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RE: HHERA – MWOO used for Mining Rehabilitation and Forestry Purposes

Background

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned by NSW EPA to assess the human health and ecological risks posed by application to land for mining rehabilitation purposes of mixed waste organic outputs (MWOO) generated at Alternative Waste Treatment facilities.

Previously, enRiskS prepared a human health and ecological risk assessment (HHERA) for the use of MWOO on agricultural land. This assessment has been documented in the report:

- enRiskS (2019), Human health and ecological risk assessment: Application of Alternative Waste Technologies Materials to Agricultural Land

This letter report provides an assessment of potential risks when MWOO is used for mining rehabilitation. The assessment has used the same approach as documented in the agricultural land report. The description of the approach has not been repeated in this letter report.

This letter should be read in conjunction with the HHERA for agricultural land (enRiskS 2019). Information included in that report that has not changed has not been repeated in this letter.

Objectives

The objectives of this assessment are:

- Update the estimates of exposure concentrations for the various chemicals of interest based on the use of MWOO for mining rehabilitation including:
  - Use of 50, 140 or 100 tonnes per hectare depending on the use pattern (forestry, mining (previous), mining (future))
  - Incorporation of MWOO into top 2 cm of soil (i.e. applied to surface and trampled in), top 10 cm of soil and top 40 cm of soil
- Determine potential risks based on the exposure concentrations along with all other aspects of the approach documented in enRiskS (2019)

The use of application rates of 50 tonnes MWOO per hectare for forestry uses (and non-contact agriculture) and 140 tonnes MWOO per hectare for mine site rehabilitation in this assessment was based on specifications detailed in the exemption. The use of an application rate of 100 tonnes MWOO per hectare was based on the outcome of the NSW EPA commissioned research program work that identified application rates of MWOO to soil which could deliver measurable benefit for agricultural production and soil health.

It is noted that the following assumptions have been included in the assessment as per the requirements of NSW EPA:

- The treated mining land will be used for livestock grazing and broad acre cropping once the land is rehabilitated. The key receptors are farmers who consume their own produce.
- The treated forestry land will be used for livestock grazing and broad acre cropping once the land is rehabilitated. The key receptors are farmers who consume their own produce.

In addition, consideration of how risks may change through time has been included.

Methodology and Scope of Works

The methodology adopted for this work is in accordance with the relevant National protocols/ guidelines including:

- enHealth (2012a) Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards;
- enHealth (2012b) Australian Exposure Factor Guide;
- ASC NEPM (1999 amended 2013) National Environmental Protection Measure – Assessment of Site Contamination including:
    - Schedule B1 Investigation Levels for Soil and Groundwater
    - Schedule B4 Guideline on Site-Specific Health Risk Assessment Methodology
    - Schedule B6 Guideline on The Framework for Risk-Based Assessment of Groundwater Contamination
    - Schedule B7 Guideline on Derivation of Health-Based Investigation Levels
    - Toolbox Note – Key principles for the remediation and management of contaminated sites; and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (as updated in 2018, www.waterquality.gov.au)

Exposure Concentrations

The approach for calculating exposure concentrations for the chemicals of potential concern in enRiskS (2019) was outlined in **Section 3.3.4** for polybrominated diphenyl ethers (PBDEs) and **Section 6.2.5** for per and polyfluoroalkyl substances (PFAS).

The same approach has been used here to determine exposure concentrations relevant for the different application rates and depth of incorporation into the soil at a site.

It is noted that there have been two sets of data collected for PBDEs and PFAS concentrations in MWOO. For PBDEs data were collected for the NSW EPA commissioned Research Program. Additional data were collected in 2018/9 – OCSE dataset (Office of Chief Scientist and Engineer). For PFAS, the original dataset was collected in 2017/8 using samples collected by the NSW EPA. Additional data were collected in 2018/9 for the samples collected by OCSE.

For both PFAS and PBDEs, the two datasets have been combined for this assessment. Statistics have been calculated using all the samples from the NSW EPA commissioned research program, samples collected by the NSW EPA for PFAS and all the samples collected by OCSE for agricultural use. OCSE also collected samples from stockpiles that were targeted for use in mine rehabilitation. These data are discussed further below.

The concentrations of PBDEs in MWOO (undiluted) based on the agricultural stockpile samples are:

- PBDE (Br1 to Br9)
    - Mean – 15 mg PBDEs (Br1 to Br9)/kg
    - Maximum – 710 mg PBDEs (Br1 to Br9)/kg
    - Minimum – 0.03 mg PBDEs (Br1 to Br9)/kg

- 95th percentile – 20 mg PBDEs (Br1 to Br9)/kg
- Median – 0.5 mg PBDEs (Br1 to Br9)/kg

- Deca BDE
  - Mean – 2 mg DecaBDE /kg
  - Maximum – 13 mg DecaBDE /kg
  - Minimum – 0.05 mg DecaBDE /kg
  - 95th percentile – 6.1 mg DecaBDE /kg
  - Median – 1 mg DecaBDE /kg

The concentrations of PBDEs in MWOO (undiluted) based on the non-agricultural stockpile samples are:

- PBDE (Br1 to Br9)
  - Mean – 2 mg PBDEs (Br1 to Br9)/kg
  - Maximum – 21 mg PBDEs (Br1 to Br9)/kg
  - Minimum – 0.4 mg PBDEs (Br1 to Br9)/kg
  - 95th percentile – 5 mg PBDEs (Br1 to Br9)/kg
  - Median – 0.7 mg PBDEs (Br1 to Br9)/kg
- Deca BDE
  - Mean – 6 mg DecaBDE /kg
  - Maximum – 77 mg DecaBDE /kg
  - Minimum – 0.7 mg DecaBDE /kg
  - 95th percentile – 17 mg DecaBDE /kg
  - Median – 1 mg DecaBDE /kg

The concentrations in the non-agricultural stockpiles for PBDE (Br1 to Br 9) are within the range already assessed in the agricultural assessment.

The concentrations for deca BDE, however, are higher so this assessment uses the agricultural assessment risk estimates for the mean of 2 mg/kg. These risk estimates for deca BDE have then been adjusted to a mean of 6 mg/kg by multiplying by a factor of 3 before being used to assess use for forestry or mining rehabilitation. The risk estimates for deca BDE make only a minor contribution to the overall risk estimates so this change makes no significant change to the overall estimate.

As described in enRiskS (2019), due to the availability of screening guidelines (and toxicity reference values), PFAS have been assessed assuming all chemicals similar to PFOS are of similar toxicity to PFOS and can be assessed using the screening guidelines for PFOS and that the same for all chemicals similar to PFOA.

The concentrations of PFAS in MWOO (undiluted) are:

- PFOS (and related chemicals)
  - Mean – 0.1 mg PFOS/kg
  - Maximum – 0.13 mg PFOS/kg
  - Minimum – 0.08 mg PFOS/kg
  - 95th percentile – 0.11 mg PFOS/kg
  - Median – 0.1 mg PFOS/kg
- PFOA (and related chemicals)
  - Mean – 0.12 mg PFOA/kg
  - Maximum – 0.64 mg PFOA/kg
  - Minimum – 0.07 mg PFOA/kg
  - 95th percentile – 0.3 mg PFOA/kg
  - Median – 0.1 mg PFOA/kg

The assessment for use on agricultural land assumed an application rate of 10 tonnes per hectare and a soil bulk density of 1300 kg/m^3 with the MWOO applied to the surface of the ground, trampled into the top 2 cm or mixed into the top 10 cm of soil.

For this assessment, it is assumed that the application rates of MWOO are:

- 50 tonnes per hectare
- 100 tonnes per hectare
- 140 tonnes per hectare

In addition, it is assumed that the applied material is mixed into the soil as follows:

- Mixed into top 2 cm
- Mixed into top 10 cm
- Mixed into top 40 cm (deep ripping)

based on advice from the NSW EPA about how MWOO is applied at forestry plantations or mining rehabilitation sites.

This results in the following dilution factors to be applied to the concentrations of PBDEs and PFAS and other chemicals in MWOO:

- 50 tonnes per hectare
  - 2 cm incorporation (5.2 fold dilution of undiluted concentrations)
  - 10 cm incorporation (26 fold dilution of undiluted concentrations)
  - 40 cm incorporation (104 fold dilution of undiluted concentrations)
- 100 tonnes per hectare
  - 2 cm incorporation (2.6 fold dilution of undiluted concentrations)
  - 10 cm incorporation (13 fold dilution of undiluted concentrations)
  - 40 cm incorporation (52 fold dilution of undiluted concentrations)
- 140 tonnes per hectare
  - 2 cm incorporation (1.9 fold dilution of undiluted concentrations)
  - 10 cm incorporation (9.3 fold dilution of undiluted concentrations)
  - 40 cm incorporation (37 fold dilution of undiluted concentrations)

Exposure concentrations have been determined by applying these dilution factors to the concentrations in undiluted MWOO reported in the agricultural assessment. **Table 1** lists the exposure concentrations to be assessed for these uses.

Table 1 Exposure Concentrations

Chemicals/Application Rates	MWOO (Undiluted)	Incorporated into 2 cm	Incorporated into 10 cm	Incorporated into 40 cm
50 Tonnes per Hectare – Overall Dataset				
PBDEs (Br1 to Br9)				
Minimum	0.04	0.008	0.002	0.0004
Mean	15	3	0.6	0.1
Maximum	710	137	27	6.8
95th Percentile	20	4	0.8	0.2
Median	0.5	0.1	0.02	0.005
DecaBDE				
Minimum	0.05	0.01	0.002	0.0005
Mean	2	0.4	0.08	0.02
Maximum	13	2.5	0.5	0.1
95th Percentile	9	1.7	0.3	0.09

