNSW	DR4 0.1-0.2	SS13	0.1-0.2	09/10/2018	621846	<0.01	<0.005	<0.005	<0.05	<0.005	<0.01	<0.005	<0.005
Albion Park FRNSW	GW01_0.0_0.2	GW01	0-0.2	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0491	0.0347	0.0466	-	-
Albion Park FRNSW	GW01_4.0_4.1	GW01	4-4.1	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW02_0.5_0.6	GW02	0.5-0.6	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0688	0.0603	0.0667	-	-
Albion Park FRNSW	GW02_5.0_5.1	GW02	5-5.1	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.002	0.002	0.002	-	-
Albion Park FRNSW	GW03_0.0_0.1	GW03	0-0.1	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.937	0.816	0.907	-	-
Albion Park FRNSW	GW03_5.0_5.1	GW03	5-5.1	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.001	0.0005	0.001	-	-
Albion Park FRNSW	GW04_0.5_0.6	GW04	0.5-0.6	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0019	0.0019	0.0019	-	-
Albion Park FRNSW	GW04_6.0_6.1	GW04	6-6.1	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW05_1.6_1.7	GW05	1.6-1.7	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0053	0.0036	0.005	-	-
Albion Park FRNSW	GW05_3.4_3.5	GW05	3.4-3.5	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW06_3.0-3.1	GW06	3-3.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW06_6.0-6.1	GW06	6-6.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW07_3.0-3.1	GW07	3-3.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW07_5.0-5.1	GW07	5-5.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW08_2.0-2.1	GW08	2-2.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	GW08_5.0-5.1	GW08	5-5.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	QC1 0.3-0.4	STP1	0.3-0.4	09/10/2018	621846	<0.01	<0.005	<0.005	<0.05	0.009	<0.01	0.009	0.009
Albion Park FRNSW	QC2 0.0-0.1	SS11	0-0.1	09/10/2018	621846	<0.01	<0.005	<0.005	<0.05	<0.005	<0.01	<0.005	<0.005
Albion Park FRNSW	SB06_0.5_0.6	SB06	0.5-0.6	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	3.89	*3.73*	3.83	-	-
Albion Park FRNSW	SB06_5.0_5.1	SB06	5-5.1	06/12/2016	ES1628401	0.0043	<0.0005	<0.0005	0.162	0.0959	0.148	-	-
Albion Park FRNSW	SB07_0.5_0.6	SB07	0.5-0.6	05/12/2016	ES1628401	0.0015	<0.0005	<0.0005	0.005	0.0035	0.005	-	-
Albion Park FRNSW	SB07_3.0_3.1	SB07	3-3.1	05/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.004	0.0037	0.004	-	-
Albion Park FRNSW	SB07_ASHPALT_0.0_0.3	SB07	0-0.3	05/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0151	0.0146	0.0148	-	-
Albion Park FRNSW	SB08_0.5_0.6	SB08	0.5-0.6	05/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.152	0.138	0.146	-	-
Albion Park FRNSW	SB08_5.0_5.1	SB08	5-5.1	05/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0241	0.0103	0.0211	-	-
Albion Park FRNSW	SB09_0.0_0.1	SB09	0-0.1	05/12/2016	ES1628401	0.0175	0.0028	0.0008	4.67	*4.21*	4.49	-	-
Albion Park FRNSW	SB09_4.0_4.1	SB09	4-4.1	06/12/2016	ES1628401	0.0013	<0.0005	<0.0005	0.152	0.0903	0.139	-	-
Albion Park FRNSW	SB10_0.0_0.1	SB10	0-0.1	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.196	0.146	0.185	-	-
Albion Park FRNSW	SB10_2.3_2.5	SB10	2.3-2.5	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0015	0.0013	0.0015	-	-
Albion Park FRNSW	SB11_1.0_1.1	SB11	1-1.1	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SB11_5.4-5.5	SB11	5.4-5.5	06/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SB12_0.0_0.1	SB12	0-0.1	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0338	0.0163	0.0297	-	-
Albion Park FRNSW	SB12_5.6_5.7	SB12	5.6-5.7	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SB13_0.5_0.6	SB13	0.5-0.6	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0068	0.0068	0.0068	-	-
Albion Park FRNSW	SB13_2.0_2.1	SB13	2-2.1	07/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SB14_0.5_0.6	SB14	0.5-0.6	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0147	0.0123	0.0131	-	-
Albion Park FRNSW	SB14_3.0_3.1	SB14	3-3.1	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SB15_1.0_1.1	SB15	1-1.1	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	0.0377	0.029	0.0357	-	-
Albion Park FRNSW	SB15_5.0_5.1	SB15	5-5.1	08/12/2016	ES1628401	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SS01	SS01		16/12/2016	ES1629123	<0.0005	<0.0005	<0.0005	-	0.0049	0.0049	-	-
Albion Park FRNSW	SS01	SS01		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.0441	0.0409	0.0416	-	-
Albion Park FRNSW	SS02	SS02		16/12/2016	ES1629123	<0.0005	<0.0005	<0.0005	-	<0.0002	<0.0002	-	-
Albion Park FRNSW	SS02	SS02		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SS03	SS03		16/12/2016	ES1629123	0.0008	<0.0005	<0.0005	-	0.115	0.116	-	-

