

Appendix B

Ground Investigation Technical Information

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Sampling protocols

Throughout these further investigations, strict soil sampling protocols were implemented on site to protect the integrity of the resulting analysis data. These include:

- Frequent changing of gloves during sampling;
- Washing of excavator bucket and other relevant plant with mains water between sampling;
- Soils that have been in contact with the excavator bucket were not sampled;
- Washing of all hand-held and other sampling equipment with deionised water before and after each sample is taken;
- The use of HDPE containers for recovery of samples;
- Permanent marker pens were not used for labelling samples.

Following issues that arose during the January 2023 PFAS ground investigation, the following additional steps were added to the soil sampling protocols:

- Use of a single analytical laboratory to avoid chain of custody issues during sub-sampling and leachate preparation.
- The use of HDPE containers at all stages of the laboratory preparation and analysis.

PFAS analysis – repeatability

Current regulatory thresholds for PFAS require reporting of analysis results for liquid samples at the ng/l level – parts per trillion. At these very low concentrations, laboratory repeatability was considered to be a potential issue, with very small variations in the analytical conditions becoming potentially significant. In addition, given the potential behaviour of PFAS in the environment (**Section 8.5**), any PFAS present may not be distributed evenly throughout a sample.

To address the repeatability of analysis, a surface water sample recovered on 29th April 2023 (SW02RH) was separated into three sub-samples. Each sub-sample was prepared and underwent analysis in an identical manner. The results of analysis for PFOS and PFOA are summarised in **Table 48**.

Compound	SWS02RH Sub-sample A (ng/l)	SWS02RH Sub-sample B (ng/l)	SW02RH Sub-sample C (ng/l)
	Pre-Ox	Pre-Ox	Pre-Ox
PFOS	7	6	5
PFOA	7	7	7

Table 48: results of repeatability assessment (Pre-Ox)

This data suggests that for analysis of liquid samples, laboratory data has a resolution in the order of +/- 1ng/l.

PFAS analysis – sensitivity

Whereas the sensitivity of available soil analytical techniques is limited to parts per billion (µg/kg), the available analytical techniques achieve analysis of liquid samples down to a resolution of ng/l (parts per trillion). Hence analysis of liquid samples is currently three orders of magnitude more sensitive than analysis of soil samples.

Given the reduced sensitivity associated with analysis of solid media and the potential for elements of the PFAS soil content to be mobile in the environment (i.e. leachable), during PFAS investigation at Victoria North, selected samples have undergone leachability analysis to allow the greater sensitivity of analysis of liquid samples to be applied when assessing the presence and distribution of PFAS.

It should be noted that the preparation of soil leachate involves the use of an aggressive process whereby soil is agitated with water for several hours and is likely to result in an overestimate of what would leach out of the soil if it were in situ.

PFAS analysis – TOP assay

Given their status as an emerging contaminant, protocols for analysis of PFAS and the assessment of the analysis data are currently being developed. Approved laboratory analysis methods exist for a relatively small number of the thousands of PFAS compounds that are known, such as those listed in **Table 1**. It has also been recognised that degradation in the environment (for example degradation of PFAS by oxidation) may result in the transformation of longer-chain PFAS compounds into shorter, more mobile compounds.

According to Atelia et al [19] “While the currently available targeted analytical methods provide information about many PFASs, the measured PFASs may be a fraction of the PFASs present in products or environmental sites due to the presence of PFAS precursors or intermediate degradation products that are not target analytes.” To address this uncertainty in the current methods of analysis, the TOP-assay protocol has been introduced (total oxidisable precursor). In order to undertake a TOP assay assessment, samples undergo an aggressive extraction process, involving the application of heat and the use of oxidising agents. Following oxidation, further analysis allows a more comprehensive assessment of PFAS risk to be undertaken by providing an indication of the potential fate of the extant PFAS compounds, once released into the environment.

Although it is widely regarded as good practice to apply the TOP assay approach during ground investigation, there are a number of inherent disadvantages. According to Gockener et al [20] “...the results received by the TOP assay have to be treated with caution. Because of the harsh oxidising procedure in the laboratory, different degradation processes may be possible in contrast to the conditions in the environment”. These considerations have led some to researchers to suggest that the results of TOP assay assessment should be considered as a worst-case scenario and indicative only [20].

Where TOP assay has been completed on samples taken from Victoria North, the results are referred to as “Post-Ox” (post-oxidation). Samples tested for PFAS without TOP assay being completed are referred to as “Pre-Ox”.