Chemicals/Application Rates	MWOO (Undiluted)	Incorporated into 2 cm	Incorporated into 10 cm	Incorporated into 40 cm
Median	1	0.2	0.04	0.01
PFOS				
Minimum	0.08	0.02	0.003	0.0008
Mean	0.1	0.02	0.004	0.001
Maximum	0.13	0.03	0.005	0.001
95th Percentile	0.11	0.02	0.004	0.001
Median	0.1	0.02	0.004	0.001
PFOA				
Minimum	0.07	0.01	0.003	0.0007
Mean	0.12	0.02	0.005	0.001
Maximum	0.64	0.1	0.02	0.006
95th Percentile	0.3	0.05	0.01	0.003
Median	0.1	0.02	0.004	0.001
100 Tonnes per Hectare – Overall Dataset				
PBDEs (Br1 to Br9)				
Minimum	0.04	0.02	0.003	0.0008
Mean	15	6	1.2	0.3
Maximum	710	273	55	14
95th Percentile	20	8	1.5	0.4
Median	0.5	0.2	0.04	0.01
DecaBDE				
Minimum	0.05	0.02	0.004	0.001
Mean	2	0.8	0.2	0.04
Maximum	13	5	1	0.25
95th Percentile	9	3.5	0.7	0.2
Median	1	0.4	0.08	0.02
PFOS				
Minimum	0.08	0.03	0.006	0.002
Mean	0.1	0.04	0.008	0.002
Maximum	0.13	0.05	0.01	0.003
95th Percentile	0.11	0.04	0.008	0.002
Median	0.1	0.04	0.008	0.002
PFOA				
Minimum	0.07	0.03	0.005	0.001
Mean	0.12	0.05	0.009	0.002
Maximum	0.64	0.2	0.05	0.01
95th Percentile	0.3	0.1	0.02	0.006
Median	0.1	0.04	0.008	0.002
140 Tonnes per Hectare – Overall Dataset				
PBDEs (Br1 to Br9)				
Minimum	0.04	0.02	0.004	0.001
Mean	15	8	1.6	0.4
Maximum	710	374	76	19
95th Percentile	20	11	2.2	0.5
Median	0.5	0.3	0.05	0.01
DecaBDE				
Minimum	0.05	0.03	0.005	0.001
Mean	2	1	0.2	0.05
Maximum	13	7	1.4	0.4

Chemicals/Application Rates	MWOO (Undiluted)	Incorporated into 2 cm	Incorporated into 10 cm	Incorporated into 40 cm
95th Percentile	9	5	1	0.2
Median	1	0.5	0.1	0.03
PFOS				
Minimum	0.08	0.04	0.009	0.002
Mean	0.1	0.05	0.01	0.003
Maximum	0.13	0.07	0.01	0.004
95th Percentile	0.11	0.06	0.01	0.003
Median	0.1	0.05	0.01	0.003
PFOA				
Minimum	0.07	0.04	0.008	0.002
Mean	0.12	0.06	0.01	0.003
Maximum	0.64	0.3	0.07	0.02
95th Percentile	0.3	0.2	0.03	0.008
Median	0.1	0.05	0.01	0.003

Risk Estimates – PBDEs

Updating the risk estimates can be easily undertaken using the same dilution factors indicated above for the exposure concentrations. This is because the calculations of risk are linear if only the exposure concentrations are changed.

The risk estimates from enRiskS (2019) for the scenario where MWOO is applied directly to the surface of grazing land without being incorporated at all (i.e. undiluted) have been used to provide these estimates. The risk estimates for this scenario are adjusted using the dilution factors listed above.

As noted above, the concentrations for deca BDE, however, are higher than those used for the agricultural assessment – mean of 2 mg/kg for the agricultural stockpile samples compared to a mean of 6 mg/kg for the non-agricultural stockpiles samples so this assessment uses the agricultural assessment risk estimates for the mean of 2 mg/kg as the basis then these are adjusted to a mean of 6 mg/kg by multiplying by a factor of 3 before being assessed for use for forestry or mining rehabilitation. However, the risk estimates for deca BDE make only a minor contribution to the overall risk estimates so this change makes no significant change to the overall estimate or the conclusions of this assessment.

In addition, assessment of potential risks due to use of MWOO on land used to grow blueberries has been undertaken. This use pattern has been included in this assessment to cover any uses for non-contact agriculture. This type of use was defined as "*application to land where the land is used for the growing of fruit or nut trees or vines but not where fallen produce is or may be collected off the ground".* The exemption permitted the application of MWOO at 50 tonnes per hectare to land for non-contact agriculture so this use pattern is not covered by the assessment in enRiskS (2019). The calculation spreadsheets just for consumption of blueberries are attached at **Appendix B**.

APPLICATION TO FOREST PLANTATIONS

DIRECT CONTACT WITH SOIL/MWOO

Table 2 Summary of Risk Estimates (mean) – 50 tonnes per hectare/ incorporated into top 2 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	1
- Adults	0.1
Dermal contact with PBDEs in soil	
- Young children	0.8
- Adults	0.4
Inhalation of PBDEs in dust	
- Young children	0.000001
- Adults	0.000001
Below Reference Dose	**≤1**

Table 3 Summary of Risk Estimates (mean) – 50 tonnes per hectare/ incorporated into top 10 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.2
- Adults	0.02
Dermal contact with PBDEs in soil	
- Young children	0.1
- Adults	0.08
Inhalation of PBDEs in dust	
- Young children	0.0000003
- Adults	0.0000003
Below Reference Dose	**≤1**

Table 4 Summary of Risk Estimates (mean) – 50 tonnes per hectare/ incorporated into top 40 cm[1]

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.05
- Adults	0.005
Dermal contact with PBDEs in soil	
- Young children	0.04
- Adults	0.02
Inhalation of PBDEs in dust	
- Young children	0.00000007
- Adults	0.00000007

[1] It is noted that deep ripping of MWOO into the soil is not expected in this scenario (forestry). It is only expected for mine rehabilitation uses. It has been included here for comparison.

Receptor/Exposure Pathway	Threshold Risk
Below Reference Dose	**≤1**

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present when MWOO is applied to forestry plantations at 50 tonnes per hectare results in the following:

- Most scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil for forestry uses indicate exposure will be below the reference doses for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied and mixed into 2 cm depth may be equal to the reference doses for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

INGESTION OF HOME-GROWN PRODUCE

Table 5 Summary of Risk Estimates (mean) – 50 tonnes per hectare

Receptor/Exposure Pathway	Threshold Risk Incorp 2 cm	Threshold Risk Incorp 10 cm	Threshold Risk Incorp 40 cm
6 months on treated pasture – higher bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	13	3	0.6
- Adults	3	0.7	0.2
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	18	4	0.9
- Adults	8	1.5	0.4
6 months on treated pasture – lower bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	5	1	0.3
- Adults	1	0.3	0.07
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	7	1.5	0.4
- Adults	3	0.6	0.2
52 days on treated pasture – higher bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	4	0.7	0.2
- Adults	1	0.2	0.04
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	5	1	0.3
- Adults	2	0.4	0.1
52 days on treated pasture – lower bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			

Receptor/Exposure Pathway	Threshold Risk Incorp 2 cm	Threshold Risk Incorp 10 cm	Threshold Risk Incorp 40 cm
- Young children	1	0.3	0.07
- Adults	0.4	0.08	0.02
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	2	0.4	0.1
- Adults	0.8	0.2	0.04
Below Reference Dose		**≤1**	

Based on the risk estimates for ingestion of home-grown produce where MWOO was used for application in forestry plantations and incorporated into the soil (2, 10 or 40 cm), the potential for PBDEs to be present results in the following:

- Most scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied and mixed into the top 2 cm indicate exposure will be above the reference doses for PBDEs
- Those scenarios where MWOO has been mixed into the top 10 cm and where people may consume home grown milk or meat on a regular basis are estimated to result in exposure above the reference dose for PBDEs for cattle kept on the treated area for 6 months of the year and equal to or below the reference dose for PBDEs for cattle kept on the treated area for 52 days per year
- Those scenarios where MWOO has been deeply ripped (mixed into 40 cm) will result in exposure equal to or below the reference dose for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

USE IN BLUEBERRY FARMING

DIRECT CONTACT WITH SOIL/MWOO AND INGESTION OF BLUEBERRIES GROWN WHERE MWOO HAS BEEN APPLIED

Table 6 Summary of Risk Estimates (mean) – 50 tonnes per hectare/ incorporated into top 10 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.2
- Adults	0.02
Dermal contact with PBDEs in soil	
- Young children	0.1
- Adults	0.08
Inhalation of PBDEs in dust	
- Young children	0.0000003
- Adults	0.0000003
Ingestion of PBDEs in home grown blueberries	
- Young children	0.0002
- Adults	0.00003
Below Reference Dose	**≤1**

Based on the risk estimates, the potential for PBDEs to be present when MWOO is applied to blueberry farms at 50 tonnes per hectare results in the following:

- Exposure to people who may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil where blueberries are grown or who regularly consume blueberries grown on such sites will be below the reference doses for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

Application to Mining Rehabilitation Sites – Future Uses

Direct Contact with Soil/MWOO

Table 7 Summary of Risk Estimates (mean) – 100 tonnes per hectare/ incorporated into top 2 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	2
- Adults	0.2
Dermal contact with PBDEs in soil	
- Young children	1.5
- Adults	0.8
Inhalation of PBDEs in dust	
- Young children	0.000003
- Adults	0.000003
Below Reference Dose	**≤1**

Table 8 Summary of Risk Estimates (mean) – 100 tonnes per hectare/ incorporated into top 10 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.4
- Adults	0.04
Dermal contact with PBDEs in soil	
- Young children	0.3
- Adults	0.2
Inhalation of PBDEs in dust	
- Young children	0.0000005
- Adults	0.0000005
Below Reference Dose	**≤1**

Table 9 Summary of Risk Estimates (mean) – 100 tonnes per hectare/ incorporated into top 40 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.1
- Adults	0.01
Dermal contact with PBDEs in soil	
- Young children	0.08
- Adults	0.04

Receptor/Exposure Pathway	Threshold Risk
Inhalation of PBDEs in dust	
- Young children	0.0000001
- Adults	0.0000001
Below Reference Dose	**≤1**

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present when MWOO is applied for future mining rehabilitation at 100 tonnes per hectare results in the following:

- Most scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure is estimated to be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied and mixed into 2 cm depth is estimated to be higher than the reference dose for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

INGESTION OF HOME-GROWN PRODUCE

Table 10 Summary of Risk Estimates (mean) – 100 tonnes per hectare

Receptor/Exposure Pathway	Threshold Risk Incorp 2 cm	Threshold Risk Incorp 10 cm	Threshold Risk Incorp 40 cm
6 months on treated pasture – higher bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	25	5	1
- Adults	7	1	0.3
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	37	7	2
- Adults	15	3	0.8
6 months on treated pasture – lower bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	10	2	0.5
- Adults	3	0.5	0.1
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	15	3	0.7
- Adults	6	1	0.3
52 days on treated pasture – higher bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	7	1.5	0.4
- Adults	2	0.4	0.1
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	10	2	0.5
- Adults	4	0.8	0.2

Receptor/Exposure Pathway	Threshold Risk Incorp 2 cm	Threshold Risk Incorp 10 cm	Threshold Risk Incorp 40 cm
52 days on treated pasture – lower bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	3	0.6	0.1
- Adults	0.8	0.2	0.04
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	4	0.8	0.2
- Adults	1.5	0.3	0.08
Below Reference Dose		**≤1**	

Based on the risk estimates for ingestion of home-grown produce where MWOO was used for application for future mining rehabilitation at 100 tonnes per hectare and incorporated into the soil (2, 10 or 40 cm), the potential for PBDEs to be present results in the following:

- Most scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied and mixed into the top 2 cm indicate exposure will be above the reference doses for PBDEs
- Those scenarios where MWOO has been mixed into the top 10 cm and where people may consume home grown milk or meat on a regular basis are estimated to result in exposure above the reference dose for PBDEs
- Those scenarios where MWOO has been deeply ripped (mixed into 40 cm) will result in exposure above the reference dose for PBDEs for cattle kept on the treated area for 6 months of the year and below the reference dose for PBDEs for cattle kept on the treated area for 52 days per year

It is noted that these calculations have listed the results for the mean concentrations.