Appendix C
Table 1
Previous analytical results - soil and sediment

						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)	Sum of US EPA PFAS (PFOS + PFOA)*	Sum of enHealth PFAS (PFHxS + PFOS + PFOA)*
						mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL						0.0005	0.0005	0.0005	0.0002	0.0002	0.0002	0.005	0.005
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													
PFAS NEMP 2018 Interim Ecological Indirect Exposure Residential													
Site_ID	**Field_ID**	**Location_Code**	**Sample_Depth_Range**	**Sampled_Date**	**Lab_Report_Number**								
Albion Park FRNSW	SS03	SS03		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.109	0.0985	0.105	-	-
Albion Park FRNSW	SS04	SS04		16/12/2016	ES1629123	<0.0005	<0.0005	<0.0005	-	0.0015	0.0015	-	-
Albion Park FRNSW	SS04	SS04		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.0007	0.0007	0.0007	-	-
Albion Park FRNSW	SS05	SS05		16/12/2016	ES1629123	0.0007	<0.0005	<0.0005	-	0.0757	0.0845	-	-
Albion Park FRNSW	SS05	SS05		25/05/2017	ES1712870	<0.0005	0.0008	<0.0005	0.294	0.267	0.273	-	-
Albion Park FRNSW	SS06	SS06		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	SS07	SS07		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.001	0.001	0.001	-	-
Albion Park FRNSW	SS08	SS08		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.0053	0.005	0.005	-	-
Albion Park FRNSW	SS09	SS09		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.021	0.0202	0.0202	-	-
Albion Park FRNSW	SSQA2	SS05		16/12/2016	ES1629123	0.0019	<0.0005	0.0006	-	0.197	0.212	-	-
Albion Park FRNSW	TQA01	GW06	6-6.1	18/05/2017	ES1712281	<0.0005	<0.0005	<0.0005	<0.0002	<0.0002	<0.0002	-	-
Albion Park FRNSW	TQA06	SS05		25/05/2017	ES1712870	<0.0005	<0.0005	<0.0005	0.115	0.103	0.106	-	-