PFAS analysis – assessment of the potential for oxidation of PFAS

The TOP Assay was carried out on a number of samples, to determine the potential of the PFAS in various media to oxidise into shorter, more toxic end products, as described above. The assessment of degradation potential is presented below.

Assessment of potential PFAS oxidation in the emerging water

The emerging water samples recovered on 28th March 2023 also underwent TOP assay analysis to allow an assessment of the potential for future oxidation of PFAS in the source. As indicated in **Table 49**, the difference between Pre-Ox and Post-Ox analysis results, which is taken to indicate the potential for future oxidation, are as follows:

- PFOS – up to +3ng/l.
- PFOA – up to +2ng/l.

Compound		Showmens'Guild (ng/l)		SWS08 Down (ng/l)		SWS08 Up (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		16	19	9	9	18	18
PFOA		12	12	10	9	11	13
Difference	PFOS	+3		0		0	
	PFOA	0		-1		+2	

Table 49: Comparison of Pre-Ox and Post-Ox data for emerging water samples

The results of this comparison show that the emerging water has very little potential to oxidise further in the environment.

Assessment of potential PFAS oxidation of surface water samples

The samples recovered from the river on 13th April 2023 also underwent TOP assay analysis, as summarised in **Table 50**. There was no potential for future oxidation of PFAS in the river water samples tested.

Compound		Upstream		Midstream		Downstream	
		SWS03 (ng/l)		SWS02 (ng/l)		SWS01 (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		9	9	12	10	11	9
PFOA		7	4	7	4	7	5
Difference	PFOS	0		-2		-2	
	PFOA	-3		-3		-2	

Table 50: Comparison of Pre-Ox and Post-Ox data for river samples

11.2.1 Assessment of potential for PFAS oxidation in earthworks area 3

PFAS in shallow soils have the potential to oxidise, which may increase the longer-term risk from any PFAS present. The PFAS in soils that are to be newly exposed to air, for example during excavations, may undergo oxidation.

The March 2023 investigation included an assessment of Pre-Ox and Post-Ox analysis results for leachability samples recovered from a range of relevant depths in earthworks area 3

From **Table 51**, with the exception of PFOS in the sample from TP405A at 0.5m, the relevant Post-Ox concentrations are generally not greater than the appropriate Pre-Ox concentrations. This suggests that there is no significant potential for future oxidation of the made ground in this area of the site. This data indicates that oxidation of newly-exposed soils following reduced-level excavation in earthworks area 3 will not lead to an increased risk from PFAS compounds in the made ground soils.

Compound		TP403A, 0.5m		TP403A, 1m		TP403A, 2m	
		Leachability (ng/l)		Leachability (ng/l)		Leachability (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
PFOA		15.6	10.3	<LOD	<LOD	<LOD	<LOD
Difference	PFOS	-		-		-	
	PFOA	-5		-		-	

Compound		TP405A, 0.5m		TP405A, 1.5m		TP405A, 2m	
		Leachability (ng/l)		Leachability (ng/l)		Leachability (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		11.2	14.8	<LOD	<LOD	92.2	<LOD
PFOA		15.8	11.7	<LOD	2.9	<LOD	<LOD
Difference	PFOS	+3.6		-		-	
	PFOA	-4		-		-	

Table 51: Summary of oxidation assessment of earthworks area 3 (leachability samples)

Potential for oxidation in the TP422/TP423 area

A selection of both soil and soil leachate samples from the TP422/TP423 area underwent TOP assay. As shown on **Table 53**, only one soil sample (TP423, 0.5m) had Post-Ox concentrations greater than the Pre-Ox values, with a difference of 5.8µg/kg PFOS recorded.

Compound		TP422 0.50m		TP422 1.0m		TP422 2.0m	
		Soils (µg/kg)		Soils (µg/kg)		Soils (µg/kg)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		7.4	5.3	<LOD	<LOD	<LOD	<LOD
PFOA		29.8	15	4.9	<LOD	1.2	<LOD
Difference	PFOS	-2.1		-		-	
	PFOA	-14.8		-		-	

Compound		TP423 0.50m		TP423 1.0m		TP423 2.0m	
		Soils (µg/kg)		Soils (µg/kg)		Soils (µg/kg)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		14.2	20	<LOD	<LOD	<LOD	<LOD
PFOA		<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Difference	PFOS	+5.8		-		-	
	PFOA	-		-		-	

Table 52: Comparison of Pre- and Post-Ox analysis for soils in the TP422/TP423 outlier

In all soil leachate samples in which PFOS and PFOA were present above the limit of detection (**Table 53**), concentrations in the Post-Ox analysis results were greater than in the Pre-Ox data by as much as 150ng/l.