Application to Mining Rehabilitation Sites – Past Uses

Direct Contact with Soil/MWOO

Table 11 Summary of Risk Estimates (mean) – 140 tonnes per hectare/ incorporated into top 2 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	3
- Adults	0.3
Dermal contact with PBDEs in soil	
- Young children	2
- Adults	1
Inhalation of PBDEs in dust	
- Young children	0.000004
- Adults	0.000004
Below Reference Dose	**≤1**

Table 12 Summary of Risk Estimates (mean) – 140 tonnes per hectare/ incorporated into top 10 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.5
- Adults	0.05
Dermal contact with PBDEs in soil	
- Young children	0.4
- Adults	0.2
Inhalation of PBDEs in dust	
- Young children	0.0000008
- Adults	0.0000008
Below Reference Dose	**≤1**

Table 13 Summary of Risk Estimates (mean) – 140 tonnes per hectare/ incorporated into top 40 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PBDEs in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.1
- Adults	0.01
Dermal contact with PBDEs in soil	
- Young children	0.1
- Adults	0.05
Inhalation of PBDEs in dust	
- Young children	0.0000002
- Adults	0.0000002
Below Reference Dose	**≤1**

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present when MWOO was applied for mining rehabilitation before 2019 at 140 tonnes per hectare results in the following:

- Most scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference doses for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied and mixed into 2 cm depth may be higher than the reference doses for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

INGESTION OF HOME-GROWN PRODUCE

Table 14 Summary of Risk Estimates (mean) – 140 tonnes per hectare

Receptor/Exposure Pathway	Threshold Risk Incorp 2 cm	Threshold Risk Incorp 10 cm	Threshold Risk Incorp 40 cm
6 months on treated pasture – higher bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	35	7	2

Receptor/Exposure Pathway	Threshold Risk Incorp 2 cm	Threshold Risk Incorp 10 cm	Threshold Risk Incorp 40 cm
- Adults	9	2	0.5
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	50	10	3
- Adults	21	4	1
6 months on treated pasture – lower bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	14	3	0.7
- Adults	4	0.8	0.2
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	20	4	1
- Adults	8	2	0.4
52 days on treated pasture – higher bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	10	2	0.5
- Adults	3	0.5	0.1
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	14	3	0.7
- Adults	6	1	0.3
52 days on treated pasture – lower bioaccessibility value			
Ingestion of PBDEs in milk produced at a site (100% contribution to diet)			
- Young children	4	0.8	0.2
- Adults	1	0.2	0.05
Ingestion of PBDEs in meat produced at a site (35% contribution to diet)			
- Young children	6	1	0.3
- Adults	2	0.4	0.1
Below Reference Dose		**≤1**	

Based on the risk estimates for ingestion of home-grown produce**,** the potential for PBDEs to be present when MWOO was applied for mining rehabilitation before 2019 at 140 tonnes per hectare results in the following:

- Almost all scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied including some where the material is deeply ripped (mixed into 40 cm) indicate exposure will be above the reference dose for PBDEs

It is noted that these calculations have listed the results for the mean concentrations.

Risk Estimates – PFAS

Updating the risk estimates can be easily undertaken using the same dilution factors indicated above for the exposure concentrations. This is because the calculations of risk are linear if only the exposure concentrations are changing.

The risk estimates from enRiskS (2019) for the scenario where MWOO is applied directly to the surface of grazing land without being incorporated at all (i.e. undiluted) have been used to provide these estimates. The risk estimates for this scenario are adjusted using the dilution factors listed above.

In addition, assessment of potential risks due to use of MWOO on land used to grow blueberries has been undertaken. This was an agricultural use but used a higher application rate than assessed in enRiskS (2019). The calculation spreadsheets just for consumption of blueberries are attached at **Appendix B**.

Application to Forest Plantations

Table 15 Summary of Risk Estimates (PFOS) (mean) – 50 Tonnes per Hectare

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOS in soil			
- Young children	0.008	0.002	0.0004
- Adults	0.0008	0.0002	0.00004
Dermal contact with PFOS in soil			
- Young children	Dermal absorption is very low for this chemical, so risk is negligible		
- Adults			
Inhalation of PFOS in dust			
- Young children	Negligible		
- Adults			
Ingestion of PFOS in milk from a site (100% contribution to diet)			
- Young children	2.7	0.5	0.1
- Adults	0.7	0.1	0.03
Ingestion of PFOS in meat at a site (35% contribution to diet)			
- Young children	0.2	0.04	0.01
- Adults	0.1	0.02	0.005
Below Reference Dose		**≤1**	

Table 16 Summary of Risk Estimates (PFOA mean) – 50 Tonnes per Hectare

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOA in soil			
- Young children	0.001	0.0002	0.00006
- Adults	0.0001	0.00002	0.000006
Dermal contact with PFOA in soil			

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
- Young children - Adults	Dermal absorption is very low for this chemical, so risk is negligible		
Inhalation of PFOA in dust - Young children - Adults		Negligible	
Ingestion of PFOA in milk from a site (100% contribution to diet) - Young children - Adults	0.01 0.002	0.002 0.0004	0.0005 0.0001
Ingestion of PFOA in meat at a site (35% contribution to diet) - Young children - Adults	0.001 0.0006	0.0002 0.0001	0.00006 0.00003
Below Reference Dose		**≤1**	

Based on these risk estimates**,** the potential for PFAS to be present in surface soil after application of MWOO for forestry plantations, results in the following conclusions:

- Scenarios where people may come into contact with soil from land where MWOO has been incorporated into the soil (top 2, 10 or 40 cm) at 50 tonnes per hectare indicate exposure will be below the reference doses for PFAS (PFOS or PFOA related chemicals).
- Consumption of home grown milk where cattle graze on ground to which MWOO has been applied at 50 tonnes per hectare and only trampled in (i.e. top 2 cm) at the surface is estimated to result in exposure greater than the reference dose for PFOS related chemicals but not for PFOA related chemicals.
- All other scenarios where consumption of home grown milk and meat may occur where cattle graze on ground where MWOO has been applied at 50 tonnes per hectare indicate exposure will be below the reference doses for PFAS (PFOS or PFOA related chemicals).

USE IN BLUEBERRY FARMING

DIRECT CONTACT WITH SOIL/MWOO AND INGESTION OF BLUEBERRIES GROWN WHERE MWOO HAS BEEN APPLIED

Table 17 Summary of Risk Estimates (PFOS) (mean) – 50 Tonnes per Hectare / incorporated into top 10 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOS in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE) - Young children - Adults	0.002 0.0002
Dermal contact with PFOS in soil - Young children - Adults	Dermal absorption is very low for this chemical, so risk is negligible
Inhalation of PFOS in dust - Young children - Adults	Negligible

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOS in home grown blueberries	
- Young children	0.009
- Adults	0.002
Below Reference Dose	**≤1**

Table 18 Summary of Risk Estimates (PFOA) (mean) – 50 Tonnes per Hectare / incorporated into top 10 cm

Receptor/Exposure Pathway	Threshold Risk
Ingestion of PFOA in soil (includes summation of risks for both Br1 to Br 9 and Deca BDE)	
- Young children	0.0002
- Adults	0.00002
Dermal contact with PFOA in soil	Dermal absorption is very low for this chemical, so risk is negligible
- Young children	
- Adults	
Inhalation of PFOA in dust	
- Young children	Negligible
- Adults	
Ingestion of PFOA in home grown blueberries	
- Young children	0.0006
- Adults	0.0001
Below Reference Dose	**≤1**

Based on the risk estimates for direct contact, the potential for PFAS to be present when MWOO is applied to blueberry farms at 50 tonnes per hectare results in the following:

- Exposure to people who may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil where blueberries are grown or who regularly consume blueberries grown on such sites will be below the reference doses for PFOS and PFOA

It is noted that these calculations have listed the results for the mean concentrations.

Application for Mining Rehabilitation – Future Uses

Table 19 Summary of Risk Estimates (PFOS) (mean) – 100 Tonnes per Hectare

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOS in soil			
- Young children	0.02	0.003	0.0008
- Adults	0.002	0.0003	0.00008
Dermal contact with PFOS in soil	Dermal absorption is very low for this chemical, so risk is negligible		
- Young children			
- Adults			
Inhalation of PFOS in dust	Negligible		
- Young children			
- Adults			

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOS in milk from a site (100% contribution to diet)			
- Young children	5	1	0.3
- Adults	1	0.3	0.07
Ingestion of PFOS in meat at a site (35% contribution to diet)			
- Young children	0.4	0.08	0.02
- Adults	0.2	0.04	0.01
Below Reference Dose		**≤1**	

Table 20 Summary of Risk Estimates (PFOA) (mean) – 100 Tonnes per Hectare

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOA in soil			
- Young children	0.002	0.0005	0.0001
- Adults	0.0002	0.00005	0.00001
Dermal contact with PFOA in soil			
- Young children	Dermal absorption is very low for this chemical, so risk is negligible		
- Adults			
Inhalation of PFOA in dust			
- Young children		Negligible	
- Adults			
Ingestion of PFOA in milk from a site (100% contribution to diet)			
- Young children	0.02	0.004	0.001
- Adults	0.004	0.0008	0.0002
Ingestion of PFOA in meat at a site (35% contribution to diet)			
- Young children	0.002	0.0005	0.0001
- Adults	0.001	0.0002	0.00006
Below Reference Dose		**≤1**	

Based on these risk estimates, the potential for PFAS to be present in surface soil after application of MWOO, results in the following conclusions:

- Scenarios where people may come into contact with soil from land where MWOO has been incorporated into the soil (top 2, 10 or 40 cm) at 100 tonnes per hectare indicate exposure will be below the reference doses for PFAS (PFOS or PFOA related chemicals).
- Consumption of home grown milk where cattle graze on ground to which MWOO has been applied at 100 tonnes per hectare and trampled in at the surface (top 2 cm) or mixed into the top 10 cm may

result in exposure greater than or equal to the reference dose for PFOS related chemicals but not for PFOA related chemicals.

