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Attention: Craig Lamberton/Andrew Mitchell

Proposed Decision Tree for Prioritising Sites Potentially Contaminated with PFASs

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned by the NSW EPA to prepare a paper discussing a proposed decision tree for the prioritization of sites potentially contaminated with per and polyfluorinated alkyl substances (PFASs).

1. Objectives

This letter report outlines a decision tree, triggers points for decision and background information for consideration by the NSW EPA.

2. Background to the Development of the Decision Tree and Trigger Points

Per and polyfluorinated alkyl substances (PFASs) are a group of chemicals that are manufactured for their unique properties. They repel oil, grease and water – a unique mix. As a result, they are ingredients in products that give stain resistance to a range of articles including carpet, clothing, paper and cardboard. They are also used as surfactants in aqueous film forming foams (AFFFs) for firefighting. These foams have been used in firefighting training and operations at airports, fire brigade (employed and volunteer) training grounds and industrial facilities where flammable materials are handled (ATSDR 2015; OECD 2013).

In recent years some of the chemicals in this group have been recognized as highly persistent, potentially bioaccumulative and toxic and they have been detected globally in the environment, wildlife, people and food (OECD 2013).

PFOS and PFOA are the two major PFASs. They are found at the highest concentrations in the environment. They were originally found as components in the products used to apply stain resistance or as fire-fighting foams but they are also the compounds some other PFASs breakdown into once released into the environment. There are numerous other PFASs that may be present in the environment (ATSDR 2015; OECD 2013).

PFASs are extremely long lived chemicals that are also water soluble. This makes them highly mobile in the environment and they can travel long distances from where they are used or manufactured (ATSDR 2015; OECD 2013).

Many manufacturers have stopped producing the products that contain PFOS and PFOA or generate these chemicals. They have moved to producing shorter chain PFASs which don't appear to bioaccumulate to the same extent as the longer chain compounds and they do not breakdown into PFOS or PFOA (ATSDR 2015; OECD 2013).

Everyone is exposed to these chemicals at low levels. Testing of blood in various developed countries (including Australia) finds these chemicals commonly across the population (ATSDR 2015; Toms et al. 2014). Levels were measured in blood in these studies to determine whether or not people were exposed to these chemicals, not to predict health risks.

People are exposed to these chemicals through air, water, food, indoor dust and consumer products (like carpet, upholstery). Food is expected to be the major source of exposure for most people (ATSDR 2015; OECD 2013).

3. Screening Program

Sites in NSW that may be contaminated by these chemicals are those where AFFF fire-fighting foams have been used in fire-fighting training or to extinguish flammable liquid fires (i.e. fuels and other hydrocarbons). The NSW Government is undertaking a program of initial screening of sites to determine a prioritised list for detailed investigation particularly focusing on whether the chemicals potentially present in soil or water at a site could affect neighbouring areas. There are other sources of these chemicals which will also be considered.

Industrial sites may have been contaminated by these chemicals in a number of ways:

- Application of PFAS containing materials directly onto the ground
- Wash off from part of site where chemicals used during rain events
- Leaks from materials stored in drums or during manufacturing
- Disposal practices
- Wastewater management
- Stormwater management

Consequently, at such sites it is possible that PFASs could be present in:

- soils at or surrounding areas where PFASs were used or disposed
- water retained in ponds on-site
- sediments of such ponds
- groundwater underlying usage areas
- water management systems used at such sites (within the pipes or soils/sediments accumulated within the pipes)

If these chemicals are present in one or more of these locations it may also be possible that they will have moved off-site in groundwater or surface water.

Finding these chemicals in soil, surface water or groundwater in and around airports and other facilities is not unusual. Robust analytical methods for measuring these chemicals have only been available since about 2000 with standardised methods initially available in 2005 and finalised in 2011.