Compound		TP422 0.50m		TP422 1.0m		TP422 2.0m	
		leachability (ng/l)		leachability (ng/l)		leachability (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		51.9	72.6	<LOD	<LOD	<LOD	<LOD
PFOA		3230	3380	1930	3790	118	128
Difference	PFOS	+20.7		-		-	
	PFOA	+150		-		-	

Compound		TP423 0.50m		TP423 1.0m		TP423 2.0m	
		leachability (ng/l)		leachability (ng/l)		leachability (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		75.8	96.5	<LOD	<LOD	<LOD	<LOD
PFOA		20.9	28	13.3	7.7	10.2	<LOD
Difference	PFOS	+20.7		-		-	
	PFOA	+7.1		-		-	

Table 53: Comparison of Pre- and Post-Ox analysis for leachability testing in the TP422/TP423 outlier

Both the soils analysis data and the leachability analysis data suggest therefore, that the TP422/TP423 outlier has the potential for future oxidation, however the potential for oxidation of PFAS in the soils in the TP422/TP423 outlier appears to be more limited. This supports the observation that the PFAS observed in TP422/TP423 is of fairly recent origin.

Potential for oxidation in the emerging water area

No soil samples were identified in the emerging water area with PFAS concentrations greater than the limit of detection (**Appendix C3**). Soil leachate samples and samples of perched groundwater from the emerging water area that underwent TOP assay, have therefore been used for an assessment of potential oxidation of PFAS in the emerging water area.

As shown on **Table 54**, only one sample (TP EW07, 0.5m) had Post-Ox concentrations greater than the Pre-Ox values. The difference in this example however, was very low (1.0ng/l for PFOA). This assessment suggests that the emerging water area has little or no potential for future oxidation of PFAS and is consistent with the findings for the emerging water itself, which also has very little potential to oxidise in the environment (see **Table 49**).

Compound		TP EW02 1.5m		TP EW03 0.5m		TP EW05 0.75m	
		leachability (ng/l)		leachability (ng/l)		perched GW (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		<LOD	<LOD	2.0	<LOD	5.0	-
PFOA		<LOD	<LOD	2.3	<LOD	5.0	-
Difference	PFOS	-		-		-	
	PFOA	-		-		-	

Compound		TP EW07 0.50m		TP EW08 1.0m		TP EW11 1.0m	
		leachability (ng/l)		perched GW (ng/l)		perched GW (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		2.6	<LOD	5.0	-	1.0	-
PFOA		4.6	5.6	11.0	-	11.0	-
Difference	PFOS	-		-		-	
	PFOA	+1.0		-		-	

Table 54: Comparison of EW-series trial pit data for liquid phase samples (Pre- and Post-Ox analysis)

It is concluded, from the information obtained in the EW-series trial pits, that the low concentrations of PFAS detected in samples of soil leachate are likely to be derived from the emerging water source.

Potential for oxidation in the carriage shed area

Given that only marginal exceedances of LOD were identified for soil samples in the carriage shed area, the assessment of the potential for PFAS oxidation has been limited to the results of perched groundwater analysis. As shown on **Table 55**, the majority of samples had Post-Ox concentrations greater than the Pre-Ox values, with differences of up to 34ng/l indicating that there is potential for future oxidation of PFAS in the carriage shed area.

Compound		TP CS3 1.7m		TP CS4 1.7m		TP CS7 0.75m	
		perched GW (ng/l)		perched GW (ng/l)		perched GW (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		50	59	33	41	19	23
PFOA		41	44	50	47	35	30
Difference	PFOS	+9		+8		+4	
	PFOA	+3		-3		-5	

Compound		TP CS8 1.50m		TP CS9 3.1m	
		perched GW (ng/l)		perched GW (ng/l)	
		Pre-Ox	Post-Ox	Pre-Ox	Post-Ox
PFOS		43	56	22	56
PFOA		50	56	29	56
Difference	PFOS	+13		+34	
	PFOA	+6		+27	

Table 55: Comparison of carriage shed trial pit data for liquid phase samples (Pre- and Post-Ox analysis)