- All other scenarios where consumption of home grown milk and meat may occur where cattle graze on ground where MWOO has been applied at 100 tonnes per hectare indicate exposure will be below the reference doses for PFAS (PFOS or PFOA related chemicals).

Application for Mining Rehabilitation – Past Uses

Table 21 Summary of Risk Estimates (PFOS) (mean) – 140 Tonnes per Hectare

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOS in soil			
- Young children	0.02	0.004	0.001
- Adults	0.002	0.0004	0.0001
Dermal contact with PFOS in soil			
- Young children	Dermal absorption is very low for this chemical, so risk is negligible		
- Adults			
Inhalation of PFOS in dust			
- Young children	Negligible		
- Adults			
Ingestion of PFOS in milk from a site (100% contribution to diet)			
- Young children	7	1.5	0.4
- Adults	2	0.4	0.09
Ingestion of PFOS in meat at a site (35% contribution to diet)			
- Young children	0.5	0.1	0.03
- Adults	0.3	0.05	0.01
Below Reference Dose		**≤1**	

Table 22 Summary of Risk Estimates (PFOA) (mean) – 140 Tonnes per Hectare

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOA in soil			
- Young children	0.003	0.0006	0.0002
- Adults	0.0003	0.00006	0.00002
Dermal contact with PFOA in soil			
- Young children	Dermal absorption is very low for this chemical, so risk is negligible		
- Adults			
Inhalation of PFOA in dust			
- Young children	Negligible		
- Adults			

Receptor/Exposure Pathway	Threshold Risk 2 cm Incorporation	Threshold Risk 10 cm Incorporation	Threshold Risk 40 cm Incorporation
Ingestion of PFOA in milk from a site (100% contribution to diet)			
- Young children	0.02	0.005	0.001
- Adults	0.005	0.001	0.0003
Ingestion of PFOA in meat at a site (35% contribution to diet)			
- Young children	0.003	0.0006	0.0002
- Adults	0.002	0.0003	0.00008
Below Reference Dose		**≤1**	

Based on these risk estimates**,** the potential for PFAS to be present in surface soil after application of MWOO, results in the following conclusions:

- Scenarios where people may come into contact with soil from land where MWOO has been incorporated into the soil (top 2, 10 or 40 cm) at 140 tonnes per hectare indicate exposure will be below the reference doses for PFAS (PFOS or PFOA related chemicals).
- Consumption of home grown milk where cattle graze on ground to which MWOO has been applied at 140 tonnes per hectare and trampled in at the surface (top 2 cm) or mixed into the top 10 cm may result in exposure greater than or equal to the reference dose for PFOS related chemicals but not for PFOA related chemicals.
- All other scenarios where consumption of home grown milk and meat may occur where cattle graze on ground where MWOO has been applied at 140 tonnes per hectare indicate exposure will be below the reference doses for PFAS (PFOS or PFOA related chemicals).

Risk Estimates – Other Chemicals

The assessment of potential human health impacts from other chemicals in MWOO was undertaken in enRiskS (2019) and involved comparison of the 95th percentile concentration of each chemical in undiluted MWOO with a relevant screening guideline.

The 95th percentile concentration used in enRiskS (2019) was that taken from routine monitoring data provided by the facilities or the data for parked chemicals from the NSW EPA commissioned research program.

The screening guidelines were those for low density residential land uses. Using those guidelines to compare to undiluted MWOO implies that all soil in a backyard could be MWOO and so it is a conservative approach.

For chemicals that passed screening on that basis, there is no need to update the assessment for the different application rates used in mining rehabilitation and forestry.

There were a number of chemicals present in undiluted MWOO at concentrations above the screening guideline. The assessment for these chemicals has been undertaken using the application rates used in mining rehabilitation and forestry.

Table 23 Detailed Assessment – MWOO (solid)

Chemicals (Parked Chemicals and Facility Data)	Screening Guideline (mg/kg)	Concentration – 2 cm Incorporation (mg/kg)	Concentration – 10 cm Incorporation (mg/kg)	Concentration – 40 cm Incorporation (mg/kg)
50 Tonnes per Hectare				
Lead	300	65	13	3
Molybdenum	5	1.3	0.3	0.06
Sum Carcinogenic PAHs (BaP equivalents)	3[N]	1.4	0.3	0.07
Total phthalates (assumed as Di-ethylhexyl phthalate) (95th percentile)	30	**98**	20	5
Total phthalates (assumed as Di-ethylhexyl phthalate) (mean)	30	**38**	8	2
100 Tonnes per Hectare				
Lead	300	130	26	7
Molybdenum	5	2.5	0.5	0.1
Sum Carcinogenic PAHs (BaP equivalents)	3[N]	2.7	0.5	0.1
Total phthalates (assumed as Di-ethylhexyl phthalate) (95th percentile)	30	**196**	**39**	10
Total phthalates (assumed as Di-ethylhexyl phthalate) (mean)	30	**77**	15	4
140 Tonnes per Hectare				
Lead	300	178	37	9
Molybdenum	5	3.4	0.7	0.2
Sum Carcinogenic PAHs (BaP equivalents)	3[N]	3.7	0.8	0.2
Total phthalates (assumed as Di-ethylhexyl phthalate) (95th percentile)	30	**268**	**55**	14
Total phthalates (assumed as Di-ethylhexyl phthalate) (mean)	30	**105**	21	5

This screening assessment identifies that phthalates can be present above guidelines when incorporated into either the top 2 cm or top 10 cm of soil when applied at 50, 100 or 140 tonnes per hectare. This group of chemicals is used as plasticisers so it is not unexpected that they may be present at levels above guidelines.

This screening assessment is based on the 95th percentile of the routine monitoring data from all the facilities – 510 mg/kg.

The screening assessment has also included use of the mean value for this data set – 199 mg/kg. If this value is used as the basis for the screening instead then these chemicals remain at levels above the screening guideline when just trampled into the ground (i.e. top 2 cm) but are below the screening guideline for all other scenarios.

Further Assessment – Phthalates

Phthalates are not chemicals that get taken up into home grown produce so only direct contact needs to be assessed for these chemicals. The risks posed by these chemicals via direct contact have been assessed using the same assumptions used in enRiskS (2019).

Soil Ingestion

Ingestion of soil (direct incidental ingestion) is one of the key pathways of exposure relevant for the assessment of exposures.

As noted in Section 5.3.1.2 of Schedule B7 of the ASC NEPM, another pathway of exposure to soil is incidental ingestion of soil that is adhered to home grown produce (like carrots or potatoes). The UK Environment Agency has developed a methodology to estimate how much soil people are likely to consume in this way from home grown produce (i.e. indirect incidental ingestion). The approach found that 2-3 mg of soil is ingested via this pathway. The ingestion rate currently used in the calculations for the national health investigation levels is considered to be sufficient to cover direct and indirect incidental ingestion of soil.

The potential intake of PBDEs identified in surface soil via incidental ingestion (direct and indirect) has been undertaken using the following equation:

$$\text{Daily Chemical Intake}_{ls} = C_s \bullet \frac{IRs \bullet FI \bullet B \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs	= Concentration of treated soil (mg/kg)
IRs	= Ingestion rate of soil (mg/day)
FI	= Fraction of daily ingestion that is derived from contamination source (unitless), taken as 1
B	= Bioavailability or absorption of chemical via ingestion (unitless), taken as 1
CF	= Conversion factor of $1x10^{-6}$ to convert mg to kg
EF	= Exposure frequency (days/year)
ED	= Exposure duration (years)
BW	= Body weight (kg)
AT	= Averaging time for threshold exposures, (=ED x 365 days)
AT(NT)	= Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via soil ingestion for a child or an adult are presented in **Table 24**. All calculations are presented in **Appendix A**.

Dermal Exposures

Dermal absorption of chemicals from soil depends on the area of skin in contact with soil, the duration of contact, how well sorbed the chemical is to the soil and the ability of the chemical to penetrate the skin.

The assessment of the potential dermal absorption of PBDEs has been generally undertaken using the approach presented by the USEPA. They define a simple approach to the evaluation of dermal absorption associated with soil contact (USEPA 1989, 2004). This is presented in the following equation:

$$\text{Daily Chemical Intake} = C_s \bullet \frac{SAs \bullet AF \bullet ABSd \bullet CF \bullet EF \bullet ED}{BW \bullet AT} \qquad \text{(mg/kg/day)}$$

where:

Cs	= Concentration in soil (mg/kg)
SAs	= Surface area of body exposed to soil per day (cm^2/day)
AF	= Adherence factor, amount of soil that adheres to the skin per unit area which depends on soil properties and area of body (mg/cm^2 per event)
ABSd	= Dermal absorption fraction (unitless), refer to note below
CF	= Conversion factor of $1x10^{-6}$ to convert mg to kg

EF = Exposure frequency (days/year)
ED = Exposure duration, taken to be 6 years for children and 29 years for adults
BW = Body weight (kg), taken to be 15 kg for children and 70 kg for adults as per ASC NEPM 1999
AT = Averaging time for threshold exposures, (=ED x 365 days)
AT(NT) = Averaging time for non-threshold exposures (=70 years x 365 days)

The assumptions adopted for the quantification of potential intakes via dermal absorption from soil ingestion for a child or an adult are presented in **Table 24**. All calculations are presented in **Appendix A**.

Table 24 Summary of Exposure Parameters Adopted –Ingestion and Dermal Contact with Soil

Exposure Parameter	Value adopted for Child (aged 0-5 years)	Value adopted for adults
Ingestion rate (soil)	100 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013a)	50 mg/day of soil and dust assuming time is spent outdoors and indoors on the site (NEPC 1999 amended 2013a)
Skin surface area	2 700 cm^2 based on the surface area for hands, legs, arms (NEPC 1999 amended 2013a)	6 300 cm^2 based on the surface area for hands, legs, arms (NEPC 1999 amended 2013a)
Soil to skin adherence factor	0.3 (USEPA 2004)	0.3 (USEPA 2004)
Fraction of day exposed	1 - assumes that the child remains in contact with the dirt on their skin for 24 hours (i.e. doesn't shower until next day)	1 - assumes that the adult remains in contact with the dirt on their skin for 24 hours (i.e. doesn't shower until next day)
Exposure frequency	365 days per year	365 days per year
Exposure duration	6 years as a young child	29 years as an adult assuming a total of 35 years residency at the same location as a child and adult (NEPC 1999 amended 2013a)
Body weight	15 kg (NEPC 1999 amended 2013a)	70 kg (NEPC 1999 amended 2013a)
Bioavailability	100%	100%

Risks have been determined for the worst case – application at 140 tonnes per hectare and mixing into the top 2 cm of soil only. The 95th percentile concentration listed in **Table 23** for this combination is 268 mg/kg. This value has been used to calculate the potential risks from direct contact as a worst case for all scenarios.