4. Initial Screening Assessment

The NSW Government has identified a range of sites that may be contaminated by PFASs. These are sites where:

- fire training may have occurred
- large flammable liquids fires may have occurred
- these products may have been used in manufacturing

In each case whether these chemicals are present at a site at elevated concentrations will depend on a number of factors including:

- how frequently PFASs containing products were used or disposed
- the amount of these products used or disposed at a site
- practices used during fire training or manufacturing
- disposal practices

An initial screening is required for each site to determine if these chemicals are present at the site. The initial program will be quite limited to enable a rapid prioritisation exercise across many sites. The design of this initial program is based on taking samples from areas of a site most likely to be contaminated.

Initial screening of each identified site will include analysis of one or more of the following sample types:

- Surface water at the site (from retention pond or within water management system);
- Soil samples collected at or adjacent to the training pad or location of the fire;
- Groundwater samples at the site; and
- Surface water immediately off-site (if relevant).

Australian laboratories are able to analyse for approximately 20 different PFASs. Investigations at some high profile sites both in Australia and overseas have found that PFOS and PFOA are the two compounds found at the highest concentrations and most frequently. The initial screening will focus on these 2 chemicals. The need to assess the full list of PFASs will be determined during the more detailed investigations depending on the PFAS sources at a particular site.

In addition to collecting samples of soil, groundwater and surface waters, a brief review of activities down gradient of each site and the geology/hydrogeology at the site will be undertaken as part of the initial screening assessment. Information about the geology/hydrogeology will assist in identifying whether the PFASs are likely to leave the site. Understanding the land uses (potable/domestic use of surface or groundwater; food production; waterways with fish and other seafood) down gradient of the site will assist in determining whether temporary control measures will be needed while detailed investigations occur.

The results from the initial screening samples will be evaluated using the decision tree described below to rank each site for more detailed investigation, management and/or remediation. The initial screening will not provide sufficient information to allow decisions about long-term management or remediation. Detailed investigations following guidance in the Assessment of Site Contamination National Environment Protection Measure and NSW contaminated land regulations will be needed for the Priority 1 and 2 sites.

Some sites may already have a detailed site investigation available. In such cases there may be numerous sampling results for soil and groundwater. There may be sufficient data for a site-specific risk assessment to be undertaken in which case the screening approach outlined in this paper should not be applied. If an initial screening is required then the dataset should be broken into separate categories depending on the distance to the source area(s) and the distance to human or ecological receptors (for example samples in source area, samples near boundary of site, samples in off-site area etc analysed in separate groups with averages or 95%UCLs calculated for each group). Careful consideration should be given as to which category of results is compared to the trigger points outlined in this paper. The approach outlined in the NSW EPA Duty to Report guidelines where the 95%UCL of the mean of the data for a site is used to compare to screening guidelines or trigger points should also be considered.

The decision tree shows how to rank a site into one of three categories depending on the concentrations found in water or soil – priority 1, 2 or 3.

- **Priority 1** sites are those that have these chemicals present at elevated concentrations as indicated by samples that exceed the triggers discussed below. Where sites with these elevated concentrations have a pathway by which people or the environment could be exposed to the contamination, the sites may pose a risk to people or the environment. These sites need full and timely detailed investigation as soon as possible. Such investigations should be in accordance with contaminated land guidance to determine the level of risk, the potential for the chemicals to move off the site and requirements for long term management/remediation. There is likely to be a need for temporary control measures at such sites while the detailed investigation is undertaken depending on what activities are occurring down gradient of the site (e.g. residential, agricultural, presence of surface waters). Short term management options for the contamination may also need to be implemented while the detailed investigation is underway but a full detailed plan for management/remediation of the site would be developed once the detailed investigation has been completed.

  There may be situations where the only elevated level found for a site is the sample taken for a lined retention pond on the site where the water in such ponds cannot readily escape to move off-site. Also there may be situations where a site is in a remote area and there is little opportunity for contamination to move off-site or to reach locations where people may be living or working. For such sites even if the initial samples are elevated above Trigger Point 1 values (see Section 5) they may not need to be allocated to Priority 1.