Env Stds Comments

#1:Ecological Direct Exposure

#2:Ecological Indirect Exposure

Data Comments

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

Appendix C
Table 2
Previous analytical results - Groundwater and surface water

Site_ID	Location_Code	Field_ID	Sampled_Date_Time	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)	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 Freshwater 99%									0.00023[#2]						19[#2]																				
PFAS NEMP 2018 Health Drinking Water															**0.56**																			**0.07**	
PFAS NEMP 2018 Health Recreational Water															*5.6*																			*0.7*	
Albion Park FRNSW	GW01	GW01	16/12/2016	ES1629123	<0.02	-	<0.02	-	<0.01	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	<0.01	<0.01
Albion Park FRNSW	GW01	GW01	16/12/2016	ES1701791	<0.1	<0.1	0.22 - 0.3	<0.1	0.11 - 0.23	<0.1	<0.5	<0.1	0.12 - 0.15	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.1	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	0.53 - 0.57	**0.38 - 0.45**	0.53 - 0.57
Albion Park FRNSW	GW01	GW01	25/05/2017	ES1712870	0.26	0.21	1.1	0.08	0.35	<0.02	<0.1	<0.02	0.13	<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	2.16	***1.45***	1.87
Albion Park FRNSW	GW01	GWQA3	16/12/2016	ES1629123	<0.02	-	<0.02	-	<0.01	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	<0.01	<0.01
Albion Park FRNSW	GW01	GWQA3	16/12/2016	ES1701791	<0.1	<0.1	0.34	<0.1	0.23	<0.1	<0.5	<0.1	0.14	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.1	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	0.71	**0.57**	0.71
Albion Park FRNSW	GW02	GW02	16/12/2016	ES1629123	<0.02	-	<0.02	-	<0.01	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	<0.01	<0.01
Albion Park FRNSW	GW02	GW02	16/12/2016	ES1701791	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.5	<0.1	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.1	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	0.2	**0.2**	0.2
Albion Park FRNSW	GW02	GW02	25/05/2017	ES1712870	2.76	2.37	15.4	0.21	3.56	<0.02	<0.1	0.18	0.69	0.07	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	25.4	***19***	22.8
Albion Park FRNSW	GW02	TQA04	25/05/2017	ES1712870	2.73	2.38	16	0.22	3.66	<0.02	<0.1	0.18	0.64	0.08	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	26	***19.7***	23.4
Albion Park FRNSW	GW03	GW03	16/12/2016	ES1629123	0.78	-	2.15	-	0.35	-	<0.1	0.25	0.93	0.15	0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	***2.5***	4.82
Albion Park FRNSW	GW03	GW03	16/12/2016	ES1701791	8.26 - 12.8	8.3 - 9.22	24.9 - 38.2	1.14	3.82 - 8.26	<0.1	<0.5	2.49 - 2.96	13.1 - 14.8	1.9 - 3.01	**1.64 - 2.57**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.1	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	65.6 - 93	***28.7 - 46.5***	65.6 - 82.6
Albion Park FRNSW	GW03	GW03	25/05/2017	ES1712870	47	44	200	6.31	20	<0.02	5.2	11.4	50	4.85	***7.21***	<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	2.52	<0.05	<0.05	398	***220***	348
Albion Park FRNSW	GW04	GW04	16/12/2016	ES1629123	<0.02	-	<0.02	-	<0.01	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	<0.01	<0.01
Albion Park FRNSW	GW04	GW04	16/12/2016	ES1701791	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.5	<0.1	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.1	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	0.2	**0.2**	0.2
Albion Park FRNSW	GW04	GW04	25/05/2017	ES1712870	0.03	<0.02	0.08	<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	0.14	**0.11**	0.14
Albion Park FRNSW	GW05	GW05	16/12/2016	ES1629123	<0.02	-	<0.02	-	<0.01	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	<0.01	<0.01
Albion Park FRNSW	GW05	GW05	16/12/2016	ES1701791	0.12	<0.1	<0.1	<0.1	0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.25	<0.1	<0.25	<0.25	<0.25	<0.25	<0.1	<0.1	<0.25	<0.25	<0.25	<0.25	0.22	**0.1**	0.22
Albion Park FRNSW	GW05	GW05	25/05/2017	ES1712870	0.05	0.03	0.04	<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	0.51	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	0.65	0.06	0.11
Albion Park FRNSW	GW06	GW06	25/05/2017	ES1712870	<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
Albion Park FRNSW	GW07	GW07	25/05/2017	ES1712870	<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
Albion Park FRNSW	GW08	GW08	25/05/2017	ES1712870	<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
Albion Park FRNSW	SW01		16/12/2016	ES1701791	0.04	0.04	0.34	<0.02	1.68	<0.02	<0.1	0.06	0.08	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	2.29	***2.02***	2.25