The reference dose for diethylhexyl phthalate provided in the NHMRC Australian Drinking Water Guidelines has been used for this assessment – 0.025 mg/kg bw/day (NHMRC 2011 updated 2018).

Table 25 Summary of Risk Estimates (mean) – 140 tonnes per hectare/2 cm incorporation

Receptor/Exposure Pathway	Threshold Risk (2 cm)
Ingestion of phthalates in soil	
- Young children	0.09
- Adults	0.01
Dermal contact with phthalates in soil	
- Young children	0.07
- Adults	0.04
Inhalation of phthalates in dust	
- Young children	0.0000001
- Adults	0.0000001
Below Reference Dose	**≤1**

Based on the risk estimates for direct contact**,** the potential for phthalates to be present when MWOO is applied for forestry or mining rehabilitation results in the following:

- All scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure will be below the reference doses for phthalates

Ecological Risk

The assessment of potential ecological impacts from other chemicals in MWOO in enRiskS (2019) involved comparison of the 95th percentile concentration of each chemical in undiluted MWOO with a relevant screening guideline.

The 95th percentile concentration used in enRiskS (2019) was that taken from routine monitoring data provided by the facilities or the data for parked chemicals from the NSW EPA commissioned research program.

The screening guidelines were developed in enRiskS (2019) using the approach recommended in the ASC NEPM (NEPC 1999 amended 2013b). Using those screening guidelines to compare to undiluted MWOO implies that all soil could be MWOO and so it is a conservative approach.

For chemicals that passed screening on that basis, there is no need to update the assessment for the different application rates used in mining rehabilitation and forestry.

There were a number of chemicals present in undiluted MWOO at concentrations above the screening guideline. The assessment for these chemicals has been undertaken using the application rates used in mining rehabilitation and forestry as shown in **Table 26**.

Table 26 Detailed Assessment – MWOO (solid) – Ecological

Chemicals (Parked Chemicals and Facility Data)	Screening Guideline (mg/kg)	Concentration – 2 cm Incorporation (mg/kg)	Concentration – 10 cm Incorporation (mg/kg)	Concentration – 40 cm Incorporation (mg/kg)
50 Tonnes per Hectare				
Iron	7.5	3270	650	160
Di-n-octyl phthalate	0.8	0.4	0.07	0.02
Organotins	0.0003	0.1	0.03	0.007
Atrazine	0.01	0.3	0.06	0.01
Endosulfan	0.004	0.1	0.03	0.007
Dicamba	0.002	0.03	0.007	0.002
Chlordane	0.02	0.07	0.01	0.003
2,4,5-T	0.02	0.03	0.007	0.002
Boron	5.7	9.6	1.9	0.5
Cadmium	0.9	0.8	0.2	0.04
Copper	60	230	46	12
Lead	130	65	13	3
Lithium	1.76	0.5	0.1	0.03
Manganese	220	90	18	5
Mercury	0.022	0.1	0.03	0.007
Nickel	10	8	2	0.4
Tin	50	11	2	0.5
Titanium	60	23	5	1
Vanadium	6	3	0.7	0.2
Zinc	100	144	29	7
Di-ethylhexyl phthalate	13	35	7	2
Dibutyl phthalate	0.05	2	0.5	0.1

Chemicals (Parked Chemicals and Facility Data)	Screening Guideline (mg/kg)	Concentration – 2 cm Incorporation (mg/kg)	Concentration – 10 cm Incorporation (mg/kg)	Concentration – 40 cm Incorporation (mg/kg)
Total phthalates	13	98	20	5
PBDE (Br1toBr9)	0.38[1]	4	0.8	0.2
Deca BDE	98[1]	1.7	0.3	0.09
PFOS (and related chemicals)	0.01[2]	0.02	0.004	0.001
PFOA (and related chemicals)	0.1[3]	0.05	0.01	0.003
100 Tonnes per Hectare				
Iron	7.5	6500	1300	330
Di-n-octyl phthalate	0.8	0.7	0.1	0.04
Organotins	0.0003	0.3	0.05	0.01
Atrazine	0.01	0.6	0.1	0.03
Endosulfan	0.004	0.3	0.05	0.01
Dicamba	0.002	0.07	0.01	0.003
Chlordane	0.02	0.1	0.03	0.007
2,4,5-T	0.02	0.07	0.01	0.003
Boron	5.7	19	4	1
Cadmium	0.9	1.5	0.3	0.08
Copper	60	460	92	23
Lead	130	130	26	7
Lithium	1.76	1	0.2	0.05
Manganese	220	180	36	9
Mercury	0.022	0.3	0.05	0.01
Nickel	10	17	3	0.8
Tin	50	21	4	1
Titanium	60	46	9	2
Vanadium	6	7	1	0.3
Zinc	100	290	58	14
Di-ethylhexyl phthalate	13	70	14	3
Dibutyl phthalate	0.05	5	0.9	0.2
Total phthalates	13	196	39	10
PBDE (Br1toBr9)	0.38[1]	8	1.5	0.4
Deca BDE	98[1]	3.5	0.7	0.2
PFOS (and related chemicals)	0.01[2]	0.04	0.008	0.002
PFOA (and related chemicals)	0.1[3]	0.1	0.02	0.006
140 Tonnes per Hectare				
Iron	7.5	8900	1800	460
Di-n-octyl phthalate	0.8	1	0.2	0.05
Organotins	0.0003	0.4	0.08	0.02
Atrazine	0.01	0.8	0.2	0.04
Endosulfan	0.004	0.4	0.08	0.02
Dicamba	0.002	0.09	0.02	0.005
Chlordane	0.02	0.2	0.04	0.009
2,4,5-T	0.02	0.09	0.02	0.005
Boron	5.7	26	5	1
Cadmium	0.9	2	0.4	0.1
Copper	60	630	130	32
Lead	130	180	37	9
Lithium	1.76	1	0.3	0.08

Chemicals (Parked Chemicals and Facility Data)	Screening Guideline (mg/kg)	Concentration – 2 cm Incorporation (mg/kg)	Concentration – 10 cm Incorporation (mg/kg)	Concentration – 40 cm Incorporation (mg/kg)
Manganese	220	250	50	13
Mercury	0.022	0.4	0.08	0.02
Nickel	10	23	5	1
Tin	50	29	6	1
Titanium	60	63	13	3
Vanadium	6	9	2	0.5
Zinc	100	395	81	10
Di-ethylhexyl phthalate	13	95	19	5
Dibutyl phthalate	0.05	6	1	0.3
Total phthalates	13	270	55	14
PBDE (Br1toBr9)	0.38[1]	11	2.2	0.5
Deca BDE	98[1]	5	1	0.2
PFOS (and related chemicals)	0.01[2]	0.06	0.01	0.003
PFOA (and related chemicals)	0.1[3]	0.2	0.03	0.008

Notes:

1 Criteria adopted are those from NSW EPA commissioned Research Program

2 Criteria adopted is from PFAS National Environmental Management Plan – indirect exposure (i.e. direct contact and bioaccumulation) (HEPA 2019)

3 Criteria adopted is from PFAS National Environmental Management Plan – PFOA value for direct exposure only adjusted for indirect exposure (i.e. direct contact and bioaccumulation) using same factor as for PFOS (HEPA 2019)

This ecological assessment indicates the following:

- 50 tonnes per hectare
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 2 cm include iron, organotins, atrazine, endosulfan, dicamba, chlordane, 2,4,5-T, boron, copper, mercury, zinc, di-ethylhexyl phthalate, dibutyl phthalate, total phthalates, PBDEs (Br1 to Br9) and PFOS (and related chemicals)
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 10 cm include iron, organotins, atrazine, endosulfan, dicamba, mercury, dibutyl phthalate, total phthalates and PBDEs (Br1 to Br9)
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 40 cm include iron, organotins, endosulfan and dibutyl phthalate
- 100 tonnes per hectare
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 2 cm include iron, organotins, atrazine, endosulfan, dicamba, chlordane, 2,4,5-T, boron, cadmium, copper, lead, mercury, nickel, vanadium, zinc, di-ethylhexyl phthalate, dibutyl phthalate, total phthalates, PBDEs (Br1 to Br9) and PFOS (and related chemicals)
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 10 cm include iron, organotins, atrazine, endosulfan, dicamba, chlordane, copper, mercury, di-ethylhexyl phthalate, dibutyl phthalate, PBDEs (Br1 to Br9) and total phthalates
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 40 cm include iron, organotins, atrazine, endosulfan, dicamba, PBDEs (Br1 to Br9) and dibutyl phthalate
- 140 tonnes per hectare
  - Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 2 cm include iron, di-n-octyl phthalate, organotins, atrazine, endosulfan, dicamba, chlordane, 2,4,5-T, boron, cadmium, copper, lead, manganese, mercury, nickel, titanium, vanadium,

zinc, di-ethylhexyl phthalate, dibutyl phthalate, total phthalates, PBDEs (Br1 to Br9) and PFOS (and related chemicals)
- Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 10 cm include iron, organotins, atrazine, endosulfan, dicamba, chlordane, copper, mercury, di-ethylhexyl phthalate, dibutyl phthalate, PBDEs (Br1 to Br9) and total phthalates
- Chemicals at levels that may impact ecosystems when MWOO is incorporated into the top 40 cm include iron, organotins, atrazine, endosulfan, dicamba, dibutyl phthalate, PBDEs (Br1 to Br9) and total phthalates

This assessment indicates that there is potential for unacceptable ecological risks for all of these scenarios. It is not possible to refine this assessment further so such risks cannot be ruled out.

It is noted that the approach taken to determine the screening guidelines is likely to provide conservative guidelines as it is based on assuming that the chemicals can move from the MWOO into rainwater (or during irrigation), leach into groundwater or runoff into surface waters and impact on aquatic organisms. There is little terrestrial ecotoxicological data available for many of these chemicals, so it has been assumed that the soil organisms have similar sensitivity to aquatic organisms. This approach is in line with Australian guidance but is acknowledged to have limitations.