- **Priority 2** sites are those where these chemicals have been shown to be present above screening guidelines but at lower concentrations than priority 1 sites. The potential for these sites to pose a risk to people or the environment that requires management and/or remediation will depend on the geology/hydrogeology of the site and the land uses downgradient of the site. These sites will need detailed investigation following the priority 1 sites.
- **Priority 3** sites are those where these chemicals are not detected or detected at concentrations below relevant thresholds. They are unlikely to need further investigation but a final decision on the need for such an investigation will be confirmed once Australian guidelines for these chemicals are finalised later in 2016.

5. Trigger Points

The decision tree has a number of points where the results from a particular site need to be compared to trigger points to determine the need for management and/or remediation.

These trigger points have been determined to allow screening of data for site prioritization. The trigger points are not designed to be protective for all risks to people or the environment. Rather they are designed to highlight which sites need to be investigated most urgently. Consequently the values proposed in this paper are different from some of the available guideline values in the international literature.

This approach has been chosen given the goals of this program.

As understanding of the toxicology, chemistry and analytical methodologies are growing and developing rapidly at this time, it is expected that this assessment process may need to be reviewed. Some of the issues being worked on at this time include:

- In Australia guidelines for the protection of human health (enHealth) and the environment (revision of ANZECC water quality guidelines) are under development and are expected to be released

through 2016, some are in draft form at this time. Internationally almost all the human health guidelines that currently exist are draft values still under review by each agency (ATSDR 2015; EFSA 2008; USEPA 2014a, 2014b). The Danish Ministry for the Environment drinking water guideline was finalized late in 2015 (Danish Ministry of the Environment 2015).

- These chemicals are highly persistent and many will bioaccumulate, particularly PFOS and PFOA. Scientific understanding of how to predict how much these chemicals will bioaccumulate is still being developed.
- There are also limitations in the analytical methodologies available. These methods are highly sophisticated and sensitive but the limits of reporting may not be as low as needed. Further understanding of how to predict bioaccumulation and what the new guidelines will be is required before any refinement of analytical methods could be considered. The methodologies currently used are best practice so it is not clear whether the limits of reporting could be lowered significantly in the future although larger sample size may assist.

This approach has also been adopted due to the current limitations in the scientific understanding of these chemicals.

Surface Water

At sites that may be contaminated by PFASs, surface waters may be present in a retention pond or in a stormwater management system. Such waters may be from use in fire-fighting training or due to rain running across a site during storms.

The trigger points for PFASs in surface waters are:

Surface Water	Value
Trigger Point 1 Elevated contamination	10 µg/L
Trigger Point 2 Current screening guideline	0.1 µg/L
Trigger Point 3 Low level of contamination	0.05 µg/L
Limit of Reporting (LOR) as at February 2016	0.01-0.05 µg/L

These triggers are based on current understanding of the toxicology of PFOS. In the most recent reviews, PFOA has been reported to have a similar acceptable dose as PFOS. Other PFASs are expected to be of similar or lower toxicity as PFOS and PFOA. Some international bodies have developed guidelines which apply to the sum of PFAS found in a sample. They have based the guideline value on PFOS as a conservative approach. This approach has also been adopted for these Trigger Points.

Trigger Point 1 is in the range of detected concentrations at some of the highly contaminated sites that have been described in the scientific literature.

Trigger Point 2 is based on the various guidelines for direct exposure to water that currently exist to protect both people and the environment. The drinking water guideline for PFOS available from the USEPA is 0.2 µg/L. The Danish EPA has recently recommended a drinking water guideline of 0.1 µg/L (Danish Ministry of the Environment 2015). Effects on some aquatic organisms have been seen at concentrations as low as 0.5 to 10 µg/L. Also the USEPA's drinking water guideline will decrease if the change in tolerable daily intake proposed in 2014 is adopted.

Trigger Point 3 is the limit of reporting for environmental water samples (i.e. muddy/turbid samples).