Albion Park FRNSW	SW01	SW01	16/12/2016	ES1701791	0.032	0.04	0.28	<0.02	1.12 - 1.18	<0.02	<0.1	0.04 - 0.05	0.07	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	1.63 - 1.7	***1.4 - 1.46***	1.63 - 1.7
Albion Park FRNSW	SW01	SW01	16/12/2016	ES1629123	<0.02	-	0.09	-	0.61	-	<0.1	<0.02	0.03	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	***0.7***	0.73
Albion Park FRNSW	SW01	SW01	25/05/2017	ES1712870	0.16	0.15	0.82	0.05	1.63	<0.02	<0.1	<0.02	0.14	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	3.01	***2.45***	2.81
Albion Park FRNSW	SW02	SW02	16/12/2016	ES1701791	<0.02	<0.02	<0.02	<0.02	0.08	<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	0.08	**0.08**	0.08
Albion Park FRNSW	SW02	SW02	16/12/2016	ES1629123	<0.02	-	<0.02	-	<0.01	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	<0.01	<0.01
Albion Park FRNSW	SW02	SW02	25/05/2017	ES1712870	<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
Albion Park FRNSW	SW03	SW03	16/12/2016	ES1701791	0.024 - 0.03	0.03	0.18 - 0.21	<0.02	0.73 - 1.14	<0.02	<0.1	0.03 - 0.05	0.05	<0.02	0.03 - 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	1.08 - 1.55	***0.91 - 1.35***	1.08 - 1.52
Albion Park FRNSW	SW03	SW03	16/12/2016	ES1629123	<0.02	-	0.1	-	0.34	-	<0.1	<0.02	0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	**0.44**	0.46
Albion Park FRNSW	SW03	SW03	25/05/2017	ES1712870	0.07	0.06	0.36	0.03	0.91	<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	<0.05	<0.05	<0.05	1.55	***1.27***	1.41
Albion Park FRNSW	SW04	SW04	16/12/2016	ES1701791	<0.02	<0.02	0.05	<0.02	0.19	<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	0.25	**0.24**	0.25
Albion Park FRNSW	SW04	SW04	16/12/2016	ES1629123	<0.02	-	<0.02	-	0.04	-	<0.1	<0.02	<0.02	<0.02	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	0.04	0.04
Albion Park FRNSW	SW04	SW04	25/05/2017	ES1712870	<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
Albion Park FRNSW	SW05	SW05	16/12/2016	ES1701791	2.78 - 3.85	3.2 - 3.5	19.6 - 27.2	1.44	104 - 135	1.15	<0.1	4.26 - 4.78	13.5 - 18.5	2.17 - 2.93	***6.28 - 9.13***	0.13 - 0.15	0.08 - 0.09	<0.02	<0.02	<0.02	<0.05	0.9 - 1.01	<0.05	<0.05	<0.05	<0.05	0.06	<0.02	<0.05	2 - 3.64	0.4 - 0.5	<0.05	160 - 213	***124 - 162***	160 - 205
Albion Park FRNSW	SW05	SW05	16/12/2016	ES1629123	1.39	-	9.41	-	137	-	0.2	2.24	7.02	1.02	**3.12**	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	0.77	0.22	<0.05	-	***146***	162
Albion Park FRNSW	SW05	SW05	25/05/2017	ES1712870	1.74	1.74	11.3	0.74	32.8	0.11	0.8	0.88	4.36	0.65	**1.86**	0.04	<0.02	<0.02	<0.02	<0.02	<0.05	0.24	<0.05	<0.05	<0.05	<0.05	<0.02	<0.02	<0.05	1.3	0.09	<0.05	58.6	***44.1***	55.8
Albion Park FRNSW	SW05	SWQA1	16/12/2016	ES1701791	3.77	3.46	26.2	1.48	133	1.13	<0.1	4.69	18.3	2.87	***8.55***	0.1	0.08	<0.02	<0.02	<0.02	<0.05	1.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.02	<0.05	3.33	0.42	<0.05	208	***159***	201
Albion Park FRNSW	SW05	SWQA1	16/12/2016	ES1629123	1.42	-	9.11	-	124	-	0.2	2.14	6.79	0.79	**2.99**	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	0.88	0.2	<0.05	-	***133***	148
Albion Park FRNSW	SW05	TQA05	25/05/2017	548034	1.5	1.4[#1]	9.2[#1]	0.78[#1]	44[#1]	0.34[#1]	0.99	1.9	6.7[#1]	0.88[#1]	**2.3[#1]**	0.07[#1]	0.02[#1]	<0.01	<0.01[#1]	<0.01	<0.01	0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.01	0.51	0.06	<0.01	-	-	-
Albion Park FRNSW	SW06	SW06	25/05/2017	ES1712870	<0.02	<0.02	0.09	<0.02	0.06	<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	0.15	**0.15**	0.15
Albion Park FRNSW	SW07	SW07	25/05/2017	ES1712870	<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
Albion Park FRNSW	SW08	SW08	25/05/2017	ES1712870	<0.02	<0.02	<0.02	<0.02	0.06	<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	0.06	0.06	0.06
Albion Park FRNSW	SW09	SW09	25/05/2017	ES1712870	<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

Env Stds Comments

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

#2:99% species protection - high conservation value 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.

Ranges indicate samples that were analysed by the laboratory multiple times

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21-SO1-314015432-5/https://projects.ghd.com/oc/sydney2/frnswsiteimprovement/Delivery/Documents/2127877_REP site improvement plan - Albion Park.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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