It is also noted, as was done in enRiskS (2019), that some of the pesticides listed were only reported in one or two samples, so it is possible that these chemicals were not routinely present in MWOO. However, for metals and phthalates, these chemicals were detected routinely in MWOO and so the potential for damage to soil ecosystems may be present at most sites where MWOO was applied.

Changes Over Time

Once chemicals are released into the environment such as by application of MWOO to land they can travel, degrade (change form) or stay in the place where they are released. This is the case whether the chemicals are naturally occurring ones or ones that people have manufactured. The fate of a chemical in the environment depends on a number of factors including the characteristics of the chemical and the nature of the environment into which the chemical is released.

Many chemicals are readily broken down into their component parts.

Many substances get broken into their component parts by bacteria. The bacteria use the substances as food – extracting energy by breaking the bonds between atoms. This is known as biodegradation.

Some substances break apart in sunlight – photolysis. Other substances break apart when they dissolve in water – hydrolysis.

Many of the chemicals reported to be present in MWOO are those that can be broken down, however, PBDEs and PFAS are highly persistent chemicals which are not easily broken into their component parts.

For chemicals that are persistent, there are a number of factors that control where such chemicals end up. Some substances stick to clay particles or organic carbon in soil or sediments and they get stuck in the location where they are first applied, and they don't travel much further. Other chemicals are quite water soluble so they travel with the surface water or groundwater and can reach places some distance from where they were initially used.

Whenever considering the likely fate of a chemical in the environment, there are a number of issues that must be considered including:

- Will the chemical end up in soil, water, air, sediments or in organisms?
- Is the chemical persistent (short lived or long lived)?
- Does the chemical accumulate in organisms (plants, animals, people)?

- Can the chemical be broken down by chemical processes (change in environmental conditions (e.g. pH), impact of sunlight)?
- Can the chemical be broken down by microbial processes (do microorganisms use the chemical for food and do those microorganisms need oxygen or are they ones that cannot live if oxygen is present)?
- Does the chemical wash through the soil and into groundwater or surface waters when it rains (i.e. leaching from soil to water)?
- Is the chemical volatile – does it evaporate into the air and get blown away by wind?
- What mix of chemicals is already present in the environment and do those chemicals already present impact on the chemical under investigation?

PBDEs are persistent chemicals that stick to organic carbon and clays and tend not to move far from where they are placed. As noted, they do not break down easily and have half lives of many years to decades (i.e. time taken for the concentration present in soil to halve). They are not readily leachable nor are they volatile. So, these chemicals may remain in soil at a site where MWOO has been applied for many years.

There are other ways that may change the potential for exposure to MWOO over time. It is possible that wind may blow MWOO or soil containing MWOO away from the site or blow other soil toward the site. Also, changes in the presence or type of vegetation through time may change how grazing animals interact with the soil and MWOO. These changes may change the exposure of livestock over time.

PFAS are extremely persistent and cannot be broken down in the environment or by organisms. They are also highly water soluble which means they can be washed from the MWOO and leach down into groundwater or run off across land toward surface waters. So, they can readily move away from their original location. If the chemicals are washed out of the MWOO by rain, then that will lower the concentrations present in soil where livestock may graze. At sites with significant contamination by PFAS (sites where fire fighting foams have been used), these chemicals are still present on site a decade after use ceased. The potential for PFAS to be present due to application of MWOO is not expected to result in contamination at levels like these sites but it does indicate that it could take years for significant changes in exposure concentrations to occur.

Processes over time including:

- Coverage of a site with windblown dust
- Loss of MWOO from a site due to wind
- Additional coverage due to increased vegetation or change in type of vegetation
- MWOO wash off from a site due to large rain events (e.g. where significant erosion occurs)
- Leaching to groundwater
- Runoff across the land surface

may reduce the concentrations of highly persistent chemicals (like PBDEs, PFAS, or metals) present in soil at a site due to the application of MWOO through time. Other chemicals that are less persistent are likely to break down over weeks to months. The best way to determine how quickly any chemicals present in MWOO dissipate from a site would be to sample and analyse soil at regular intervals or before any changes in land use at a site.

Conclusions

Human Health Risks

Application to Forestry Plantations

PBDEs

Based on the risk estimates, the potential for PBDEs to be present when MWOO is applied to forestry plantations at 50 tonnes per hectare results in the following:

- Most scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil for forestry uses indicate exposure is estimated to be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied and mixed into 2 cm depth is estimated to be equal to the reference dose for PBDEs
- Most scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied and mixed into the top 2 cm indicate exposure is estimated to be above the reference dose for PBDEs
- Those scenarios where MWOO has been mixed into the top 10 cm and where people may consume home grown milk or meat on a regular basis are estimated to result in exposure above the reference dose for PBDEs for cattle kept on the treated area for 6 months of the year and equal to or below the reference dose for PBDEs for cattle kept on the treated area for 52 days per year
- Those scenarios where MWOO has been deeply ripped (mixed into 40 cm) will result in exposure equal to or below the reference dose for PBDEs

PFAS

Based on these risk estimates, the potential for PFAS to be present in surface soil after application of MWOO, results in the following conclusions:

- Scenarios where people may come into contact with soil from land where MWOO has been incorporated into the soil (top 2, 10 or 40 cm) at 50 tonnes per hectare indicate exposure is estimated to be below the reference doses for PFAS (PFOS or PFOA related chemicals)
- Consumption of home grown milk where cattle graze on ground to which MWOO has been applied at 50 tonnes per hectare and only trampled in (i.e. top 2 cm) at the surface is estimated to result in exposure greater than the reference dose for PFOS related chemicals but not for PFOA related chemicals
- All other scenarios where consumption of home grown milk and meat may occur where cattle graze on ground where MWOO has been applied at 50 tonnes per hectare indicate exposure is estimated to be below the reference doses for PFAS (PFOS or PFOA related chemicals)

Most other chemicals that were measured in MWOO were screened in the previous HHERA and found to not be above relevant guidelines in undiluted MWOO. No update is required to that assessment based on the higher application rates. A chemical group that was above screening guidelines in undiluted MWOO was phthalate plasticisers. These chemicals remain above screening guidelines when applied to forestry plantations and mixed only into the top 2 cm of soil. Further worst case assessment (i.e. 140 tonnes per hectare/2 cm incorporation) of risks due to direct contact indicate that exposure is estimated to be below the reference dose.

Use in Blueberry Farming

PBDEs

Based on the risk estimates, the potential for PBDEs to be present when MWOO is applied to blueberry farms at 50 tonnes per hectare results in the following:

- Exposure to people who may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil where blueberries are grown or who regularly consume blueberries grown on such sites will be below the reference doses for PBDEs

PFAS

Based on the risk estimates for direct contact, the potential for PFAS to be present when MWOO is applied to blueberry farms at 50 tonnes per hectare results in the following:

- Exposure to people who may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil where blueberries are grown or who regularly consume blueberries grown on such sites will be below the reference doses for PFOS and PFOA

Most other chemicals that were measured in MWOO were screened in the previous HHERA and found to not be above relevant guidelines in undiluted MWOO. No update is required to that assessment based on the higher application rates. A chemical group that was above screening guidelines in undiluted MWOO was phthalate plasticisers. These chemicals remain above screening guidelines when applied to forestry plantations and mixed only into the top 2 cm of soil. Further worst case assessment (i.e. 140 tonnes per hectare/2 cm incorporation) of risks due to direct contact indicate that exposure is estimated to be below the reference dose.

Application for Mining Rehabilitation (Future Use)

PBDEs

Based on the risk estimates, the potential for PBDEs to be present when MWOO is applied for future mining rehabilitation at 100 tonnes per hectare results in the following:

- Most scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure is estimated to be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied and mixed into 2 cm depth is estimated to be higher than the reference dose for PBDEs
- Scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied and mixed into the top 2 cm indicate exposure is estimated to be above the reference dose for PBDEs
- Those scenarios where MWOO has been mixed into the top 10 cm and where people may consume home grown milk or meat on a regular basis are estimated to result in exposure above the reference dose for PBDEs
- Those scenarios where MWOO has been deeply ripped (mixed into 40 cm) is estimated to result in exposure above the reference dose for PBDEs for cattle kept on the treated area for 6 months of the year and below the reference dose for PBDEs for cattle kept on the treated area for 52 days per year

PFAS

Based on these risk estimates, the potential for PFAS to be present in surface soil after application of MWOO, results in the following conclusions:

- Scenarios where people may come into contact with soil from land where MWOO has been incorporated into the soil (top 2, 10 or 40 cm) at 100 tonnes per hectare indicate exposure is estimated to be below the reference doses for PFAS (PFOS or PFOA related chemicals).
- Consumption of home grown milk where cattle graze on ground to which MWOO has been applied at 100 tonnes per hectare and trampled in at the surface (top 2 cm) or mixed into the top 10 cm is estimated to result in exposure greater than or equal to the reference dose for PFOS related chemicals but not for PFOA related chemicals.
- All other scenarios where consumption of home grown milk and meat may occur where cattle graze on ground where MWOO has been applied at 100 tonnes per hectare indicate exposure is estimated to be below the reference doses for PFAS (PFOS or PFOA related chemicals).

Most other chemicals that were measured in MWOO were screened in the previous HHERA and found to not be above relevant guidelines in undiluted MWOO. No update is required to that assessment based on the higher application rates. A chemical group that was above screening guidelines in undiluted MWOO was phthalate plasticisers. These chemicals remain above screening guidelines when applied for mine rehabilitation (future uses) and mixed into the top 2 cm or top 10 cm of soil. Further worst case assessment (i.e. 140 tonnes per hectare/2 cm incorporation) of risks due to direct contact indicate that exposure is estimated to be below the reference dose.