Classification of sites can be undertaken as follows:

- Priority 1 sites are those where on-site surface water results are above Trigger Point 1
- Priority 1 sites are those where off-site surface water results are above Trigger Point 2
- Priority 2 sites are those where on-site surface water results are between Trigger Point 1 and Trigger Point 3
- Priority 2 sites are those where off-site surface water results are between Trigger Point 2 and Trigger Point 3
- Priority 3 sites are those where on or off-site surface water results are below Trigger Point 3.

Groundwater

At sites that may be contaminated by PFASs, groundwater will be present beneath the area of the site where these chemicals were used or stored. The potential for groundwater to be contaminated will depend on the depth of groundwater at the site; volume of infiltration (rainfall and extent of hardstand); the geology of the soil above the groundwater; and how fast the groundwater is moving. The potential risk posed by groundwater at a site will depend on how fast the groundwater is moving down gradient and whether the groundwater can reach the surface where people or the environment may come into contact with it. Groundwater can reach the surface if it is extracted for domestic use or if the groundwater is shallow and seeps into a creek or other waterway.

To sample the groundwater, bores will need to be installed in appropriate locations. Initially a bore in the area of the site most likely to be contaminated along with bores close to the down gradient boundary of the site would be useful for this assessment.

The trigger points for PFASs in groundwater are the same as for surface waters:

Groundwater	Value
Trigger Point 1 Elevated contamination	10 µg/L
Trigger Point 2 Current screening guideline	0.1 µg/L
Trigger Point 3 Low level of contamination	0.05 µg/L
Limit of Reporting (LOR) as at February 2016	0.01-0.05 µg/L

These trigger point values can be applied to PFOS alone or to the sum of PFASs as discussed above.

Trigger Point 1 is in the range of detected concentrations at some of the highly contaminated sites that have been described in the scientific literature.

Trigger Point 2 is based on the various guidelines for direct exposure to water that currently exist to protect both people and the environment. The drinking water guideline for PFOS available from the USEPA is 0.2 µg/L. The Danish EPA has recently recommended a drinking water guideline of 0.1 µg/L (Danish Ministry of the Environment 2015). Effects on some aquatic organisms have been seen at concentrations as low as 0.5 to 10 µg/L. Also the USEPA's drinking water guideline will decrease if the change in tolerable daily intake proposed in 2014 is adopted.

Trigger Point 3 is the limit of reporting for environmental water samples (i.e. muddy/turbid samples).

Classification of sites can be undertaken as follows:

- Priority 1 sites are those where groundwater water samples from on-site bores have concentrations above Trigger Point 1

- Priority 1 sites are those where groundwater water samples from off-site bores have concentrations above Trigger Point 2
- Priority 2 sites are those where groundwater water samples from on-site bores are between Trigger Point 1 and Trigger Point 3
- Priority 2 sites are those where groundwater water samples from off-site bores are between Trigger Point 2 and Trigger Point 3
- Priority 3 sites are those where on or off-site groundwater results are below Trigger Point 3.

Soil

The most important process by which PFASs present in soil may pose a risk to people or the environment is contamination of surface and groundwaters from leaching from the soil. Movement of the chemicals from soil into groundwater to levels that might be of concern due to leaching occurs at much lower soil concentrations than are of concern for people, animals or plants coming into direct contact with the contaminated soil.

Most of the international guidelines that currently exist for PFOS (and other PFASs) in soil are based on direct contact with contaminated soils. However, these chemicals are water soluble and so can be washed through soil into the underlying groundwater by rain events. Initial assessment of soil contamination should, therefore, be focused on assessing leaching potential.

The most effective option for addressing leaching potential is to measure the leaching potential of these chemicals in soil samples from the site using the ASLP test (AS 1997). This test measures how much of a chemical can move from soil into water using conditions similar to rain events. Other types of leaching tests are designed to be used to evaluate leaching in landfills so the conditions used in the test are much harsher and are not relevant for the initial screening of these sites.