Application for Mining Rehabilitation (Past Use)

PBDEs

Based on the risk estimates for direct contact**,** the potential for PBDEs to be present when MWOO was applied for mining rehabilitation before 2019 at 140 tonnes per hectare results in the following:

- Most scenarios where people may come into contact with soil on a regular basis from land where MWOO has been incorporated into the soil indicate exposure is estimated to be below the reference dose for PBDEs
- Direct exposure on a regular basis to soil where MWOO has been applied and mixed into the top 2 cm depth is estimated to be higher than the reference dose for PBDEs
- Scenarios where people may consume home grown milk or meat on a regular basis produced on land where MWOO has been applied and mixed into the top 2 cm indicate exposure is estimated to be above the reference dose for PBDEs
- Those scenarios where MWOO has been mixed into the top 10 cm and where people may consume home grown milk or meat on a regular basis are estimated to result in exposure above the reference dose for PBDEs
- Those scenarios where MWOO has been deeply ripped (mixed into 40 cm) is estimated to result in exposure above the reference dose for PBDEs for cattle kept on the treated area for 6 months of the year and below the reference dose for PBDEs for cattle kept on the treated area for 52 days per year

PFAS

Based on these risk estimates**,** the potential for PFAS to be present in surface soil after application of MWOO, results in the following conclusions:

- Scenarios where people may come into contact with soil from land where MWOO has been incorporated into the soil (top 2, 10 or 40 cm) at 140 tonnes per hectare indicate exposure is estimated to be below the reference doses for PFAS (PFOS or PFOA related chemicals)
- Consumption of home grown milk where cattle graze on ground to which MWOO has been applied at 140 tonnes per hectare and trampled in at the surface (top 2 cm) or mixed into the top 10 cm is estimated to result in exposure greater than or equal to the reference dose for PFOS related chemicals but not for PFOA related chemicals

- All other scenarios where consumption of home grown milk and meat may occur where cattle graze on ground where MWOO has been applied at 140 tonnes per hectare indicate exposure is estimated to be below the reference doses for PFAS (PFOS or PFOA related chemicals)

Most other chemicals that were measured in MWOO were screened in the previous HHERA and found to not be above relevant guidelines in undiluted MWOO. No update is required to that assessment based on the higher application rates. A chemical group that was above screening guidelines in undiluted MWOO was phthalate plasticisers. These chemicals remain above screening guidelines when applied for mine rehabilitation (past uses) and mixed into the top 2 cm or top 10 cm of soil. Further worst case assessment (i.e. 140 tonnes per hectare/2 cm incorporation) of risks due to direct contact indicate that exposure is estimated to be below the reference dose.

Ecological Risks

This assessment indicates that there is potential for unacceptable ecological risks for all of these scenarios. It is not possible to refine this assessment further so such risks cannot be ruled out.

It is noted that the approach taken to determine the screening guidelines is likely to provide conservative guidelines as it is based on assuming that the chemicals can move from the MWOO into rainwater (or during irrigation), leach into groundwater or runoff into surface waters and impact on aquatic organisms. There is little terrestrial ecotoxicological data available for many of these chemicals, so it has been assumed that the soil organisms have similar sensitivity to aquatic organisms. This approach is in line with Australian guidance but is acknowledged to have limitations.

It is also noted, as was done in enRiskS (2019), that some of the pesticides listed were only reported in one or two samples, so it is possible that these chemicals were not routinely present in MWOO. However, for metals and phthalates, these chemicals were detected routinely in MWOO and so the potential for damage to soil ecosystems may be present at most sites where MWOO was applied.

Changes Over Time

Processes over time including:

- Coverage of a site with windblown dust
- Loss of MWOO from a site due to wind
- Additional coverage due to increased vegetation or change in type of vegetation
- MWOO wash off from a site due to large rain events (e.g. where significant erosion occurs)
- Leaching to groundwater
- Runoff across the land surface

may reduce the concentrations of highly persistent chemicals (like PBDEs, PFAS, or metals) present in soil at a site due to the application of MWOO through time. However, these chemicals may remain in soil at a site where MWOO has been applied for many years. Other chemicals that are less persistent are likely to break down over weeks to months. The best way to determine how quickly any chemicals present in MWOO dissipate from a site would be to sample and analyse soil at regular intervals or before any changes in land use at a site.

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.

It is prepared in accordance with the scope of work and for the purpose outlined at the beginning of this letter report and in the Section 1 of enRiskS (2019).

The methodology adopted and sources of information used are outlined in this 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. No indications were found that information provided was false.

This report was prepared in August 2019 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 should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Closure

If you require any additional information, please do not hesitate to contact us on (02) 9614 0297.

Yours sincerely,

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Appendix A

Exposure to Chemicals via Incidental Ingestion of Soil - 140 tonnes per hectare

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Young Children

Ingestion Rate (IRs, mg/day)	100	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Soil (Cs)	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Di-ethylhexyl phthalate		2.5E-02	20%	0.020000	268	1.5E-04	1.8E-03	--	0.0893

Exposure to Chemicals via Incidental Ingestion of Soil - 140 tonnes per hectare

$$Daily\ Chemical\ Intake_{IS} = C_S \bullet \frac{IR_S \bullet FI \bullet CF \bullet B \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

Parameters Relevant to Quantification of Exposure to Adults

Ingestion Rate (IRs, mg/day)	50	ASC NEPM (2013)
Fraction Ingested from Source (FI, unitless)	100%	Assumed to be 100%
Bioavailability (B)	100%	Assumed to be 100%
Exposure Frequency (EF, days/year)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Conversion Factor (CF)	1.00E-06	conversion from mg to kg
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Soil (Cs)	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Di-ethylhexyl phthalate		0.025	20%	0.020000	268	7.9E-05	1.9E-04	--	0.009571

Dermal Exposure to Chemicals via Contact with Soil - 140 tonnes per hectare

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure to Young Children

Surface Area (SAs, cm^2)	2700	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	
Exposure Duration (ED, years)	6	Exposures occur from areas 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	2190	USEPA 1989

	Toxicity Data						Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)	Concentration in Soil (Cs)	Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Di-ethylhexyl phthalate		0.025	20%	0.02000	0.1	268	[illegible]	1.4E-03	--	0.072360

Dermal Exposure to Chemicals via Contact with Soil - 140 tonnes per hectare

$$Daily\ Chemical\ Intake_{DS} = C_S \bullet \frac{SA_S \bullet AF \bullet FE \bullet ABS \bullet CF \bullet EF \bullet ED}{BW \bullet AT}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure to Adults

Surface Area (SAs, cm^2)	6300	Based on hands, legs and arms getting dirty ASC NEPM (2013)
Adherence Factor (AF, mg/cm^2)	0.3	USEPA 2004
Fraction of Day Exposed	1	Assume the child remains dirty for a whole day
Conversion Factor (CF)	1.E-06	Conversion of units
Dermal absorption (ABS, unitless)	Chemical-specific (as below)	
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	USEPA 1989
Averaging Time - Threshold (Atn, days)	10585	USEPA 1989

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Dermal Absorption (ABS)	Concentration in Soil (Cs)	Non-Threshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)		(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Di-ethylhexyl phthalate	0.025	20%	0.02000	0.1	268	3.0E-04	7.2E-04	--	0.036180	

Soil to Air Particulate Emission Factor (PEF) - Outdoors - 140 tonnes per hectare

(Reference: USEPA Soil Screening Guidance (1996), Supplemental Guidance (2002))

$$PEF = \frac{Q/C \cdot 3600}{0.036 \cdot (1-V) \cdot (\frac{U_m}{U_t})^3 \cdot F_x}$$

where:

A	area of site (acres)
Q/C =	dispersion factor (g/m²/s per kg/m³)
V =	fraction of vegetative cover (unitless)
U_m =	mean annual windspeed (m/s)
U_t =	equivalent threshold value (m/s)
U_t/U_m =	ratio of threshold value to windspeed
F_x =	windspeed distribution function (unitless)

Site Data	Comments
2.50	Area of concern covers approx. 0.1 ha
71.01	Calculated using equations for outdoor worker from US EPA, 2002
0.5	Assume half of the area has vegetation cover
3.6	Mean windspeed from 9am and 3pm readings from Scoresby Research Institute Met Station
11.3	Calculated for a threshold velocity of 1 m/s (US EPA, 1996)
3.1	Ratio
3.91E-02	Value based on Ut/Um ratio, Cowherd (1985)

PEF = 1.13E+10 (m³/kg)

COPC	Soil Concentration, C_{soil} (mg/kg)	Dust Concentration C_{dust} [=C_{soil}/PEF] (mg/m³)
Di-ethylhexyl phthalate	268.0000	2.4E-08

PEF for fugitive dust emissions considered relevant for the quantification of inhalation exposures by outdoor workers on a residential or commercial/industrial site (including gardening and landscaping activities). However it is noted that the fugitive model may not be relevant for activities and conditions that may result in the generation of potentially high dust emissions such as dry soils (MC<8%), fine soils (high silt or clay content), high annual average winds (>5.3 m/s) and less than 50% vegetative cover.

Inhalation of Dust (derived from Soil Source) - Children and Adults - 140 tonnes per hectare

$$Inhalation\ Exposure\ Conc_P = C_a \bullet \frac{ET \bullet FI \bullet DF \bullet CC \bullet EF \bullet ED}{AT}$$ (mg/m³)

Parameters Relevant to Quantification of Exposureto Residents

Exposure Time (ET, hr/day)	24	Assumed time spent at the site each day
Exposure Time Indoors (hours/day)	20	ASC NEPM (2013)
Exposure Time Outdoors (hours/day)	4	ASC NEPM (2013)
Fraction Inhaled from Contaminated Source (FI, unitless)	1	Assume all of dust is from site related soil
Deposition Fraction (DF, unitless)	0.75	Assume 75% inhaled dust reaches lungs
Cilliary Clearance (CC, unitless)	0.5	Assume 50% small enough to penetrate deep enough for absorption
Exposure Frequency (EF, days/yr)	365	ASC NEPM (2013)
Exposure Duration (ED, years)	35	Duration of exposure as young child and adult
Averaging Time - NonThreshold (Atc, hours)	613200	USEPA 2009
Averaging Time - Threshold (Atn, hours)	306600	USEPA 2009

	Toxicity Data				Concentration	Daily Exposure		Calculated Risk	
Key Chemical	**Inhalation Unit Risk**	**Chronic TC air**	**Background Intake (% Chronic TC)**	**Chronic TC Allowable for Assessment (TC-Background)**	**in Air (Ca)**	**Inhalation Exposure Concentration - NonThreshold**	**Inhalation Exposure Concentration - Threshold**	**Non-Threshold Risk**	**Chronic Hazard Quotient**
	$(mg/m^3)^{-1}$	(mg/m^3)		(mg/m^3)	(mg/m^3)	(mg/m^3)	(mg/m^3)	(unitless)	(unitless)
Di-ethylhexyl phthalate		0.09	20%	0.07200	2.4E-08	4.4E-09	8.9E-09	--	1.24E-07

Appendix B

Calculation of Uptake Factors for Home-Grown Produce

Refined calculation

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	**Log Kow**	**Root Concentration Factor (i.e. below ground portions)** (Briggs et al 1982) (mg/kg in roots dry weight/mg/kg in solution)	**Root Concentration Factor (i.e. below ground portions)** (Briggs et al 1982) (mg/kg in roots wet weight/mg/kg in solution)	**Leaching factor (%)**	**Transfer into below ground portions** (mg/kg in roots/mg/kg in MWOO)
Sum Br1 to Br9 (mean)	6.5	3056	458	0.13%	0.595869517
DecaBDE (maximum)	6.3	2144	322	0.13%	0.418023567

Organic Chemical (where plant uptake has been identified as of potential significance, refer to Appendix A)	**Log Kow**	**Translocation (i.e. above ground portions)** (Travis & Arms 1988) (mg/kg dry weight /mg/kg in soil dry weight)	**Translocation (i.e. above ground portions)** (Travis & Arms 1988) (mg/kg wet weight /mg/kg in soil dry weight)	**Leaching factor (%)**	**Transfer into above ground portions** (mg/kg in roots/mg/kg in MWOO)
Sum Br1 to Br9 (mean)	6.5	0.006776	0.001016	0.13%	1.3214E-06
DecaBDE (maximum)	6.3	0.008843	0.001326	0.13%	1.72439E-06

Exposure to Chemicals via Ingestion of Home-Grown Produce - Children

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \text{(kg/day)}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF incl FHG (kg/d)	
Consumption Rate - Children	0.055	0.017	0.028	0.18		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (min)				1.32E-06	2.38E-07	(mg/kg produce per mg/kg soil)
Deca BDE (median)				1.72E-06	3.10E-07	

Parameters Relevant to Quantification of Exposure to Young Children

Fraction Home-Grown (FHG)	0.35	Assumed relevant
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	ASC NEPM (2013)
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Cropping Land - Overall Dataset

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Soil (Cs)	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)$^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0020	6.5E-19	1.1E-11	--	0.000000555
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.0000		1.5E-07		0.00749
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.6000		3.3E-09		0.000166
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.8000		4.4E-09		0.000222
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0200		1.1E-10		0.00000555
Deca BDE (min)		0.007	80%	0.0014	0.0020		1.1E-11		0.000000008
Deca BDE (max)		0.007	80%	0.0014	0.5000		2.8E-09		0.00000198
Deca BDE (mean)		0.007	80%	0.0014	0.0800		4.4E-10		0.000000317
Deca BDE (95th percentile)		0.007	80%	0.0014	0.3000		1.7E-09		0.00000119
Deca BDE (median)		0.007	80%	0.0014	0.0400		2.2E-10		0.000000159

Exposure to Chemicals via Ingestion of Home-Grown Produce - Adult

$$\text{Daily Chemical Intake}_{FV} = C_s \bullet \frac{UF \bullet FHG \bullet EF \bullet ED}{BW \bullet AT} \quad \text{(mg/kg/day)}$$

$$UF\ (kg/day) = (CF_{tuber} \times C_{tuber}) + (CF_{root} \times C_{root}) + (CF_{green} \times C_{green}) + (CF_{fruit} \times C_{fruit}) \quad \text{(kg/day)}$$

	Produce Group					
	Green Vegetables	Root Vegetables	Tuber Vegetables	Tree Fruit	Combined UF incl FHG (kg/d)	
Consumption Rate - Adult	0.1534	0.0468	0.0598	0.14		(kg/day)
Plant Uptake Factors for Key Chemicals						
Sum Br1 to Br9 (min)				1.32E-06	1.85E-07	(mg/kg produce per mg/kg soil)
Deca BDE (median)				1.72E-06	2.41E-07	

Parameters Relevant to Quantification of Exposure to Adults

~~Fraction Home Grown (FHG)~~	~~0.35~~	~~Assumed relevant for on site~~
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	ASC NEPM (2013)
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Cropping Land - Overall Dataset

Key Chemical	Toxicity Data				Concentration in Soil (Cs)	Daily Intake		Calculated Risk	
	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)		NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	$(mg/kg\text{-}day)^{-1}$	(mg/kg/day)		(mg/kg/day)	(mg/kg)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
Sum Br1 to Br9 (min)		0.0001	80%	0.00002	0.0020	4.1E-19	1.8E-12	-	0.0000000925
Sum Br1 to Br9 (max)		0.0001	80%	0.00002	27.0000		2.5E-08		0.00125
Sum Br1 to Br9 (mean)		0.0001	80%	0.00002	0.6000		5.5E-10		0.0000277
Sum Br1 to Br9 (95th percentile)		0.0001	80%	0.00002	0.8000		7.4E-10		0.0000370
Sum Br1 to Br9 (median)		0.0001	80%	0.00002	0.0200		1.8E-11		0.000000925
Deca BDE (min)		0.007	80%	0.0014	0.0020		1.8E-12		0.00000000132
Deca BDE (max)		0.007	80%	0.0014	0.5000		4.6E-10		0.000000330
Deca BDE (mean)		0.007	80%	0.0014	0.0800		7.4E-11		0.0000000529
Deca BDE (95th percentile)		0.007	80%	0.0014	0.3000		2.8E-10		0.000000198
Deca BDE (median)		0.007	80%	0.0014	0.0400		3.7E-11		0.0000000264

Uptake of PFAS into Plants

Overall Data

C_{plant} = Csoil x Transfer Factor **(mg/kg fresh produce)**

Incorporated into Soil

Maximum Case

Key Chemical	Concentration in MWOO (C) (mg/kg)	Concentration in Soil when incorporated (Cs) (mg/kg)	Transfer Factor = (mg/kg in plant ww/dw)/(mg/kg soil)	Conversion Factor (dw to ww)	Concentration in Plant (mg/kg) wet weight
PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)			2.2	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.04	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.13	0.0050	0.07	0.15	0.0000525
Wheat (Cereals) (based on dry weight)			0.5	0.15	
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)			1.5	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.1	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.64	0.025	0.03	0.15	0.000111
Wheat (Cereals) (based on dry weight)			3.2	0.15	

Average Case

PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)			2.2	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.04	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.1	0.0038	0.07	0.15	0.00004038
Wheat (Cereals) (based on dry weight)			0.5	0.15	
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)			1.5	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.1	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.12	0.0046	0.03	0.15	0.00002077
Wheat (Cereals) (based on dry weight)			3.2	0.15	

95th Percentile

PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)			2.2	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.04	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.11	0.0042	0.07	0.15	0.00004442
Wheat (Cereals) (based on dry weight)			0.5	0.15	
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)			1.5	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.1	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.3	0.012	0.03	0.15	0.000052
Wheat (Cereals) (based on dry weight)			3.2	0.15	

Median

PFOS (PFOS + other sulfonates like PFOS)					
Green Vegetables (based on dry weight)			2.2	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.04	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.1	0.0038	0.07	0.15	0.00004038
Wheat (Cereals) (based on dry weight)			0.5	0.15	
PFOA (PFOA + other acids like PFOA)					
Green Vegetables (based on dry weight)			1.5	0.15	
Root Vegetables (based on wet weight)			0.05	not required	
Tuber Vegetables (based on wet weight)			0.1	not required	
Tree Fruit (incl Blueberries) (based on dry weight)	0.1	0.004	0.03	0.15	0.000017
Wheat (Cereals) (based on dry weight)			3.2	0.15	

Exposure to PFAS in Produce - Children - Incorporated into Soil - Overall Data

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$

(mg/kg/day)

Parameters Relevant to Quantification of Exposure to Young Children

Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
green vegetables	0.055	as per PBDE assessment
root vegetables	0.017	as per PBDE assessment
tuber vegetables	0.028	as per PBDE assessment
tree fruit	0.18	as per PBDE assessment
wheat/oats/barley	0.038	as per PBDE assessment
eggs	0.036	as per PBDE assessment
Fraction Home-Grown Eggs (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Fruit, Wheat/Oats, Vegetables (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	6	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	15	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	2190	ASC NEPM (2013)

Maximum Case

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000525		2.2E-07	--	0.01225
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.000111		4.7E-07	--	0.0032308

Average Case

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000404		1.7E-07	--	0.009423
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.0000208		8.7E-08	--	0.000606

95th Percentile

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000444		1.9E-07	--	0.010365
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.0000519		2.2E-07	--	0.001514

Median

	Toxicity Data					Daily Intake		Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000404		1.7E-07	--	0.00942
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.0000173		7.3E-08	--	0.000505

Exposure to PFAS in Produce - Adult - Incorporated into Soil - Overall Dataset

$$DailyChemicalIntake = C \bullet \frac{IR \bullet FHG \bullet EF \bullet ED}{AT \bullet BW}$$ (mg/kg/day)

Parameters Relevant to Quantification of Exposure for Adults

Bioaccessibility (B)	100%	
Ingestion Rate (kg/day)		
green vegetables	0.15	as per PBDE assessment
root vegetables	0.05	as per PBDE assessment
tuber vegetables	0.06	as per PBDE assessment
tree fruit	0.14	as per PBDE assessment
wheat/oats/barley	0.095	as per PBDE assessment
eggs	0.059	as per PBDE assessment
Fraction Home-Grown Eggs (FHG)	100%	as per PBDE assessment
Fraction Home-Grown Fruit, Wheat/Oats, Vegetables (FHG)	35%	as per PBDE assessment
Exposure Frequency (EF, days/year)	365	Assume produce consumed every day of the year
Exposure Duration (ED, years)	29	Exposures occur from ages 0 to 5 years
Body Weight (BW, kg)	70	ASC NEPM (2013)
Averaging Time - NonThreshold (Atc, days)	25550	ASC NEPM (2013)
Averaging Time - Threshold (Atn, days)	10585	ASC NEPM (2013)

Maximum Case

	Toxicity Data				Daily Intake			Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000525		3.7E-08	--	0.00204
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.000111		7.8E-08	--	0.000538

Average Case

	Toxicity Data				Daily Intake			Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000404		2.8E-08	--	0.00157
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.0000208		1.5E-08	--	0.000101

95th Percentile

	Toxicity Data				Daily Intake			Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000444		3.1E-08	--	0.00173
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.0000519		1.7E-11	--	0.000000115

Median

	Toxicity Data				Daily Intake			Calculated Risk	
Key Chemical	Non-Threshold Slope Factor	Threshold TDI	Background Intake (% TDI)	TDI Allowable for Assessment (TDI-Background)	Concentration in Produce	NonThreshold	Threshold	Non-Threshold Risk	Chronic Hazard Quotient
	(mg/kg-day)-1	(mg/kg/day)		(mg/kg/day)	(mg/kg ww)	(mg/kg/day)	(mg/kg/day)	(unitless)	(unitless)
PFOS (PFOS + other sulfonates like PFOS)									
Tree Fruit		2.0E-05	10%	0.000018	0.0000404		2.8E-08	--	0.00157
PFOA (PFOA + other acids like PFOA)									
Tree Fruit		1.6E-04	10%	0.000144	0.0000173		5.5E-12	--	0.0000000385