The trigger points for PFASs in leachate as measured in an ASLP test are the trigger points for water and groundwater multiplied by a dilution factor of 10. A dilution factor of 20 is recommended by the USEPA as the minimum dilution that is likely to occur as a chemical moves from soil into underlying groundwater (USEPA 1996). Using a dilution factor of 10 provides some additional conservatism.

The trigger points for leachate are, therefore, as follows:

Leachate	Value
Trigger Point 1	100 µg/L
Trigger Point 2	1 µg/L

These trigger point values can be applied to PFOS alone or to the sum of PFASs as discussed above.

Only two trigger points are needed to classify leachate results for on-site soil samples.

Classification of sites using ASLP data can be undertaken as follows:

- Priority 1 sites are those where leachate results are above Trigger Point 1
- Priority 2 sites are those where leachate results are between Trigger Point 1 and Trigger Point 2
- Priority 3 sites are those where leachate results are below Trigger Point 2.

6. Decision Tree

The decision tree is shown in **Figures 1** and **2**.

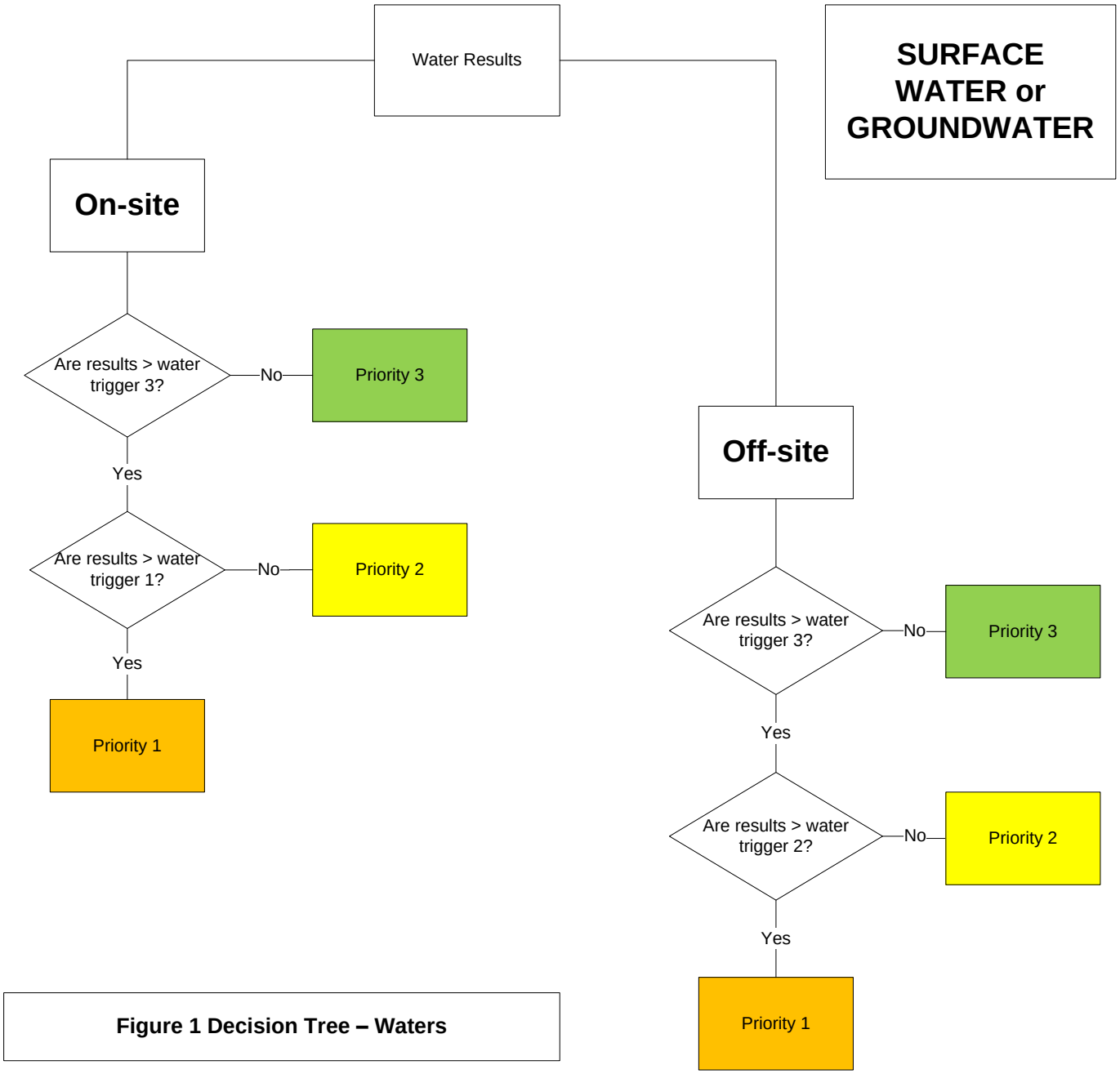

Figure 1 Decision Tree – Waters

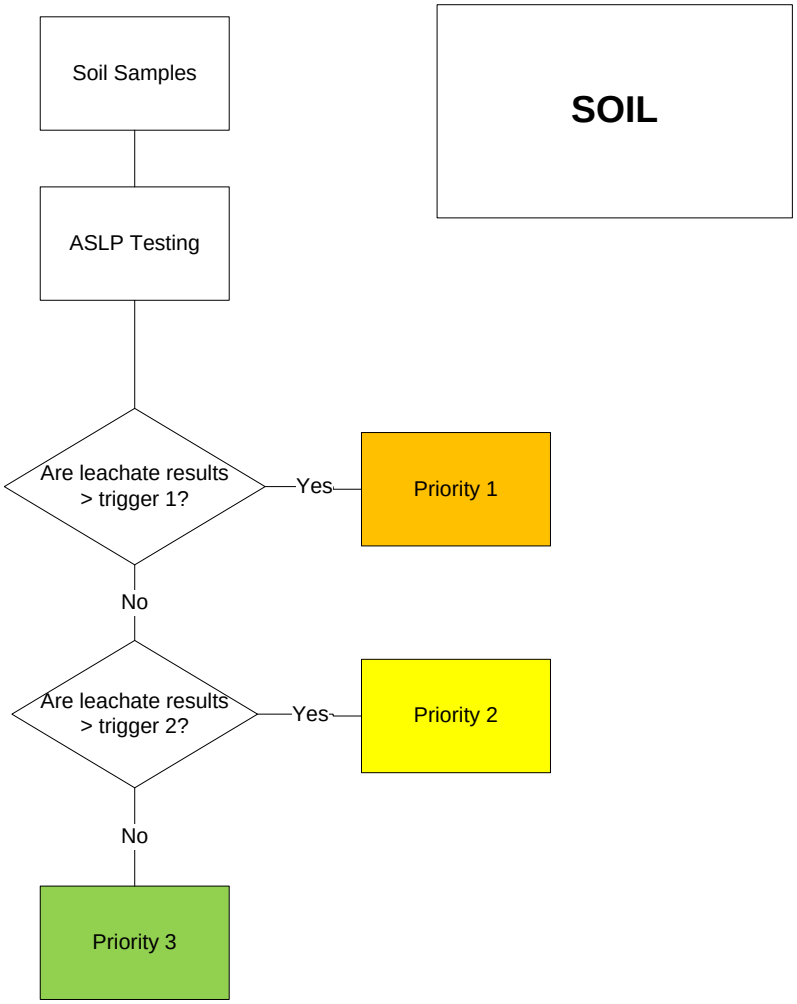

Figure 2 Decision Tree – Soil

If you require any additional information, please do not hesitate to contact Therese on (02) 9614 0297 or 0487 622 551.

Yours sincerely,

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Limitations

Environmental Risk Sciences has prepared this report for the use of NSW EPA in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

The methodology adopted and sources of information used are outlined in this letter report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions.

This report was prepared in February 2016 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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